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AQUACULTURE STUDIES

RESEARCH PAPER

Step-by-Step and Progressive Transformation of Aquaculture Value Chain for Climate Adaptation in Burkina Faso

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Abstract

Food security solutions are the African Sahel's fierce urgency of now, especially with climate change which is already impacting the region. Climate change can have a huge impact on agriculture and subsequently, on food availability. Recurrent episodes of environmental phenomena (e.g., granivorous birds, acarine invasions, epizootics, epidemics), and climatic hazards (e.g., severe hydrological droughts, nationwide hydrological floods) have repeatedly plunged most rural families into poverty, food insecurity, and malnutrition. The history of Burkina Faso's experience in aquaculture spans seven decade-long efforts, but, in its current weak production status, will aquaculture be able to help face future challenges? This study reviewed the potential of the aquaculture sector while determining its weakness in order to make appropriate recommendations to guide the Next Generation Aquaculture (NGA) in the country. Therefore, we review the history, from 1950 to 2022, of the different nodes of the aquaculture value chain in relation to livelihoods, food and nutrition security, and climate change. The historical context of aquaculture in Burkina Faso showed a need for a transformative approach towards climate resilience. We found many barriers for aquaculture adoption including its management (i.e., staff, biological and chemical management) its political leadership, its economic sustainability, its environmental and climate challenges, and its sociological factors. Mitigation actions are needed both at aqua-farm and national levels. These include proper governance, gender inclusivity and, promoting climate-smart aquaculture (CSA). To ensure the environmental sustainability of aquaculture, considerable efforts should be made in terms of climate-smart aquaculture research, development, training and education in order to address economic, social and environmental paradigms. Definition, implementation and maintenance of the principles of good practices in aquaculture (GPA) at each stakeholder level, is necessary to regulate all aspects of the aquaculture value chain for NGA, including relationships with other sectors. As such, this paper provided solutions meant to transform the Burkina Faso aquaculture industry through innovations in the sustainability area. It is recommended that both state officials and private stakeholders work together to achieve GPA in the industry. This review further discusses how coherence of aquaculture development policies can help mitigate future disturbance about food availability and climate change in Sahel countries facing similar kinds of challenges as Burkina Faso.

Introduction

The debate on climate change is now becoming increasingly relevant because of its impact on food systems. Available data project severe constraints on climate and food availability in the Sahel region. Climate projections predict a highly probable decrease in summer rainfall in the Sahel (IPCC, 2019a). Additionally, reductions in projected food availability are larger at 2°C than at 1.5°C of global warming in the region (IPCC, 2019b). For several years, Burkina Faso has been experiencing prolonged hydrological drought conditions as well as hydrological flooding due to heavy rains. Since the 1970s, Burkina Faso has experienced more than 20 episodes of catastrophic drought, climatic hazards and other environmental phenomena. Some of the most catastrophic drought episodes that Burkina Faso experienced occurred in 1970, 1973, 1974, 1985, 2011 and 2012. These have led to numerous food crises in the country (Bantenga, 2015). Mindful of these challenges, the Government has begun to mainstream climate change issues into adaptation policies and planning, prioritizing measures related to water resources management, sustainable agriculture, improved livestock and forest management (Crawford et al., 2016).As such, the public is encouraged to improve their conduct, with regards to climate adaptation activities and collaborate with government efforts so as to achieve sustainable conduct (Osmundsen et al., 2020), as is the case in many other countries.

Aquatic living resources are paramount for achieving the targets set by United Nations Sustainable Development Goals (SDG), particularly those aiming to eliminate hunger and malnutrition (Becker & Calado, 2021). Globally, aquaculture has already demonstrated its crucial role in food insecurity reduction, with its production growing at 7.5% per year since 1970 (FAO, 2020a). Aquaculture offers the promise of increased resilience in the face of increasing resource scarcity and climate change (Troell et al., 2014). However, the contribution of aquaculture to food security remains a major necessity and challenge in the Sahel as some coastal countries of the region face an extraction of more than 500,000 tons of small pelagic fish that are processed into feed for aquaculture and agriculture, dietary supplements, cosmetics and pet food products outside the African continent (Greenpeace Africa, 2021). To ensure the sustainability of global aquaculture, the primary policy and regulatory influencers should include not only traditional fisheries managers, environmental groups and natural scientists but also economists (Anderson et al., 2019). We also believe that including the views of individual aqua-farmers, especially those from low-income countries, in the development of these policies would add great value and contribute to ensuring aquaculture sustainability.

In Burkina Faso, the national demand for fisheries products totaled 176,750 tons in 2020, with a national production estimated at 29,750 tons and recorded imports of 147,000 tons of fisheries products. Hence, only 17% of the quantity of fisheries products in demand are produced at national level (DGRH, 2021). The country has a water potential consisting of more than 200,000 ha of rivers, and 1,450 dam lakes and reservoirs. The most important dams are those of Samendéni (68 202 ha) (Ramsar, 2023), Bagré (21,000 to 25,000 ha), Kompienga (16,000 to 20,000 ha), Sourou (10,000 ha), Dourou/Toécé (8,000 ha), Ziga (7,000 to 10,000 ha) (DGRH, 2007), and Bazega (253 ha) (Lingani, 1992). These hydro-agricultural facilities make the water usable in the dry season, through the effect of water reservoirs and irrigation. This potential represents an important and exploitable asset for aquaculture. However, the country is facing an ever-increasing increase in imports of fish either frozen, smoked and / or dried. This increase in imports is seen as a barrier to aquaculture development by capping fish prices at levels too low to stimulate investment in local fish production (Sanon et al., 2021). The existing aquaculture community plays a multi-functional role as it contributes to solidarity between farmers, offers opportunities to obtain fish, improves the standard of living in rural areas, and gives children the opportunity to increase their protein diet (Kabré et al., 2014).

In Burkina Faso, aquaculture development could offer alternative livelihoods and help for natural fish stocks' recruitment, while reducing fishers’ vulnerability and easing resources' over-exploitation (Amoussou et al., 2014; Sanon et al., 2020). In terms of food security, aquaculture in the rural system provides high quality animal protein and essential nutrients, such as vitamin B12, calcium and potassium (Rajee & Mun, 2017). The majority of Burkina Faso people eat fish. However, due to high price of fish feed and increases in other production costs, locally cultured fish is very expensive compared to imported fish. As such, not everyone can afford cultured fish. Therefore, a new way of scaling up aquaculture models is very important. In addition, aquaculture has long been marginalized in terms of the limited investment it has received. Indeed, Burkina Faso's aquaculture industry appears to be more neglected as the focus is on capture fisheries, the provision of primix and coldstores to fishers, ignoring aquaculture production. In addition, efforts made for aquaculture must be deployed over all geographic zones either with low or high aquaculture potential.

There are about 600 aquaculture entrepreneurs across the country, ranging from farmers and agro-industrialists to civil servants, politicians, religious and traditional authorities (Sanon et al., 2021). The existing aquaculture entrepreneurs in Burkina Faso use various aquaculture infrastructure like ponds, enclosures, floating cages, draining, irrigation canal, and concrete tanks (Sanon et al., 2021). Some private entrepreneurs have invested in the installation of plastic membrane tanks and Recirculating Aquaculture Systems (RAS), as well. Aquaculture in floating cages and enclosures is managed by concessionaires on Bapla river, Moussodougou river and Léra river in the South-West and Tandjari river in the East (MRAH, 2013a). But it remains to be properly determined which administrative region of the country is best suited for which aquaculture infrastructure. This is also important to define the future pathways for a real take-off of the aquaculture industry in the country.

The aquaculture industry deserves to be rethought in term of the employment, food security, nutrition, climate change and civil security challenges currently facing the country. Policies for aquaculture development, have frequently been confused with those for fishing activities, and it is now necessary to initiate some specific ones in order to ensure a real and sustainable development. Moreover, the significative contribution of aquaculture to resilience to both food insecurity and climate change, can only be effective if government policies provide adequate incentives for resource efficiency, equity and environmental protection (Troell et al., 2014). In addition, aqua-farmers need to be the custodians and implementers of aquaculture development policy. It is mainly through the success of aqua-farmers that government policy and regulation can be properly evaluated and recalibrated to provide a framework that will foster economic and social growth. Indeed, it is known that economies are mostly based on people productivity. So, aqua-farmers will need to be carefully monitored and assisted to increase their contribution to the national economy. Before enacting aquaculture policies, it appears necessary to define aquaculture development poles through the country in order to ensure the resilience of communities to environmental, climatic, nutritional, aquatic biodiversity loss, and food challenges. Of urgency is the need to deeply analyze the limits of current legislation, institutionalization and regulation of aquaculture in order to orientate policy makers towards effective Good Practices in Aquaculture (GPA). So, it is important to determine whether the enforcement of aquaculture regulations is done through prescriptive and incentive mechanisms. Therefore, this study aims to analyze the existing gender-based aquaculture policies in the country in order to determine whether they are able to regulate all aspects of the aquaculture value chain.

In addition to the above-mentioned questions, rural women play a central role in agricultural production in Burkina Faso. Their contributions are well documented with regard to cereal and vegetable production (Bantenga, 2015). And the question arises as to the share of this population group in aquaculture production, specially reservoir aquaculture production. To answer this concern, a review of the current legislation is needed to convince decision makers of the importance of including gender in the aquaculture sector. The aim here is to question the evolution of gender awareness in the various aquaculture development projects. Additionally, the country faces many challenges owed to a changing climate, characterized by heat waves alongside strong evaporation of rural water intended for agricultural activities. It is absolutely essential to take stock of the use made of this water by the various producers in order to suggest a model that can help to ensure the sustainability of agro-aqua activities in order to anticipate any risk of food insecurity.

This paper emphasizes the criticality of food security in the face of climate change. And, aquaculture has an essential role to make in overcoming these challenges. That is why the work seeks to determine if aquaculture in the country is sustainable or not. It includes both conceptual and empirical insights (Jaakkola, 2020) and its methodological approach is two-fold. First point is that a literature review has been conducted for an efficient diagnosis of the aquaculture sector. Secondly, the study addresses the identification of the different constraints to the development of proper environmental conservation scheme for a sustainable aquaculture in the country. In both options, potential mitigation solutions have been suggested to adequately guide future aquaculture research and development. Overall, several factors have been considered including sector management, social impact, economic viability, feed management, species or strain selection, water quality management, environmental impact, aquaculture education, and resilience to climate change.

Material and Methods

Conceptual Framework for the Study

Several actors are involved in the regulation and management of aquaculture in Burkina Faso. Interventions are made at government as well as actors' level. The ministerial departments with a contribution to aquaculture include those of fisheries resources, environment, water and forests. The official public institution responsible for the supervision and monitoring of aquaculture activities is the Direction Générale des Ressources Halieutiques (DGRH). The country has experienced a certain degree of instability with regard to the institution that should be responsible for the development and the implementation of the government's policy in the aquaculture sector (MRAH, 2013). From 1960 to the present day, the successive ministries in charge of aquaculture was as follows: (i) Ministry of Rural development, (ii) Ministry of Environment, (iii) Ministry of Agriculture, Hydraulic and Fisheries Resources, (iv) Ministry of Environment and Sustainable Development, (v) Ministry of Animal and Fisheries Resources.

The country's aquaculture model involves different actors such as private investors, non-governmental organizations (NGOs), academia and researchers. The private investors are mainly involved in the supply of feed, seed, fry, and aquaculture equipment. Non-profit companies (e.g. NGOs) help with the organization of actors, the set-up of fish restocking, the training of actors and the maintenance of infrastructures. Research institutions and universities provide expertise for further improvement and innovation of aquaculture production techniques.

Burkina Faso has a portfolio of legislation regulating the practice of aquaculture in all administrative regions of the country (MERH, 2015), but their actual application remains questionable. However, most aquaculture legislation does not differentiate between fishers and aquafarmers, probably reflecting the fact that the country has a policy of converting fishers to aquafarmers in order to boost national production. This is seen in the fact that, for a long time the country opted for the development of aquaculture around its various waterways (Amoussou et al., 2014). The strategy was to create some halieutic zones of economic interest mostly around the major dam including fisheries and aquaculture activities as well as its development. Other legislation deals exclusively with the determination of the nomenclature of installations, facilities, works and activities (IFWAs) requiring declaration or authorization for the use of groundwater, surface water in aquaculture. In the country, aquaculture ponds, floating cages, areas or parts of waterways may be subject to concessions for aquaculture in waterways or any aquaculture site forming part of the public domain. Similarly, an authorization from the Minister in charge of Fisheries and Aquaculture is required for the introduction of fish species or eggs from foreign countries into Burkinabe waters. In addition, any aquaculture establishment must be installed and operated in such a way as to not have an impact on the environment. To this end, the concession application is examined by the Minister in charge of Fisheries and Aquaculture, which may undertake an environmental impact assessment. However, the legislation in force shows a lack of awareness and inclusion of rural women involvement in aquaculture.

Under the various pieces of legislation mentioned above, in the time period of 1980 to 1985, the average aquaculture production was 78 tonnes (Lazard, 1987); from 2004 to 2006, the production averaged 90 tonnes (Moehl et al., 2001); in 2007, the average production was 300 tonnes (DGRH, 2021); in 2008, the production was estimated at 400 tonnes (MRAH, 2013b); from 2009 to 2020, the aquaculture production increased from 200 to 647 tonnes (DGRH, 2021). The evolution of the national aquaculture production is presented in Figure 1. These different production series remain low in relation to the country's potential (i.e., the country's large surface area, the country's high-water potential). The next section outlines the methodology adopted for this study.

Literature Search on National Aquaculture

This paper focused on the extraction and analysis of existing literature on national aquaculture. Based on the method described in Alexander et al. (2015), a snowball approach was used in combination with a theoretical and empirical literature review (Jaakkola, 2020) to identify existing gaps in national legislation and development concerning gender in aquaculture in Burkina Faso. One focus of this review was to determine the level of involvement of rural women in the various aquaculture development initiatives in the country.

Extracted data covered (i) previous and current aquaculture projects in the country, (ii) national aquaculture production, (iii) the constraints to aquaculture development, and (iv) the management aspects. These data were retrieved from the technical reports of the sector-based ministries involved in aquaculture, the dissertations and theses dealing with aquaculture in the country, as well as scientific articles. The sector-based ministries in charge of aquaculture development included: Ministry of Rural development (from 1960 to 1976), Ministry of Environment (from 1976 to 2002), Ministry of Agriculture, Hydraulic and Fisheries Resources (from 2002 to 2011), Ministry of Environment and Sustainable Development (from 2011 to 2012), and Ministry of Animal and Fisheries Resources (from 2013 to present). Details of the aquaculture projects and initiatives included the name of the project/initiative, the period of implementation of the project/initiative, the financial backer of the project/initiative, the aquaculture infrastructure put in

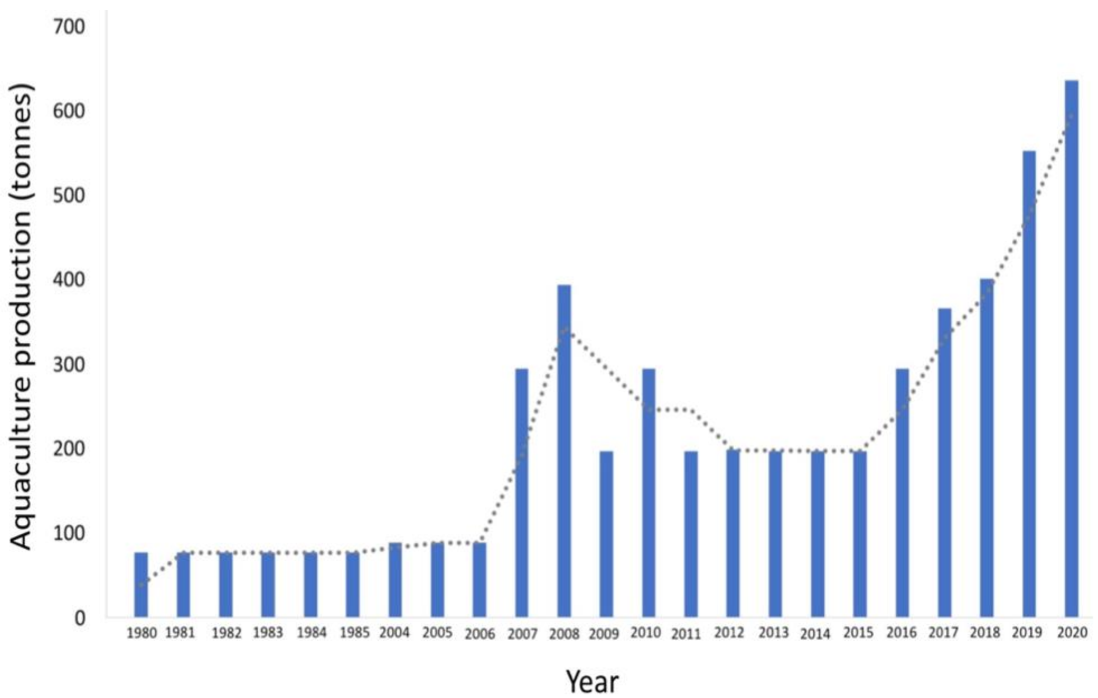

Figure 1. Average aquaculture production from 1980 to 2020 in Burkina Faso.

place, the city or town of implementation of the project/initiative, the geographical area of the project/initiative, the objective of the project/initiative, the mode of aquaculture employed in each project/initiative, and the species used during the project/initiative. Data on the size of aquaculture production were obtained from different sources, including statistics from the ministries, over the period 1980 to 2020 divided into five production-based major stages: the time period of 1980 to 1985, from 2004 to 2006, in 2007, in 2008, and from 2009 to 2020. The constraints to aquaculture development have been categorized into five types: (i) aquaculture management and political leadership, (ii) economic sustainability of aquaculture initiatives, (iii) aquaculture-related environmental and climate challenges, (iv) aquaculture-related biological and chemical management, (v) aquaculture-related sociological factors. The narratives of the key laws governing aquaculture in the country have been listed according to the date the law was put in place, and the public institution that legislated it.

For the literature review, the Boolean Search Terms (BSTs) used have been run in both French and English in order to make the review systematic and also because Burkina Faso is a predominantly French-speaking country. The pillar BSTs used were as follow: aquaculture AND legislation AND sustainability AND governance AND management AND gender AND burkina. For a more in-depth selection of literature, these key pillars of the study were further detailed (Supplementary material Table S1). For the literature retrieval, we used the following three search engines: Google Scholar, Web of Science and Scopus. Documents dealing with the global and regional context were used for comparison with those of Burkina Faso in order to make endogenously adapted recommendations.

Data Sampling at Bagrépôle

The other approach adopted in this study was to collect production data on an aqua-farm scale. To achieve this, this study took as a model the BagréPôle company, which has the largest aquaculture production farm in Burkina Faso. Data was collected from 2020 to 2022 on production and sales parameters for fry and merchant fish. Most of the data have been sorted from BagréPôle production reports.

For the production of fry, data were collected on the type of customer, the year and semester of purchase of the fry, the fry destination, the fish species, the seed strain used, the sex of the fry sold, the fry biomass collected, the average individual weight of the fry, the number of fry, the unit price of the fry, the type of packaging used to transport the fry, the number of containers used to transport the fry, the unit price of the packaging and the total revenue from the sale of fry. Regarding the sale of fry, when a customer wishes to purchase fry, an appointment is made and the fry of the required size are transferred from the pre-growth ponds to the storage ponds for a quarantine period of at least 3 days. On the day of the sale, the fry in storage are collected in the presence of the customer and a sample is taken. The average individual weight of the fish is calculated to reassure the customer of their size. The number per container is decided on the basis of the duration of the transport. The fry are packed in containers and plastic bags with water and oxygen. Once the container has been prepared, it is loaded onto the customer's means of transport. A record is then made in the forms, giving the date, average individual weight, number of fry and container and the destination of the fry.

Annual data on the production of marketable fish were collected during harvests, which are carried out by pond. On the day of the harvest, to obtain the biomass of fish harvested per pond, forms were used to monitor the weighing. All quantities taken out of the water are immediately weighed and noted. The fish are weighed in batches of 40 kg and then recorded. The total quantity of fish caught is estimated at the end of the session by adding up all the 40 kg already recorded. In short, the information recorded on the merchant fish concerned the year and month of the harvesting operation, the type and species of fish, the composition of the harvest (juveniles and/or adults), the phenotypic sex of the fish harvested, the pond number, the average surface area of the pond, number of feeders and aerators placed in each pond, the weight gain, the average individual weight at stocking, the real average individual weight at harvest, the forecast average individual weight at harvest, the rate of increase in the average individual weight, the stocking period, the duration of the rearing cycle, the number of individuals stocked, the stocking density, the forecast production, the quantity fished/harvested, the rate of increase in production, the rate of decrease in production, the forecast duration of grow-out, the real duration of grow-out, the rate of increase in duration of grow-out, the rate of decrease in duration of grow-out, the number of harvest days, the mortality rate, the production success/completion rate, the yield, the quantity of feed consumed by the fish, the feed conversion rate, the total cost of feed consumed, the type/commercial name of the feed used and the difficulties encountered during each production cycle.

To investigate the performance of merchant fish produced at BagréPôle, parameters such as production completion rate, feed conversion rate, yield, and percentage increases and decreases were calculated according to their respective formulae.

The Production Completion Rate (PCR) is used to determine whether the production target has been achieved, i.e. in aquaculture production, there is a forecast target but there is a harvest result which reflects the reality of what has been harvested in the pond and which is the real value. So, the completion rate is equal to the ratio of the quantity harvested to the forecast quantity multiplied by one hundred.

$$PCR = \frac{\text{Quantity of fish harvested}}{\text{Forecast quantity}} \times 100 \quad (1)$$

The Feed Conversion Rate (FCR) represents the number of kilograms of feed needed to produce one kilogram of fish. It measures the efficiency of converting feed into fish flesh. The conversion rate is the ratio of the quantity of feed distributed to the net weight produced.

$$FCR = \frac{\text{Quantity of feed used}}{\text{Weight gain of fish harvested}} \quad (2)$$

The yield is the quantity of fish obtained per hectare over a year. It is the double ratio of the weight gain of harvested fish to the area farmed (in hectares) over the duration of the production cycle, multiplied by 365 days.

$$\text{Yield (t/ha/year)} = \frac{\text{Weight gain per unit of surface area}}{\text{Rearing period}} \times 365 \quad (3)$$

The percentage increases and decreases were estimated for grow-out time, average individual weight and harvested biomass, depending on whether these parameters had increased or decreased following the harvesting of merchantable fish.

$$\text{Rate of increase or decrease} = \frac{\text{Final or Real Value}}{\text{Initial or Forecast Value}} \times 100 \quad (4)$$

Data Analysis

The analytical techniques used a meta-analysis combining statistical comparisons of empirical data retrieved from technical reports. RStudio (RStudio Team, 2022) was used for descriptive statistics, box plots and inferences of all quantitative data. The lm() and aov() functions were used to perform one-way analyses of variance according to cultivation method (monoculture and polyculture), year of fish farming (2020, 2021 and 2022) and semester of fish farming (Semester 1 and Semester 2). For each variable, the Tukey's Honestly Significant Difference (HSD) test was used to perform a one-step multiple pairwise comparison at thresholds of 5%, 1% and 1‰.

Results

In order to ensure the environmental sustainability and good management of aquaculture nodes in a context of climate change and food insecurity in Burkina Faso, this section first presented the efforts made in terms of mobilizing partners as well as external and internal funds to develop aquaculture. In addition, the existing constraints to aquaculture development have been categorized and presented.

Milestones in Assembling Partners to Develop Aquaculture

Since 1950, the development of aquaculture in Burkina Faso has been based on external aid and government subsidies. External funds are mainly obtained from European countries (Germany, France, Belgium), the United States of America (USA) and Asian countries (Taiwan, Japan). Other donors are represented by the United Nations (FAO), the European Union (EU) and the West African Economic and Monetary Union (WAEMU) (Table 1). The various aquaculture facilities set up by these funds are made up of both traditional infrastructures (earthen ponds, concrete basins, enclosures, Whedo, integrated pond-dike systems) and modern infrastructures (floating cages, raceways, RAS type closed systems). Although there were initiatives that considered all the 13 administrative regions of the country, most of the investments have been much more concentrated in five: South-West Region, West Region, Central-East Region, Central Region, East Region. These diverse aquaculture initiatives have been aimed at promoting extensive aquaculture, to a large extent, and intensive, semi-intensive and agro-aquaculture (pond-dike), to a lesser extent. The most common species used in these projects are: *Oreochromis niloticus*, *Tilapia zillii*, *Heterotis niloticus*, *Clarias gariepinus*, *Heterobranchus* sp. For agro-aquaculture, the most used plant species was rice, while the most used land animal species was poultry. Many of these initiatives were aimed not only at organizing aqua-farmers but also at converting fishers to aquaculture. Some of the projects were aimed at promoting restocking aquaculture for the sustainable management of the resource. Other initiatives included strengthening the technical capacity of aqua-stakeholders and providing them institutional support. Some initiatives to adapt to climatic disturbances consisted of loading the enclosures at the beginning of the hydrological floods and harvesting at the time of the receding floods. Similarly, a few isolated initiatives aimed at reducing post-harvest fisheries losses through the promotion of smoking and salting. However, very few initiatives were committed to the manufacture and standardization of high-quality fish feed, using locally available resources. Very recently, a nation-wide project has tackled the problem of mastering the artificial reproduction of catfish. Overall, all these projects overlooked the awareness and inclusion of rural women and youth in aquaculture.

Barriers for Aquaculture Adoption

Burkina Faso has 13 administrative regions, each of which is an administrative division consisting of one or more provinces. Our preliminary census revealed 234 aquaculture producers throughout the country. Despite this figure, the practice of aquaculture is unevenly spread across the country with the highest proportion of

Table 1. Summary of narratives of key projects or existing major investment in aquaculture in Burkina Faso

Name of aquaculture initiative/project	Time Period	Financial backer	Aquaculture facilities set up	City/location of implementation	Geographical region of implementation	Aim of the project	Mode of aquaculture utilized	Species used	Gender narrative	Source
Fish farming research and development project	1950-1975	Missionaries of the Catholic Church	Earthen ponds	Banfora	South-West Region	Tilapia production in earthen ponds	Extensive fish farming	Tilapia	None	Kabré et al. (2014)
Bazèga Fish Farming Station Initiative	1979	United States Agency for International Development (USAID)	Ponds installed downstream of the Bazèga dam in the Toécé department	Bazèga	Central Region	Produce marketable fish and fingerlings for stocking small water reservoirs located in central Burkina Faso	Frying for the stocking of small water reservoirs	*Oreochromis niloticus*	None	DGRH (2007b; Kabré et al. (2014)
MISEROR Village Fish Farming Project	1979-1982	German funding - Kreditanstalt für Wiederaufbau (KFW)	-	-	Central, West, and East Regions	Conversion of fishers' groups to village aqua-farming	-	-	None	Kabré et al. (2014); Moehl et al. (2001)
Village fish farming Initiative	1980	American Peace Corps Volunteers	-	-	South-West Region	Promoting village aqua-farming	Extensive fish farming	Tilapia	None	Kabré et al. (2014); Moehl et al. (2001)
Banfora Aquaculture Project	1980-1986	French Central Agricultural Cooperation Fund (CCCA)	Floating cages and raceways installed in the Lobi dam	Bodiadougou/Banfora	South-West Region	Production of marketable fish	Extensive and intensive fish farming	*Oreochromis niloticus*	None	DGRH (2007b; Kabré et al. (2014); Lazard (1987)
Fisheries Potential Development Project (VPH)	1986-1991	European Development Fund (EDF)	Fish farming facilities installed in the area around the Tanguiga, Goudri and Ramitenga dams	-	All administrative regions of the country	Increasing fisheries production and improving its use through the organization of aquaculture producers and the development of accompanying research; Providing institutional support; Promoting innovative forms of fish farming; Strengthening the economic revenues of fishers; Ensuring rational management of resources	-	-	None	Kabré et al. (2014); Moehl et al. (2001)
Fisheries Management in the South-West Initiative (GPSO)	1988-2002	German Federal Republic - Gesellschaft für Technische Zusammenarbeit (GTZ)	Pond fish farming in Bounouna	Banfora	South-West Region	Experimenting with fish farming in ponds with the participation of local populations; Production and sale of fry to groups and individuals who request it; Promotion of restocking fish farming through the production of fry for stocking; Sustainable management of the resource	Semi-intensive polyculture	*Tilapia zillii*, *Oreochromis niloticus* and *Heterotis niloticus*	None	Kabré et al. (2014); MAHRH (2003); Moehl et al. (2001); Sirima (2004)
Centre for the Supply and Distribution of Fishery Products (CADIPP)	2000-2007	Republic of China, Taiwan	-	-	-	Valuation of fish interlude productions	-	-	None	DGRH (2007b)

Table1. *Continued*

Name of aquaculture initiative/project	Time Period	Financial backer	Aquaculture facilities set up	City/location of implementation	Geographical region of implementation	Aim of the project	Mode of aquaculture utilized	Species used	Gender narrative	Source
Fish Hatchery Project	2004	Burkina Faso Government	Pond construction at fish farms	Bilanga, Yanga, Douna, Tougou, and Ziga	All administrative regions of the country	Supply of fry for stocking and for aquaculture entrepreneurs	-	-	None	DGRH (2007b)
Fish Farming Project (PEP)	2004-2008	Republic of China, Taiwan	Modern aquaculture station of 15 ha, with nearly 5 ha of tanks, located within the hydro-agricultural perimeter of Bagré	Bagré	Central-East Region	Consolidating the technological bases and data needed for the development of aquaculture in the context of Burkina Faso; Producing annually about 120 tonnes of fish; training at least 30 extension agents, 100 aquaculture promoters; capitalizing on technological achievements at the national level	-	Akosombo and local strains of *Oreochromis niloticus*	None	Coulibaly et al., (2010); DGRH (2007b)
Fish Hole Project	2006	Burkina Faso Government	Excavation "hole" in the floodplain of the river or water body	-	-	Colonization of the fish hole by naturally occurring fish in the water body and harvesting during low water level	Extensive fish farming	-	None	DGRH (2007b)
Project to Support the Coordination of the Activities of the Aquaculture Sector (PACAFA)	2006-2009	Republic of China, Taiwan	-	-	-	Promoting a better organization of the aquaculture sector; Increasing the aquaculture production; Marketing the fish production; Strengthening the marketing capacities of the actors of the sector and extension of the aquaculture techniques	-	-	None	DGRH (2007b)
Semi-intensive fish farming in enclosures Project	2007	Burkina Faso Government	Construction of enclosures in marginal parts of dams	-	All administrative regions of the country	Loading of the enclosures at the beginning of the floods and harvesting at the time of deflooding	-	-	None	DGRH (2007b)
Project for Rural Development through Sustainable Aquaculture in Burkina (PDR/ADB)	2008-2014	Japanese Government - Japan International Cooperation Agency (JICA)	Fish hole, enclosure, cage, pond	-	All administrative regions of the country	Develop sustainable and adapted aquaculture methods (supply of fry, fish feed) in rural areas; Strengthen the capacity for sustainable management of aquaculture; Promote the processing (smoking, salting, etc.) of fishery products	Semi-intensive fish farming	-	None	DGRH (2007b)
Development of a pilot catfish (*Clarias gariepinus*) production chain in Burkina Faso: Improvement and implementation of a pilot closed circuit rearing system	2011	Belgian Government - Academy for Research and Higher Education (ARES)	Closed circuit of RAS types	Nasso/Bobo-Dioulasso	South-West Region	Developing a catfish production chain in Burkina Faso through genetic improvement; Optimization of feeding; Implementation of an intensive fry production system	Intensive fish farming	*Clarias gariepinus*	None	UR-ABAQ (2017a)

Table1. *Continued*

Name of aquaculture initiative/project	Time Period	Financial backer	Aquaculture facilities set up	City/location of implementation	Geographical region of implementation	Aim of the project	Mode of aquaculture utilized	Species used	Gender narrative	Source
Validation and dissemination of integrated aquaculture-agriculture systems (rice-fish farming and others) through the farmers' field-school approach	2015-2017	Food and Agriculture Organization of the United Nations (FAO)	Integrated production systems in Niassan, Bama and Bagré	Niassan, Bama, and Bagré	West, Central East, South-West Regions	Initiating and disseminating integrated fish farming techniques, particularly rice-fish culture, through the establishment of farmer field schools (FFS); Strengthening the technical capacities of stakeholders; Establishing farmer field schools (FFS); Producing quantity and quality of fry and feed for fish farming	Agro-Aquaculture	Rice, Tilapia	None	FAO (2019)
Development of a production chain for improved fish seeds, Nile tilapia (*Oreochromis niloticus*) and catfish (*Clarias gariepinus*)	2015	West African Economic and Monetary Union (WAEMU)	Basins and RAS type closed circuit	Nasso/Bobo-Dioulasso	South-West Region	Promoting sustainable growth of aquaculture production through the creation of a complete production chain of improved and available seeds for inland fish farming	Semi-intensive and intensive fish farming	*Oreochromis niloticus* et *Clarias gariepinus*	None	UR-ABAQ (2017b)
Development of fish seed production technology for African catfish (*Clarias* sp and *Heterobranchus* sp) in Burkina Faso (TCP/BKF/3801 Project)	2021-2022	Food and Agriculture Organization of the United Nations (FAO)	Aquaculture equipment for artificial reproduction of catfish in selected rearing stations	Bagré, Bérégadougou, Samendéni, Yacouta, and Kompienga	All administrative regions of the country	Ensuring the availability of 25,000 fish seeds of the species; Ensuring the training of agents and some entrepreneurs in the technology of African catfish fry production; Defining the technical specifications and needs for the start-up of 20 g African catfish fry production units; Ensuring the transfer of technologies to entrepreneurs in areas with high fisheries potential in order to support the growing aquaculture entrepreneurship initiatives in Burkina Faso	Frying up to 5 g or 10 g	*Clarias* sp et *Heterobranchus* sp	None	DGRH (2021)
Integrated Fish Farming	-	Belgium	Agro-Aquaculture facilities	Bobo-Dioulasso	South-West Region	Azolla-rice culture experiments in the Kou valley; Fish-poultry culture and tank fish culture experiments	Agro-Aquaculture	Tilapia, Rice, and Poultry	None	Moehl et al. (2001)

aquaculture producers located in the Central (22%) and Central-East (18%) regions. These two regions are followed by the Boucle du Mouhoun and Haut-Bassins regions, which have roughly the same proportion of aquaculture producers (11% - 12%). The remaining proportions of aquaculture producers are as follows: Central-South (8%), Plateau-Central (6%), Central-West (6%), Cascades (5%), South-West (4%), Sahel (3%), East (3%), North (2%), and Central-North (2%) (Figure 2). However, many constraints need to be overcome in order to ensure a significant and sustainable contribution of these aquaculture actors to the national economy.

The various aquaculture development projects that have been initiated have for the most part had short-lived successes followed by catastrophic failures (Kabré et al., 2014). These failures stem from a number of constraints that can be summarized into five categories: (i) aquaculture management and political leadership, (ii) economic sustainability of aquaculture initiatives, (iii) aquaculture-related environmental and climate challenges, (iv) aquaculture-related biological and chemical management, and (v) aquaculture-related sociological factors (Table 2).

The challenges related to management and leadership in aquaculture lie firstly in the marginalization of the sector resulting in its low profile in agricultural development programs. The lack of a national strategy involving research institutions and agricultural services in the development and extension aquaculture technologies, has been cited, as well.

The aquaculture sector also suffers from a lack of regulation to limit the introduction of alien species, a lack of transfer of aquaculture skills to local authorities, and a failure to consider the perceptions of aqua-farmers. The administrative complexity in managing aquaculture development projects is also due to a lack of leadership in the management of the sector.

With regard to the economic sustainability of aquaculture initiatives, the challenges relate not only to the lack of appropriate funding for research into the best local aquaculture production techniques, but also to the absence/inadequacy of public or private institutions to finance the development of the aquaculture industry in the country. In addition, efforts need to be made by public services to sustain aquaculture development projects with public funds.

Many environmental and climatic challenges limit the development of aquaculture in natural or semi-natural habitats. Rainfall instabilities make water control difficult. The country has many water reservoirs, but the temporary nature of the water makes them inappropriate for use during the dry season. In addition, the water in these reservoirs is multi-use (i.e. domestic, pastoral, agricultural, forestry) and this makes many reservoirs unusable for aquaculture.

The problems of biological and chemical management of aquaculture also remain obstacles. The lack of knowledge on production (e.g., artificial reproduction, technical itinerary of fish strains), post-harvest storage and distribution techniques, has been reported. Other challenges include fish diseases,

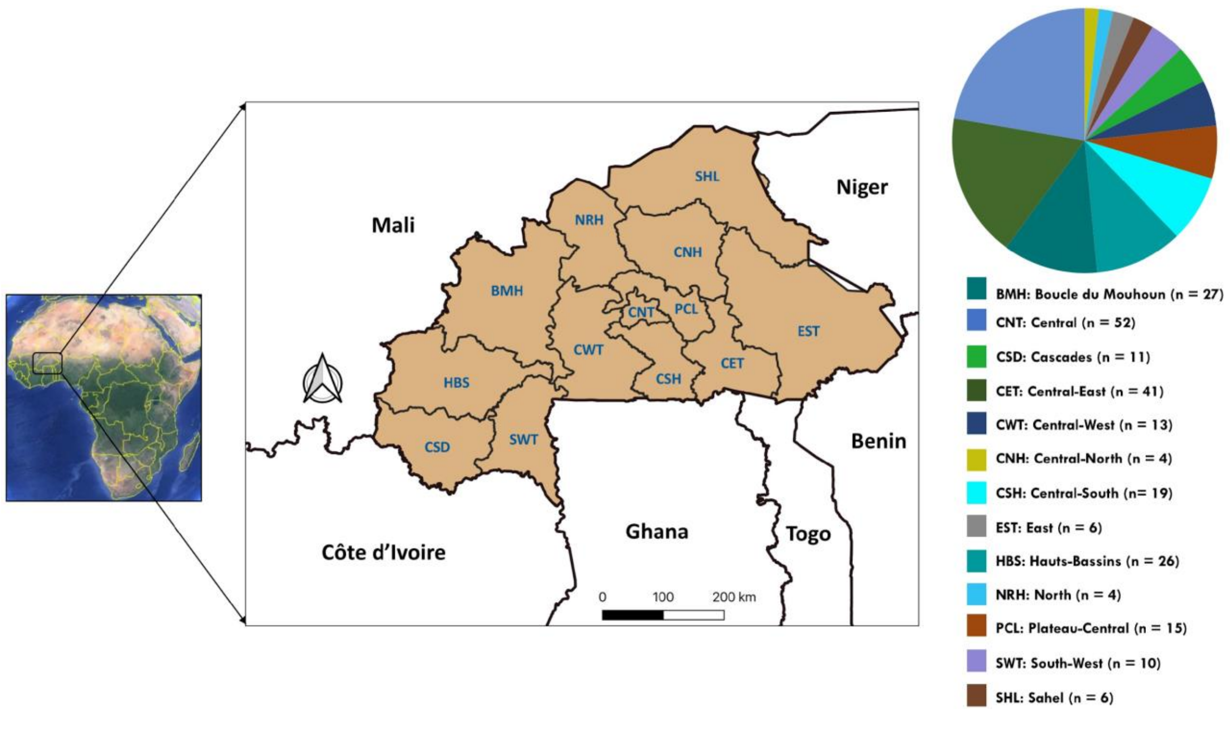

Figure 2. Map of the Burkina Faso showing the administrative regions selected for the study, along with the number and proportion of aquaculture producers per region across the country in 2022. The letter ''n'' refers to the number of aquaculture producers.

Table 2. Synopsis of the major factors limiting and hindering aquaculture development in Burkina Faso

Types of constraints/challenges	Justification	Source
Aquaculture management and political leadership	The marginalization of the aquaculture sub-sector whose contribution to the GDP remains very low Weak inclusion of aquaculture in agricultural development programs Lack of a national strategy involving research institutions and agricultural services in the development and extension aquaculture technologies Insufficient development of research and action in aquaculture Lack of regulation to limit the introduction of exotic species Lack of transfer of competences to local authorities in the field of aquaculture The administrative heaviness in the management of the aquaculture development projects Insufficient integration of fisheries and aquaculture resources in the construction and operation of water reservoirs Lack of consideration for the perception of aqua-farmers	Coulibaly et al. (2010); Kabré et al., (2014); Moehl et al. (2001); MRAH (2013b)
Economic sustainability of aquaculture initiatives	Lack of sufficient funding for research on the best local techniques for aquaculture production Poverty that affects a significant proportion of aqua-farmers Difficulties of public services to lead sustainable aquaculture development projects with their own funds Lack or inadequacy of public or private institutions to finance the development of the aquaculture industry in the country	Moehl et al. (2001); MRAH (2013b); Sanon et al. (2021)
Environmental and climate challenges for aquaculture	The rainfall instabilities generate the non-control of water, support of the aquaculture bioproductions The extremely difficult climatic conditions leading to the drying up of many water bodies and reservoirs during the year The downward trend in rainfall, resulting in a low filling rate of water reservoirs The multi-use vocation (household, pastoral, agricultural, forestry) of the water reservoirs, makes them unusable for aquaculture	Coulibaly et al. (2010); MRAH (2013b)
Aquaculture-related biological and chemical management	The lack of knowledge about production, post-harvest storage and distribution techniques Fish diseases, deterioration of production conditions, inadequate product marketing The non-availability of fish seeds both in quantity and quality Difficulty in setting up protected areas to conserve the genetic integrity of these local strains Difficulty of supply in quality and quality of local composite aquaculture feed Design of unsuitable aquaculture infrastructures for the environmental conditions of each administrative region Presence of crocodiles and hippos that destroy aquaculture infrastructures in certain regions of the country Difficulty in managing water levels, water quality and wastewater during drought periods	(Compaore (2017); Coulibaly et al. (2010); Kabré et al. (2014); Moehl et al. (2001); Sanon et al. (2021)
Aquaculture-related sociological factors	Lack of consideration of the perception of the populations (men and women) and their cultural vision of aquaculture Many actors lack technical expertise in aquaculture Aqua-farmers lack financial means to carry out appropriate aquaculture facilities and to pre-finance the activity (fry, efficient feed) Insecurity characterized by acts of vandalism on aquaculture facilities Lack of subsidy for the transportation of fry from the rearing stations to the production site Difficulties of access to land for aquaculture	Coulibaly et al. (2010); Moehl et al. (2001); MRAH (2013b)

deteriorating production conditions, inadequate marketing of products, and the unavailability of fish seed in quantity and quality. The difficulties of sourcing local composite feeds and establishing protected areas to maintain the genetic integrity of these local strains should also be addressed. It is also required to adapt the design of aquaculture infrastructure to the environmental and agro-climatic conditions of each administrative region of the country. Innovation in aquaculture will also need to focus on the design of devices for water level management, water quality management and wastewater management during hydrological drought periods.

Many sociological factors slow down the development of aquaculture in Burkina Faso. The first factor is the failure to consider people's perceptions and cultural views of aquaculture. Many actors (e.g., aqua-farmers, and aquaculture extension agents) lack technical expertise in aquaculture. Failure to take gender mainstreaming into consideration remains a key factor. Many aqua-farmers lack financial means to invest in appropriate aquaculture facilities and to pre-finance the activity (fry, efficient feed). In the same way, subsidies should be extended to the transport of fry from the hatcheries to the production or grow-out site. Furthermore, civil insecurity characterized by acts of vandalism should be reduced in the affected regions in order to secure the aquaculture facilities set up. In addition, flexibilities should be initiated to facilitate access to land for aquaculture.

Case Study: Constraints to Aquaculture Development at Bagrépôle

Description and Location of BagréPôle Aqua-farm

BagréPôle has a nationally-recognised fish farming complex located in the rural commune of Bagré, covering an area estimated at 430 km². The municipality of Bagré (Figure 3) is located in the Boulgou province, in the Centre-Est administrative region, with geographical coordinates of 11°27'04" North and 0°28'23" West. BagréPôle comprises four interdependent production units. The fry production unit has a capacity of five million male monosex tilapia fry per year. It has two hatcheries currently being equipped with a water recirculation system, 24 tanks and 14 ponds fitted with an air compressor oxygenation system. The second unit is the merchant fish production facility, with a capacity of 120 tonnes of tilapia per year. To carry out this task, BagréPôle has 21 ponds, including 8 measuring 729 m², 11 measuring 3,483 m² and 2 others covering 7,000 m² that are being rehabilitated. All the ponds are equipped with aeration systems and automatic feeders. The third unit is the commercial fish preservation and processing unit, with a pre-treatment capacity of one tonne of fish per day and a machine producing one tonne of ice flakes per day. The fourth link is the production of fish feed, with a capacity of 4,000 tonnes a year, but the plant is currently out of order. BagréPôle also offers training in fish farming and supervision to trainees. The centre also

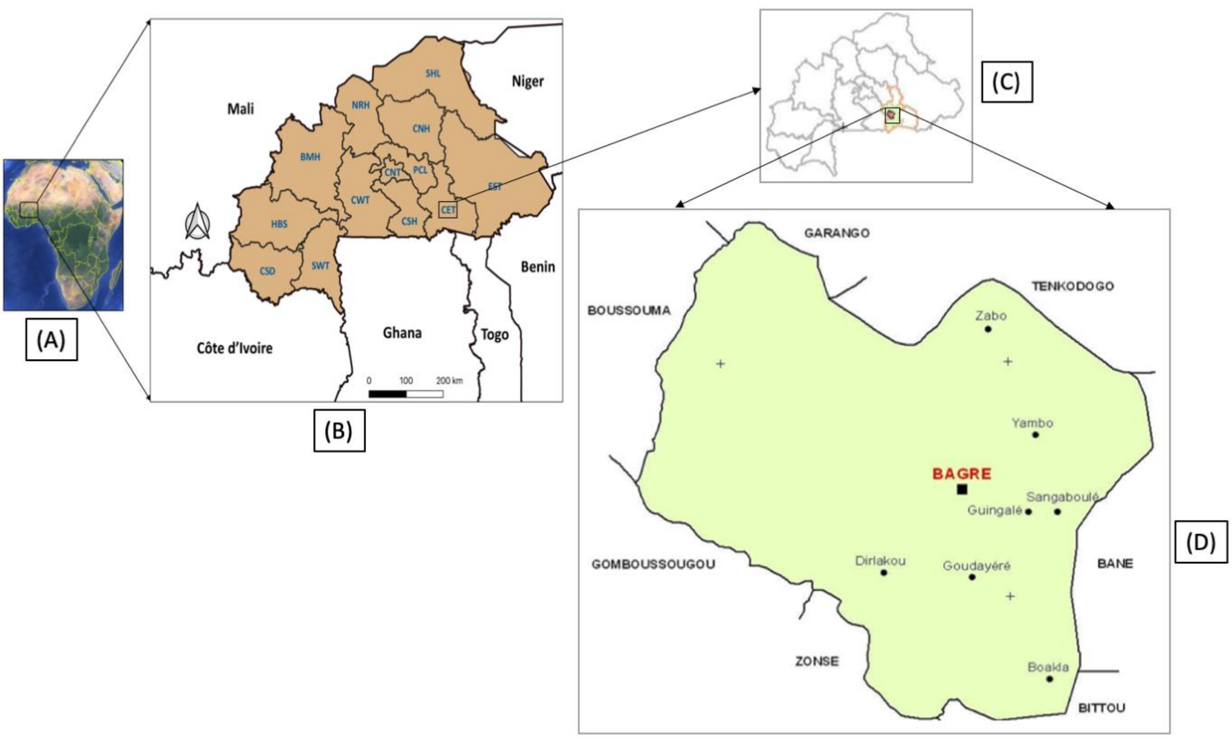

Figure 3. Location of BagréPôle in the municipality of Bagré (D), situated in the Boulgou province (C) of the Centre-Est administrative region of Burkina Faso (B) in Africa (A).

has an administrative building with offices, a meeting room, a laboratory, two flats and seven dormitories.

Variability in Fry Production and Sale at Bagrépôle

Analyzing the annual and semi-annual variability of the zootechnical parameters of the fry sold at BagréPôle, the biomass of the fry sold varied significantly (P<0.05) over the three years; 2020, 2021 and 2022, while no significant difference was observed between the two semesters of each year (P>0.05). The same trend was observed for the Number of Fry (NoF). Similarly, the Average Individual Weight (AIW) of fry across the three years and between the two semesters did not vary significantly (Figures 4A, 4B, 4C, 4D, 4G, and 4H). However, the Number of Containers (NoC) used for fry sales varied significantly (P<0.05) from year to year and from half-year to half-year (Figures 4E, and 4F).

At BagréPôle, the proportions of fry sold were 30.38%, 37.75% and 31.84% for the years 2020, 2021 and 2022 respectively. The proportions of fry sold in semester 1 and semester 2 were respectively 34.8% and 65.2% over the three years (Figure 4I). BagréPôle's customers came from several localities or regions of the country to obtain supplies of fry. In fact, proportional values for the locality or region of origin of customers in the order of 68.67%, 7.92%, 6.41%, 3.4%, 2.64% and 10.94% were recorded during the three years of sales respectively for Kadiogo, Boulgou, Oubritenga, Haut-Bassins, Kouritenga, Yatenga, Mouhoun, Boulkiemdé and many other localities or regions (Figure 4J). The strains of Nile tilapia, *Oreochromis niloticus* used at BagréPôle are mainly the Akossombo strain and the Bouaké strain, with sales rates of around 4.08% and 95.91%. Regarding the sex of the fish, customers bought 33.33% monosex males, 31.66% mixed fry and 35% immatures (Figure 4K).

In 2020 and 2021, the minimum and maximum unit prices of fry recorded were in the order of USD 0.042 and USD 0.79 respectively. In 2022, the minimum and maximum fry unit prices recorded were around USD 0.10 and USD 0.067 for semester 1 and semester 2 respectively. Additionally, the maximum recorded unit prices of around USD 1.38 and USD 0.54 corresponded respectively to semester 1 and semester 2 of the same year. In the first half of 2020, no minimum or maximum fry unit prices were recorded. On the contrary, the values of USD 6.69 and USD 1,588.97 on the one hand, and USD 10.04 and USD 12,544.51 on the other, correspond respectively to the minimum and maximum

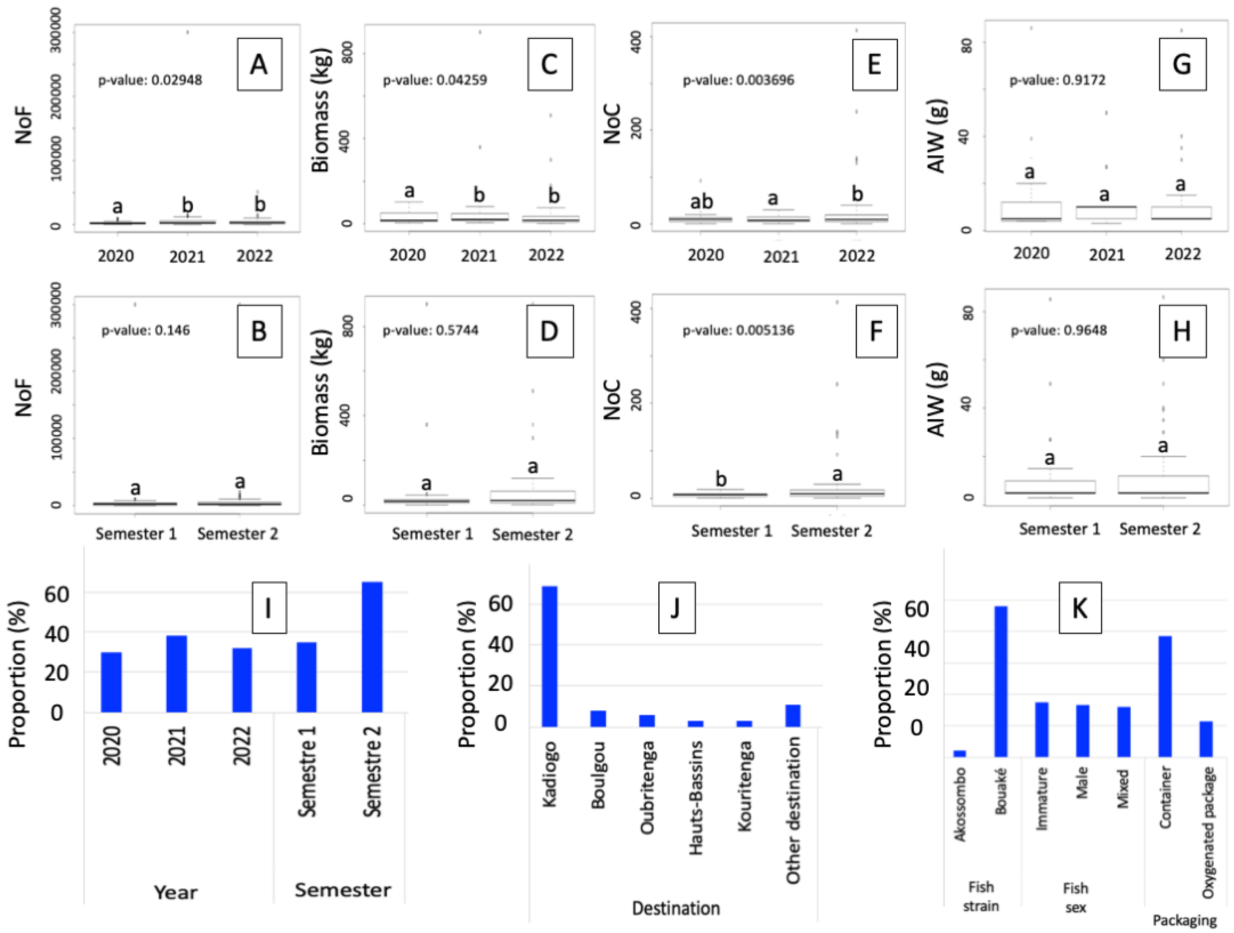

Figure 4. Evolution of production and sales parameters of *Oreochromis niloticus* fry at BagréPôle from 2020 to 2022. The zootechnical variability of fry is provided by semester and by year (A, B, C, D, E, F, G, and H). The proportions of the different sales profiles and parameters of fry are provided in I, J, and K. NoF is the Number of Fry, NoC is the Number of containers, and AIW is the Average Individual Weight of fry.

revenues for the years 2020 and 2021. The receipts of USD 20.07 and USD 702.49 on the one hand, and USD 40.14 and USD 10,656.98 on the other, correspond respectively to the minimum and maximum receipts of fry for semester 1 and semester 2 of the year 2022. The amounts of USD 8.30 and USD 155.55 in 2020 respectively corresponded to the minimum and maximum total receipts recorded. In 2021, the minimum and maximum total revenues recorded were USD 10.04 and USD 12,544.51 respectively. In 2022, USD 20.87 and USD 40.95 were recorded as the minimum and maximum total revenue for half-year 1 and half-year 2 respectively. In the same year, the amounts of USD 708.35 and USD 10,988.56 were recorded as minimum total revenue (Table 3).

BagréPôle offers extra services when preparing the transport of fry. For the transport of fry sold, BagréPôle's packaging is made up of containers and oxygenated bags in proportions of 77% and 23% respectively. In 2020, the unit price of packaging was virtually nil throughout the year. However, the minimum and maximum unit prices of packaging recorded in that year were around USD 0.42 and USD 1.67 respectively. In 2021, the minimum and maximum unit packaging prices were in the order of USD 0.42 and USD 0.33 in the first and second half of the year respectively. For 2022, the minimum price was around USD 0.80 and the maximum price around USD 0.84 and USD 0.97 in half-year 1 and half-year 2 respectively. The minimum packaging revenue was of the order of USD 0.80, USD 1.61, USD 0.33, USD 0.80 and USD 0.80 respectively in semester 2 during the year 2020, in semester 1 and semester 2 during the year 2021, and in semester 1 and semester 2 in 2022. The maximum packaging revenue recorded over the three years was in the order of USD 50.18, USD 24.09, USD 52.19, USD 46.57 and USD 331.58 in half-year 2 of 2020, in half-year 1 and half-year 2 of 2021, and in half-year 1 and half-year 2 of 2022.

Variability in Grown-Up Fish Production and Sale at Bagrépôle

For merchant fish production, BagréPôle uses monoculture of tilapia *Oreochromis niloticus* and polyculture of tilapia *Oreochromis niloticus* and catfish *Clarias gariepinus*. Weight gains, quantities of feed consumed by the fish and feed conversion rates did not vary significantly (P>0.05) for the values obtained in monoculture and polyculture. The average weight gain of merchantable fish was 500 g in monoculture and 400 g in polyculture. The feed conversion rate was 1.65% in monoculture and 1.71% in polyculture. As for parameters such as yield (23 t/ha/yr *vs.* 33 t/ha/yr), predicted production quantity (6900 kg *vs.* 6500 kg) and harvested quantity of merchantable fish (13000 kg *vs.* 13150 kg), the differences observed were also non-significant in monoculture and polyculture (Figure 5).

For both monoculture and polyculture, the number of fish loaded was 21,000 in 2021 and 20,000 in 2022, with identical average individual weights at loading of 16 g and an average loading density of 5.85 fish/m^2. The forecast average individual weights at harvest were estimated at 375 g in 2021 and 400 g in 2022, with a forecast grow-out period of 6 months. However, actual average individual weights at harvest and actual grow-out times were 380 g and 7 months respectively for 2021, compared with 500 g and 8 months for 2022. Nevertheless, favorable production completion rates were observed, at 107% and 103% respectively for 2021 and 2022. In 2021, it took an average of 03 days to harvest a pond, while in 2022 it took 02 days. The values of the total costs of feed consumed were also recorded (Figure 6). For all these parameters, no significant difference (P>0.05) was observed between 2021 and 2022. However, the values observed for the duration of the rearing cycle (305 days in 2021 *vs.* 230 days in 2022) varied significantly (P<0.05).

The frequency and composition of merchant fish harvests are summarised in Figures 7G and 7H. For the year 2021, the frequency of harvests is relatively low compared with 2022 (15% vs. 85%). In terms of monthly frequencies, in the months of December, January, June and October, harvest frequencies were around 15% over 2021 and 2022. In September and July, they were 5%, while in April, the frequency reached 30%. The harvest frequency for tilapia in monoculture is 40%, and 60% for tilapia in polyculture. In terms of harvest composition, the frequency of adults only is 70% and that of a combination of juveniles and adults is 30%. With regard to the frequency of harvests per pond, pond F1 had the

Table 3. Evaluation of prices for fry and complementary services at the BagréPôle fish farm

Year/Semester		2020		2021		2022	
		Semester 1	Semester 2	Semester 1	Semester 2	Semester 1	Semester 2
Fry unit price (UDS)	Minimum	-	0.042	0.042	0.042	0.1	0.1
	Maximum	-	0.79	0.79	0.79	1.38	0.64
Packing unit price (UDS)	Minimum	-	0.42	0.42	0.33	0.8	0.8
	Maximum	-	1.67	1.22	1.22	0.84	0.97
Fry revenue (UDS)	Minimum	-	6.69	10.04	10.04	20.08	40.16
	Maximum	-	1,590	12,550	12,550	703	10,661.79
Packaging revenue (USD)	Minimum	-	0.8	1.61	0.33	0.8	0.8
	Maximum	-	50.2	24.1	52.21	46.59	331.73
Total revenue (USD)	Minimum	-	8.3	10.04	10.04	20.88	40.96
	Maximum	-	1,556.22	12,550.18	12,550.18	709	10,994

USD refers to United State Dollar

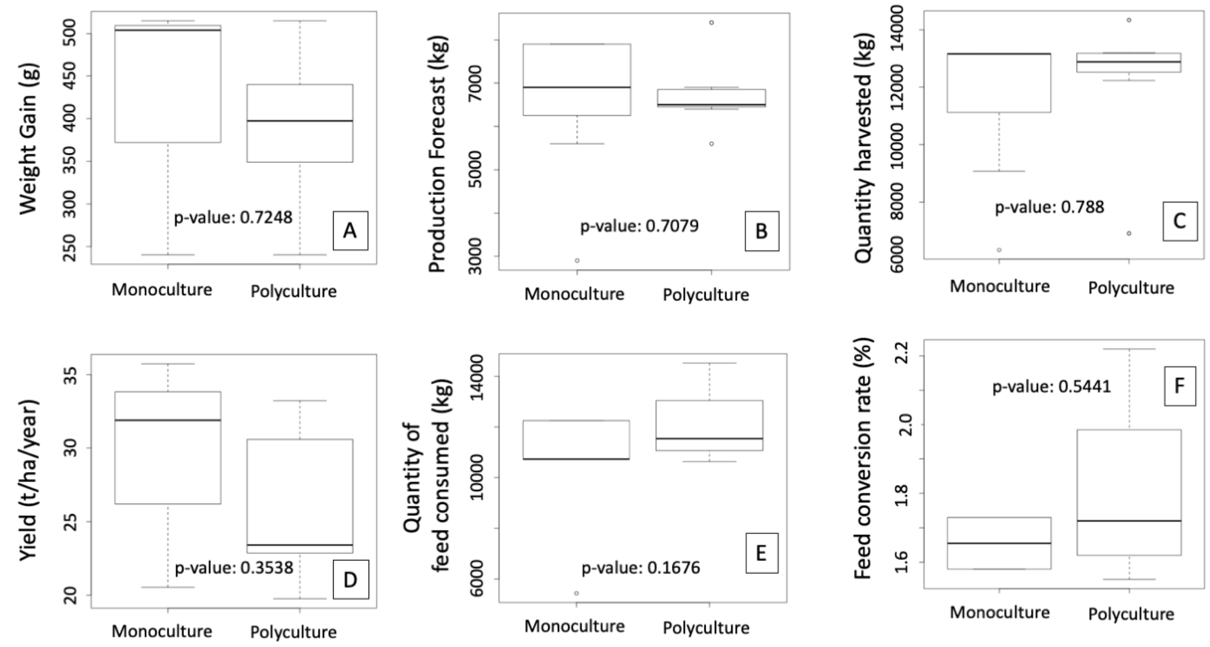

Figure 5. Variation in various production parameters for marketable fish over the period 2021 and 2022.

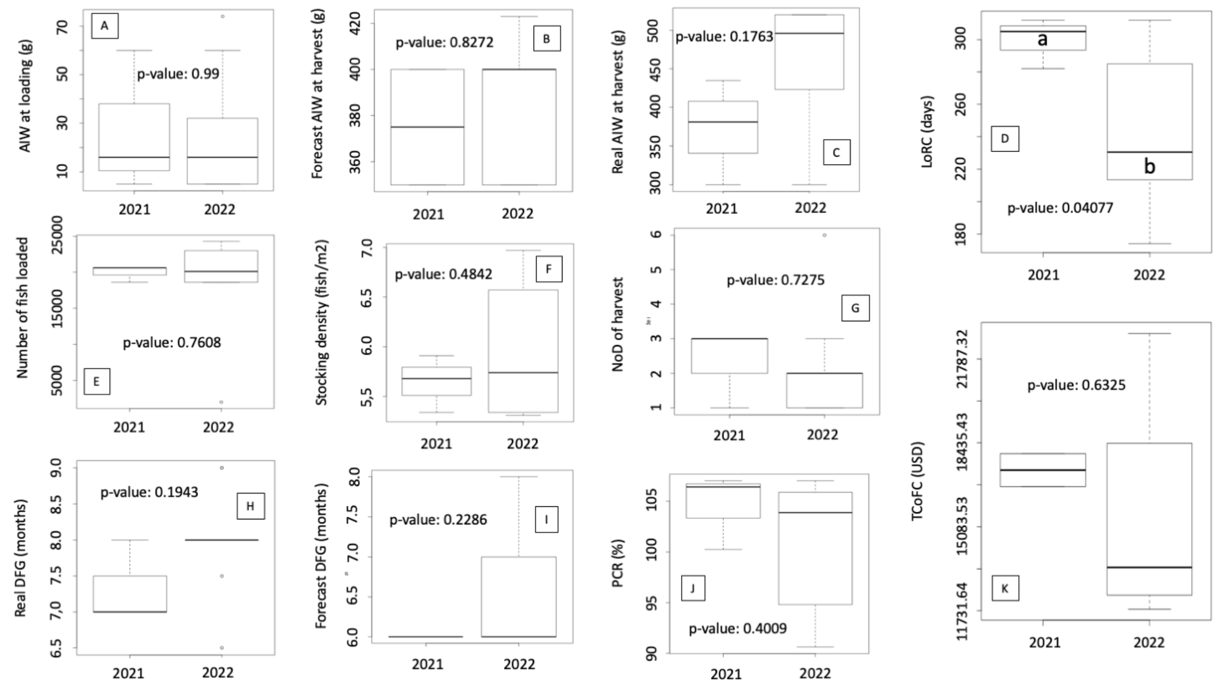

Figure 6. Variation in the various zootechnical parameters of market fish in relation to the year of production. AIW refers to the Average individual weight (g), DFG is the Duration of Fish Grow-out (months), NoD is the Number of days of harvest, PCR is the Production Completion Rate (%), LoRC is the Length of rearing cycle (days), TCoFC is the Total Cost of Feed Consumed (fCFA).

highest frequency of harvests at 27%, while ponds F2, F3 and F4 had a frequency of 15%. In ponds F4, F6, it was 10% while it was 5% in ponds E1 and E8.

The rates of decline in production were -98% and -10% for 2021 and 2022 respectively. The rates of increase in production and average individual weight were 3.5% and 9% respectively for 2021, compared with 6% and 48% for 2022. These respective percentages did not vary significantly (P>0.05) depending on the year. In addition, the rate of decline in grow-out time was -100% for 2022. The mortality rate remained constant for both years at 5% (Figure 7A, 7B, 7C, 7D, 7E, 7F).

Challenges Identified at Bagrépôle

A number of difficulties have been identified as hampering the sale of Nile tilapia *Oreochromis niloticus* fry at BagréPôle. Civil insecurity in the area means that some customers are afraid to travel to buy and transport fry. BagréPôle's remoteness from its main customers is also a constraint, as many have to travel at least 500 km each way to obtain supplies of fry. The station does not offer home delivery of fry to assist medium-sized fish farmers. There is also a lack of technical expertise on the part of fish farmers in running their grow-out farms, leading to failures or low yields. BagréPôle also lacks an after-sales service and technical assistance for certain customers who have signed up without any training in fish farming. The lack of expression of fry orders is also a problem, as many customers are unaware that orders must be placed in advance to enable the fry producer to plan production. They want to buy ready-made fry. BagréPôle is also short-staffed. Staff are often called upon to pool their skills across all the production units (fry production, merchant fish production, feed production, etc.), whereas each person should specialise in a link in the centre's production chain. In addition, there are sporadic shortages of feed stocks. The centre has to contend with an irregular supply of feedstocks, which is affecting fry production.

Based on the data recorded for merchant fish production, farm management has generally been satisfactory. However, there are some major problems in the commercial fish production sector at Bagrépôle. On the one hand, there is the very active presence of fish-eating birds (cormorants, kingfishers, herons) in the ponds. The small and medium-sized ponds were protected with nets, but it was impossible to do the same for the large ponds. However, the impact of their predation is not negligible but difficult to assess in terms of the quantity of fish taken per rearing cycle. In addition, we noted a case of mortality of several fish caused by a power cut that had momentarily stopped the aerators. We also noted the lack of a cold chain or cold room for preserving the fish caught, and the lack of delivery vehicles, which often delays harvests. One of the main bottlenecks to the development of commercial fish farming is the lack of quality and quantity of fish feed. Fish farming has been marked by periods of rationing of feed quantities and sporadic stock shortages. In addition, we noted a lack of equipment for transporting feed from the shop to the grow-out ponds, which often delayed the scheduled feed time.

Discussion

Mitigation Actions and Gender Inclusivity at Aqua-Farm Level

Based on the various constraints raised, several ways of building resilience can be proposed at farm level. For instance, it would be necessary to draw up an administrative and accounting procedure manual specific to BagréPôle and adapted to its mission of economic autonomy. BagréPôle must also review its fry sales policy by reducing the unit price of fry. Reducing the price of fry will encourage and reduce the cost of transport for fish farmers from remote areas. The station must also have a sales department that maintains a framework of communication with all customers who are supplied with fry so that production can be well coordinated and demand can be met. A gender-based recruitment of workers and technicians to carry out the tasks at BagréPôle would be a great help to this aqua-farm. This will enable each person to specialise in a production unit so that maximum rigour

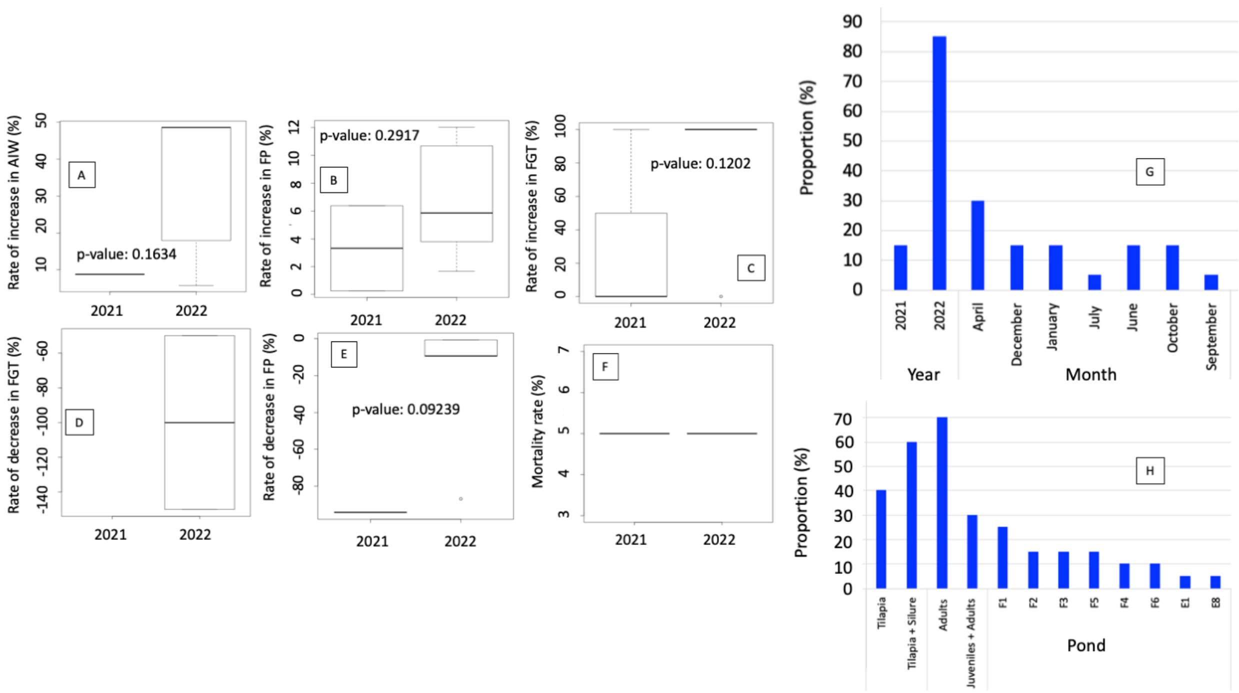

Figure 7. Rates of increase, rates of decrease, proportional production values depending on the year and composition of merchant fish harvests. AIW is the Average individual weight (%), FP refers to Fish Production, FGT refers to Fish Grow-out Time (%).

can be applied to the work. BagréPôle also needs to equip itself with a vehicle for transporting fry as a national fish farming reference centre. These means of distribution will enable the centre to make deliveries at conventional prices to those who have no means of transport in all localities. Finally, the centre needs to step up fry production by acquiring modern technical equipment and building more fish seed production facilities.

The development of an aquaculture company depends first and foremost on a judicious choice of farming species. BagréPôle made a good choice in taking *Oreochromis niloticus* as the main species to be developed, because it has good zootechnical aptitude and its flesh is appreciated by consumers. However, we suggest that BagréPôle add Clariidae fish farming, which have the ability to maintain strong growth at high densities, resist disease better and accept cheap feed. On the other hand, the feed used for the grow-out operation is a pelleted feed imported from Ghana under the RAANAN Fish Feed brand. BagréPôle imports them from this industry, but the main obstacle to the production of marketable fish is the irregular availability of feed. We suggest that BagréPôle take steps to manufacture the feed at the Centre in order to make up for this shortage. In addition, we propose that the Centre purchase fish feed trolleys to minimise delays in feed distribution. Finally, we propose that humanoids be installed at the edge of the large ponds to limit the activities of fish-eating birds.

Mitigation Actions and Gender Inclusivity in Aquaculture at National Level

In Burkina Faso, the current challenge for the sector of fisheries resources is, increasing 40% per year domestic production through aquaculture (SUSFISH Consortium, 2015). There is a need to foster transformation of aquatic foods systems for the improvement of its contribution to food security and nutrition. So, bringing and maintaining the principles of Good Practices in Aquaculture (GPA) at each stakeholder level, is necessary to regulate all aspects of the aquaculture value chain for NGA, including relationships with other sectors. Effectiveness, equity, transparency and predictability are fundamental indicators for GPA. Indeed, both public and private sectors have to effectively implement FAO technical tools and guidelines for sustainable aquaculture (FAO, 2020, 2019). GPA must be applied at three levels of management: the public administration level, the policy level, and the local community level (Figure 8A). GPA will require stakeholder involvement, accountability, and effective enforcement and compliance with the established law (Figure 8B). Thus, to ensure an economically profitable aquaculture, environmentally friendly aquaculture, and socially equitable aquaculture, the responsibility to be accountable should be shared between the public and the private sector through inclusion, transparency, awareness raising, and records keeping (Figure 8). This can only be achieved when the governing authority is willing to share its power with the private sector. It is therefore needed to strengthen the public-private partnership. So, local organizations should collaborate with the public sector and stakeholders to encourage local consumption of aquaculture products. Thus, a clearinghouse should exist to allow local buyers and developers to buy directly from small-scale aqua-farmers and support them with inputs.

The country is experiencing an overexploitation of natural aquatic resources. Subsidies, or aid provided to the fisheries industry to offset the costs of the activity, are another key factor in overfishing. Subsidies can lead to overcapacity of fishing gear and distortion of production costs, so that fishing operations continue when they would not be profitable. There is therefore a need to reduce harmful subsidies and redirect them towards the promotion of aquaculture. On the social and climatic front, it will be necessary to set up community-friendly model including community-based institutions which establish small-scale community-based protected areas, which will serve as spawning and nursery grounds for aquaculture, and which are protected by the local communities themselves. The community institutions will help collecting catch data to inform public authorities. Community-based reasoning must include gender aspects. To this end, rural women can be given responsibility for managing water reservoirs and using them for simple cage aquaculture. This is a promising idea, as women have already demonstrated their effectiveness in the post-harvest processing and marketing of processed fish products.

Aqua-farmers need to use Innovative Digital Technology (IDT) through on-line platform, online marketing (E-commerce, and E-payment) to connect themselves. This will help promoting inclusion in aquaculture by connecting aquaculture actors. Doing this, successful aquaculture initiatives should be easily inventoried annually for replication across the country. IDT will also help facilitating relevant polices and strategies through accurate data collection from key aquaculture stakeholders (e.g. aqua-farmers, feed suppliers). Reasoning about technology, the fabrication of simple replacement for machineries of treatment of waste water from aquaculture, will have to be the focus of the IDTs. Climate can affect many aspects of aquatic environments, including the temperature, oxygenation, acidity, salinity and turbidity of lakes and rivers, the depth and flow of inland waters, toxic algal blooms, etc. (FAO, 2015). The implementation of IDT should also consist of the establishment of a water monitoring platform (for both waste and aquaculture waters) on which aqua-farmers will have to report weekly climate-related water parameters. Similarly, a protocol for aquaculture wastewater treatment and management should be established and frequently updated on the platform. Achieving this will require training programs for aquaculture workers and promoting aquaculture education from the first levels of education.

Aquaculture cannot become effective without substantial private sector investment and financial institutions have to take the risk to invest in aquaculture. In addition, it is essential to go beyond subsistence aquaculture and to consider aquaculture as a business, whether it is micro, small, medium or industrial (FAO, 2006). So, innovative initiatives need be taken to increase the revenues of aquaculture entrepreneurs. To this end, several approaches can be envisaged, including the promotion of private entrepreneurship in aquaculture, the better organization and involvement of women and youth in aquaculture, and the stimulation and expansion of aquaculture activities.

In Burkina Faso, the role of women in the aquaculture sector remains poorly documented. After all, the various agricultural deficits regularly caused by environmental phenomena and climatic hazards have always required the commitment and contribution of rural women in the country. Rural women have always been active change actors and their dynamism has always been evident in the country's agricultural sector. Women are known to play an important role in the fisheries value chain and in fishing communities in Africa (Bradford & Katikiro, 2019; Du Preez, 2018; Thorpe et al., 2014) but their contribution to aquaculture needs to be accelerated. Increasing women's access to land and natural resources will go a long way to improving their ability to produce and procure food (Agarwal, 2018). In the city of Ouagadougou, for example, women represent 55% of urban agriculture producers (Ouédraogo et al., 2019), so there is a need to strengthen their capacity in integrated agro-aquaculture systems. Women decision-making power in aquaculture management institutions, communities and households, needs to be accelerated, as well. Policies to increase the decision-making capacity of women in the fisheries sector will help their real commitment to the sector (FAO, 2016). This will help to enhance women's leadership in food systems (Njuki et al., 2021) of which aquaculture is an integral part. Education and training will boost confidence level of women to start getting in aquaculture, while opening many opportunities in aquaculture for them. Education and training will help break down cultural and economic barriers that limit their participation in such income-generating activities. The provision of Financial and Technologies (FinTech) incentives will also help this. Furthermore, women should be represented in local water governance committees (Zakaria & Matsui, 2021) in order to improve their commitment to the management of water in reservoirs used for aquaculture. FinTech will be needed for financially viable aquaculture businesses and viable mechanisms for obtaining credit must be identified and implemented (FAO, 2006).

There is need for capacity building on Best Management Practices (BMP) of aquaculture production. Challenges to farmers include low prices, and local based needs such as inputs materials. In addition, certification became a barrier to trade or to sustainability. For that purpose, necessary steps should be taken to help small-scale aquaculture producers to have their fish certified by subsidizing the related payments. For the sake of transparency, the premium paid by consumers could be transferred to producers. Similarly, certification systems and private initiatives have a key role to play in mediating the problem faced by aqua-framers. Examples could be taken from countries such as Ghana (in West Africa), Kenya (in East Africa) and Malawi (in Southern Africa) where specific actions are being taken and implemented by different stakeholder groups to measurably improve aquaculture education and training (Leschen et al., 2021). The European Union (EU) guideline on legislation,

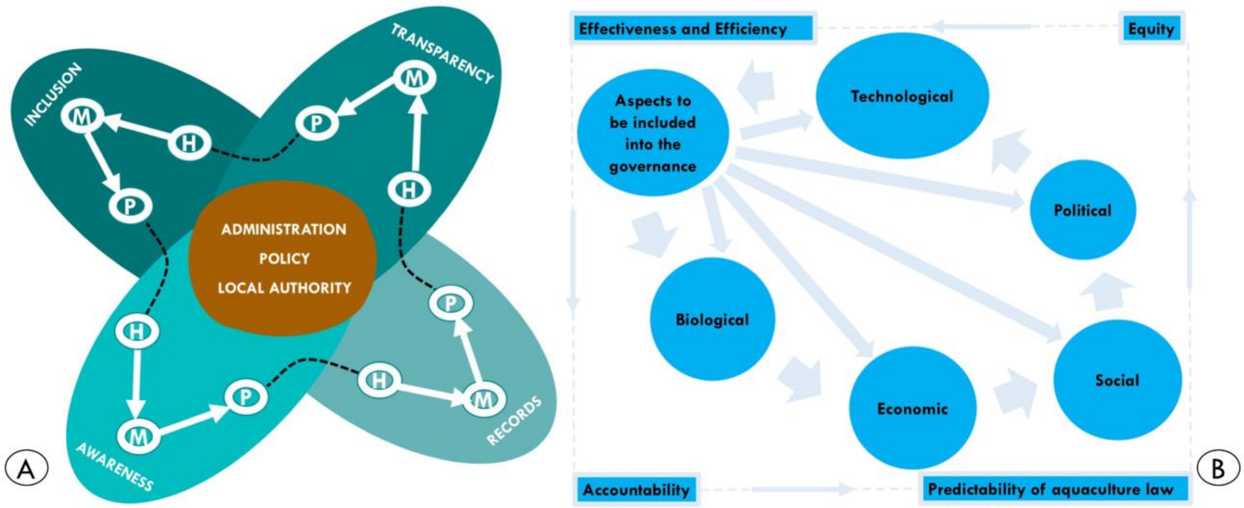

Figure 8. Applicable aquaculture management model in the Sahel zone. In (A), we use "H", "M", and "P" to refer to types of management which may be "Hierarchical", "Market", and "Participatory". Subsection (B) indicates that for good management of aquaculture all aspects including biological, social, political, economic, and technological aspects should be considered with effectiveness, efficiency, equity, accountability while ensuring the predictability of aquaculture legislation.

regulation, and certification of aquaculture within the circular economy (Regueiro et al., 2022) could be tailored to the Sahel context, as well.

There is also need for strengthening research and development in aquaculture in terms of (i) biosecurity for the control of pathologies (e.g., parasitic, bacterial, viral), (ii) quality exogenous feed, (iii) high-performance seed strains (e.g., fish, crustaceans, molluscs, algae). The selective breeding of efficient local strains for aquaculture and the development of efficient feeds from local by-products, are essential. For fish feed, the fishmeal problem needs to be solved. Seed diversification through the development of shrimp, frog, molluscs, algae (spirulina) would help with long-term sustainable development of the nation's aquaculture. The culture of molluscs, algae, etc. is increasingly recognized for its ecosystem services (Naylor et al., 2021).

Promoting Climate-Smart Aquaculture

In Africa, there is a need to keep building sustainability (environmental and social) into aquaculture policy and development (Mbaka et al., 2022). In the current Burkina Faso model, three types of aquaculture are practiced (Figure 9). This includes commercial aquaculture, community-based aquaculture, restocking aquaculture and integrated agro-aquaculture. Restocking activities include enhancement restocking, restoration restocking, and mitigation restocking. If poverty reduction, food security and sustainable income for aqua-farmers are to be achieved, considerable efforts must be made in climate-smart aquaculture (CSA) research, development, training and education. Efforts should be made to identify aquaculture education challenges, which include: limited knowledge, skills and innovative capacity to operationalize and commercialize technological advancements in fish production such as culture systems, fish breeding and genetics, as well as, fish nutrition, health management and post-harvest technologies (Nyonje et al., 2021). In addition to that, indigenous and local knowledge (ILK) are acknowledged as a valuable resource for climate adaptation (Leal Filho et al., 2022), and could be used to guide an inventory of the climatic factors that limit engagement in aquaculture in Burkina Faso.

For Next Generation Aquaculture (NGA), there is a need of diversifying aquaculture systems to nourish people, while ensuring environmental protection. If developed thoughtfully, aquatic foods can help reduce the environmental pressures on the planet from the current food system (Henriksson et al., 2021). To do this, it is worthwhile for all aquaculture actors to adopt environmental protection reflexes for future generations. However, the promotion of aquaculture in

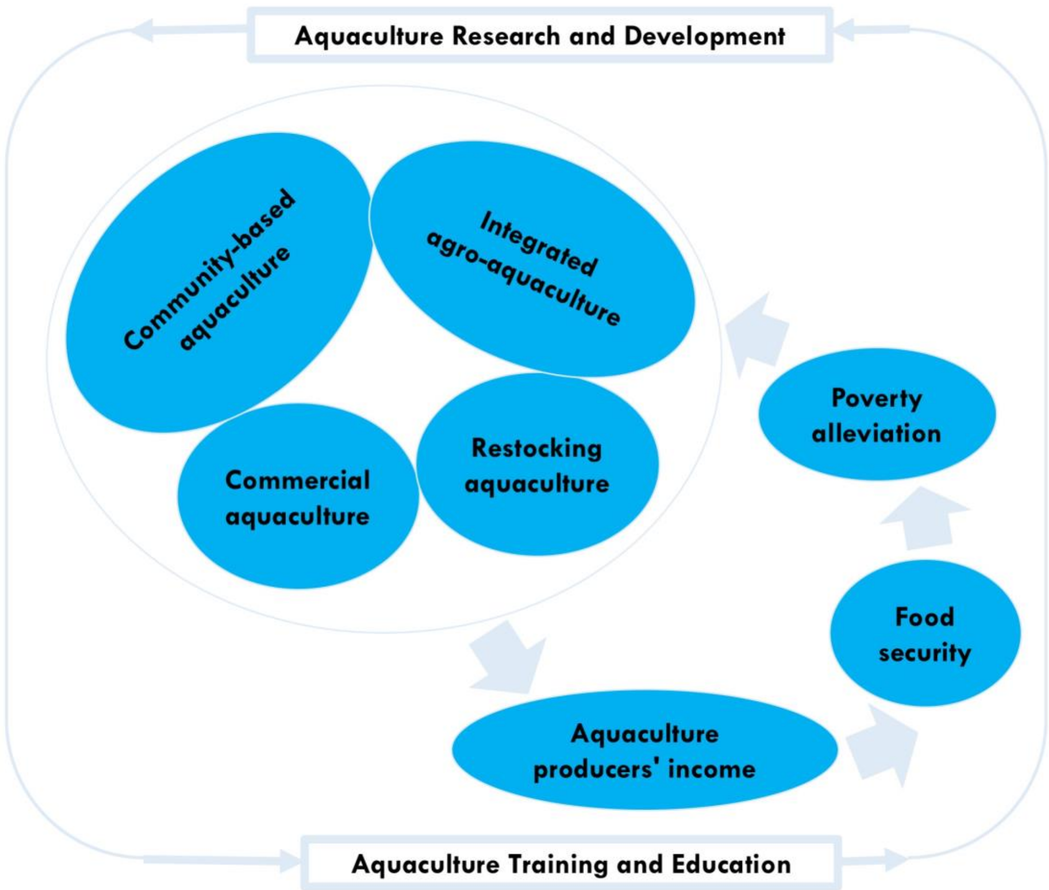

Figure 9. Conceptual model of aquaculture development in Burkina Faso.

all its forms needs redefining the types of aquaculture systems. Aqua-poles need to be suitable to each of the geographical regions of Burkina Faso. Aquaculture must be seen as an industry in which human intervention in the environmental pollution is low. Aqua-famers have an opportunity to promote climate smart aquaculture technologies by, for example, converting earthen ponds to geomembrane-equipped ponds with possibility of water treatment. In that context, regional and local interactions will be needed to promote climate-smart aqua-cultural practices and use knowledge and ground experience to train aqua-farmers. The idea here is to ensure environmental sustainability of aquaculture by rapidly scaling climate-smart aquaculture information and practices for water treatment facilities (e.g., Figure 10).

The public sector desires to mainstream aquaculture in the design and implementation of hydro-agricultural development initiatives in order to accelerate its development (MRAH, 2013). However, this initiative does not come without challenges. The two limiting factors to the development of land-based aquaculture system include; the challenge of securing land on hydro-agricultural perimeters by the aquaculture department and the relatively high cost of constructing ponds. Alternatively, aquaculture in enclosures and floating cages have comparative advantages over ponds. Floating cages and enclosures are often recommended because, in addition to the relatively low cost of setting up basic infrastructure, these techniques do not occupy peri-lacustrine land. These aquaculture techniques can therefore be scaled up primarily in rural areas of Burkina Faso. It is therefore necessary that mechanisms to minimize the risks associated with the use of floating cages and enclosures be investigated. In the same way, in order to limit pollution and aquatic organisms' diseases, it is necessary to find an ingenious alternative to open net-cage aquaculture. Open net-cage aquaculture provides no barrier between farmed fish and their environment. This means that huge amounts of fish feed, excreta and chemicals are released into the environment every day, often creating uninhabitable conditions for other species. Fish farms must additionally create the perfect environment for disease transmission. In open net-cages, these diseases can then easily spread to wild fish, wreaking havoc on local populations. Promoting CSA in a way the waste aquaculture water could be filtered and reused, should be an innovative option. This should have to be done on the basis of solar energy in order to save the cost of electricity, while also ensuring water savings. On the other side, the inland environment is often polluted with heavy metals and other contaminants, mainly from mining. Sometimes, fish and algae bioconcentrate some of these contaminants. So, the scientific community has an important advocacy and education role to play to ensure good quality water for aquaculture.

In the national strategy for the sustainable development of fisheries and aquaculture by 2025, it is planned to promote intensive and semi-intensive agro-aquaculture to increase its contribution to food security and poverty alleviation (MRAH, 2013). Of course, the adoption of mixed-use farms (e.g., row crops, livestock, and fish ponds), is known to positively affect the small-scale aquaculture market. In the same way, it has been suggested that an existing policy focusing on environmental sustainability and technological

Figure 10. A model of an aquaculture water purification system. The decantation water treatment systems (C, D and E) with the main discharge and drainage channels (A and B) to the wastewater treatment plant. All wastewater from the hatchery, tanks and ponds is discharged through a drainage channel to the decanting device where it is treated and then reclaimed by the local farmers for vegetable cultivation, fruit cultivation, etc.

innovation may be an incentive for Integrated Multi-Trophic Aquaculture (IMTA) (Alexander et al., 2015). Furthermore, an opportunity to develop intensive closed-system, such as Recirculation Aquaculture Systems (RAS) and Biofloc Technology (BFT), is available to private aquaculture entrepreneurs. These techniques are known to be based on environmentally friendly approaches. In this regard, and for the sake of transparency, the public authorities are obliged to elaborate, in concert with all stakeholders, an environmental impact assessment protocol or guide, applicable to all aquaculture initiatives and known to all.

Processing technologies such as smoking and drying can be improved by using more suitable traditional smokehouses that consume less firewood and by using solar energy to improve their economic efficiency. Very few efforts that can help address the current climate challenges are factored into the initiatives that are being taken so far. So, both climate-smart and nature-based solutions are to be promoted for local fish feed production. For private entrepreneurs investing in local feed production, the use of food waste to produce insect larvae for feeding to fish, should be the norm. However, insect production must be made financially feasible to make these feeds comparable to existing feeding options. This can have better economical inputs if feeds are produced on a large scale. This should help the smallholder farmers reduce between 15-20% of the feed costs. In addition, this will help the recovery of thousands of tonnes a week of organic waste from the urban environment. The major challenge would be to effectively integrate all stakeholders (e.g. food waste companies and feed companies) into the insect production system. The research system has the responsibility to determine the maximum inclusion level of insect protein in practical fish diets and the major antinutrients that require to be dealt with.

This work adopted an approach that examines and introduces other theories to bridge the observed gaps in the aquaculture sector in Burkina Faso. Indeed, it highlighted the main gaps existing in the aquaculture development strategy in order to make projections for the future. The gaps found are mostly related to the non-inclusion of gender in the different aquaculture initiatives, the lack of efficient rural water management strategies by the different agricultural components, the lack of awareness of environmental conservation etc. The evidence is that GPA remains a real challenge in aquaculture development in Burkina Faso. GPA must be seen as a culture. The work also provides a guide for local and foreign investors wishing to operate in the aquaculture sector in Burkina Faso. Many components of the aquaculture value chain still need to be tied up to ensure an environmentally friendly aquaculture. Inputs must be available locally and there should be a ready market for the outputs.

Aquaculture resources need to be promoted and preserved in order to ensure their sustainable exploitation and participation in the food security and the economic and social development of Burkina Faso. It would be necessary to anticipate possible unexpected events (e.g., climate change episodes, TiLV disease, COVID-19, …) by promoting safe, healthy and fair working conditions for all in the aquaculture industry. Research should be demand driven for the aquaculture industry itself at all the levels and across the value chain. So, policies should be structured based on strong scientific evidence and research should be regular to enable policy changes to be consistent in addressing real and new problems in the aquaculture industry. Future research should focus on aqua-farmers' perceptions of current aquaculture policies and proposals for inclusion in future legislation. The quantification, valuation, and market development of the ecosystem services provide by shrimp, frog, molluscs, algae, remain rare in the country. Defining the farming business model per aquaculture production system in Burkina Faso is needed, as well. There is also a need to evidence the contribution of women in the aquaculture value chains for sustainability purpose.

Ethical Statement

Ethical review and approval was not required for this study in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

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Author Contribution

TOA and IIT conceptualized the study and oversaw results. TOA and DDO collected data. TOA and DDO analyzed data, drafted the manuscript, and responded to review comments. All the authors reviewed and edited the manuscript, and contributed to the article and approved the submitted version.

Conflict of Interest

The authors declare that he has no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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References

Agarwal, B. (2018). Gender equality, food security and the sustainable development goals. Curr. Opin. Environ. Sustain. 34, 26–32. https://doi.org/10.1016/j.cosust.2018.07.002

Alexander, K.A., Potts, T.P., Freeman, S., Israel, D., Johansen, J., Kletou, D., Meland, M., Pecorino, D., Rebours, C., Shorten, M., & Angel, D.L. (2015). The implications of Aquaculture Policy and Regulation for the Development of Integrated Multi-Trophic Aquaculture in Europe. Aquaculture 443, 16–23. https://doi.org/10.1016/j.aquaculture.2015.03.005

Amoussou, T.O., Youssao, A.K.I., & Toguyeni, A. (2014). Improving aquaculture production in the Kou valley, Burkina Faso. Agric. Innov. Sustain. Dev. 4, 187–194.

Anderson, J.L., Asche, F., & Garlock, T. (2019). Economics of Aquaculture Policy and Regulation. Annu. Rev. Resour. Econ. 11, 101–123. https://doi.org/10.1146/annurev-resource-100518-093750

Becker, J., & Calado, R. (2021). Aquaculture, Fish and Fisheries: A new home for the Blue Revolution. Aquac. Fish Fish. 19–20. https://doi.org/10.1002/aff2.4

Bantenga, M.W. (2015). Histoire rurale du Burkina Faso. Presses Universitaires de Ouagadougou, Burkina Faso.

Bradford, K., & Katikiro, R.E. (2019). Fighting the tides: A review of gender and fisheries in Tanzania Kirsten. Fish. Res. 216, 79–88. https://doi.org/10.1016/j.fishres.2019.04.003

Compaore, I. (2017). Caractérisations morphologique, génétique et zootechnique de deux espèces sauvages de poisson-chat africain *Clarias gariepinus* (Burchell, 1822) et Clarias anguillaris (Linné, 1758) du Burkina Faso. Université Polytechnique de Bobo-Dioulasso, Burkina Faso.

Coulibaly, N.D., Lazard, J., & Cecchi, P. (2010). Programme d'appui au développement de l'agriculture du Burkina Faso phase 2 (PADAB 2): Composante n° 2 : développement rural décentralisée : actions pilotes proposées en pisciculture dans les régions est/centre est/Sahel : mission du 2 au 13 novembre 200. Cirad - La recherche agronomique pour le développement, Montpellier, France.

Crawford, A., Price-Kelly, H., Terton, A., & Echeverría, D. (2016). Review of current and planned adaptation action in Burkina Faso. Canada and UK Aid, London, United Kingdom.

DGRH (2021). Statistiques des importations de poissons et autres invertébrés aquatiques (2010-2019). Direction Générale des Ressources Halieutiques, Ouagadougou, Burkina Faso.

DGRH (2007a). Analyse de la filière pêche au Burkina Faso, EASYPol - Ressources pour l'élaboration des politiques. Direction Générale des Ressources Halieutiques, Ouagadougou, Burkina Faso.

DGRH (2007b). Projet de promotion du developpement rural par l'aquaculture au Burkina Faso.

Du Preez, M.-L. (2018). Gender and Small-Scale Fisheries in Africa. SAIIA Policy Brief. 173, 1–4.

Ekolu, J., Dieppois, B., Sidibe, M., Eden, J.M., Tramblay, Y., Villarini, G., Peña-Angulo, D., Mahé, G., Paturel, J.-E., Onyutha, C., & van de Wiel, M. (2022). Long-term variability in hydrological droughts and floods in sub-Saharan Africa: New perspectives from a 65-year daily streamflow dataset. Journal of Hydrology *613*, 1–17. https://doi.org/10.1016/j.jhydrol.2022.128359

FAO (2020a). The State of World Fisheries and Aquaculture 2020, Sustainability in action. Food and Agriculture Organization of the United Nations, Rome, Italy. https://doi.org/10.4060/ca9229en

FAO (2020b). Report of Regional Consultation on the development of Guidelines of Sustainable Aquaculture (GSA), Fisheries and Aquaculture Report. Food and Agriculture Organization of the United Nations, Bamako, Mali. https://doi.org/10.4060/cb0280en

FAO (2019). Draft report of the expert consultation on the development of sustainable aquaculture guidelines. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO (2016). Promoting gender equality and women's empowerment in fisheries and aquaculture. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO (2015). Climate change, the roles of genetic resources for food and agriculture. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO (2006). Guiding principles for promoting aquaculture in Africa: benchmarks for sustainable development. Food and Agriculture Organization of the United Nations, Accra, Ghana.

FAO (2019). Lancement de trois sites pilotes de pisciculture intégrée au Burkina Faso.

Greenpeace Africa, 2021. Feeding a monster: How European aquaculture and animal feed industries are stealing food from West African communities. Organisation des Nations Unies pour l'Alimentation et l'Agriculture, Dakar, Senegal.

Henriksson, P.J.G., Troell, M., Banks, L.K., Belton, B., Beveridge, M.C.M., Klinger, D.H., Pelletier, N., Phillips, M.J., & Tran, N. (2021). Interventions for improving the productivity and environmental performance of global aquaculture for future food security. One Earth 4, 1220–1232.

IPCC (2019a). IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. Summary for policymakers. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

IPCC (2019b). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

Kabré, T.J.-A., Sanogo, S., & Naba, I. (2014). Aquaculture en zone sahélo-soudanienne : diagnostic des réalisations et analyse d'impact socio- économique de la filière poisson au Burkina Faso. J. Appl. Biosci. 76, 6368–6385. https://doi.org/10.4314/jab.v76i1.13

Jaakkola, E. (2020). Designing conceptual articles: four approaches. AMS Review 10(1–2), 18–26. https://doi.org/10.1007/s13162-020-00161-0

Lazard, J. (1987). Projet aquaculture de Banfora. Bilan diagnostic. Propositions de relance. CIRAD - La recherche agronomique pour le développement, Montpellier, France.

Leal Filho, W., Wolf, F., Totin, E., Zvobgo, L., Simpson, N. P., Musiyiwa, K., Kalangu, J.W., Sanni, M., Adelekan, I., Efitre, J., Donkor, F.K., Balogun, A.-L., Rui Mucova, S.A., & Ayal, D.Y. (2022). Is indigenous knowledge serving climate adaptation? Evidence from various African regions. Development Policy Review. 42(2), 1-22. https://doi.org/10.1111/dpr.12664

Lederman, N.G., & Lederman, J.S. (2015). What Is A Theoretical Framework? A Practical Answer. Journal of Science Teacher Education 26(7), 593–597. https://doi.org/10.1007/s10972-015-9443-2

Leschen, W., Pounds, A., & Little, D. (2021). Needs Assessment for developing Capacity for improved Aquatic Resource Development in Africa (NACARDA): Regional Education and Training Needs Assessment Aquaculture and Fisheries for Sub Saharan Africa. Stirling, UK.

Lingani, H. (1992). Les aménagements hydro-agricoles du Bazéga et leurs impacts socio-économiques. Mémoire de Maîtrise, Université de Ouagadougou, Burkina Faso.

MAHRH (2003). Rapport général de l'atelier international sur l'amplification des ressources halieutiques à travers la gestion participative : Leçons et perspectives. Ministère de l'Agriculture, de l'Hydraulique et des Ressources Halieutiques, Burkina Faso.

Mbaka, M., Cox, J.H., & Ronan, S. (2022). Aquaculture in Africa: Aquatic animal welfare, impact on the environment, and the sustainability of the sector. WellBeing International, WBI Studies Repository.

MERH (2015). Recueil des textes réglementaires sur la pêche et l'aquaculture au Burkina Faso. Ministère de l'Environnement et des Ressources Halieutiques, Ouagadougou, Burkina Faso.

Moehl, J.F., Beernaerts, I., Coche, A.G., Halwart, M., & Sagua, V.O. (2001). Proposal for an African network on integrated irrigation and aquaculture, in: Moehl, J.F., Beernaerts, I., Coche, A.G., Halwart, M., Sagua, V.O. (Eds.), Proposal for an African Network on Integrated Irrigation and Aquaculture. Food and Agriculture Organization of the United Nations (FAO), Accra, Ghana.

MRAH (2013a). Enquête cadre sur la pêche artisanale continentale - Rapport National. Ministère des Ressources Animales et Halieutiques, Ouagadougou, Burkina Faso.

MRAH (2013b). Stratégie nationale de développement durable de la pêche et de l'aquaculture à l'horizon 2025. Ministère des Ressources Animales et Halieutiques, Ouagadougou, Burkina Faso.

Naylor, R.L., Hardy, R.W., Buschmann, A.H., Bush, S.R., Cao, L., Klinger, D.H., Little, D.C., Lubchenco, J., Shumway, S.E., & Troell, M. (2021). A 20-year retrospective review of global aquaculture. Nature 591, 551–563.

Njuki, J., Eissler, S., Malapit, H., Meinzen-dick, R., Bryan, E., & Quisumbing, A. (2021). A review of evidence on gender equality, women's empowerment, and food systems. Washington, DC, USA.

Nyonje, B., Nangulu, A., Van Stappen, G., Obiero, K., Opiyo, M.A., Awuor, J.F., Pynoo, B., Kisaka, L., Nevejan, N., Ngiri, J., Maina, J., & Ogello, E. (2021). Building A Strategic Framework for Aquaculture Education in Kenya. Kenya Marine and Fisheries research institute, Kenya.

Osmundsen, T.C., Olsen, M.S., & Thorvaldsen, T. (2020). The making of a louse - Constructing governmental technology for sustainable aquaculture. Environ. Sci. Policy 104, 121–128. https://doi.org/10.1016/j.envsci.2019.12.002

Ouédraogo, D.B., Belem, B., Kiba, D.I., Gnankambary, Z., Nacro, H.B., & Sedogo, P.M. (2019). Analyzing Constraints and Opportunities of Urban Agriculture in the Greenbelt of Ouagadougou, Burkina Faso. Agric. For. Fish. 8, 73–80. https://doi.org/10.11648/j.aff.20190803.13

Ramsar (2023). Barrage de Samandéni. Ramsar Sites Information Sevice (RSIS) https://rsis.ramsar.org/ris/2439?language=en. (Accessed 15th August 2023)

Rajee, O., & Mun, A.T.K. (2017). Impact of aquaculture on the livelihoods and food security of rural communities. Int. J. Fish. Aquat. Stud. 5, 278–283.

Regueiro, L., Newton, R., Soula, M., Méndez, D., Kok, B., Little, D.C., Pastres, R., Johansen, J., & Ferreira, M. (2022). Opportunities and limitations for the introduction of circular economy principles in EU aquaculture based on the regulatory framework. J. Indust. Ecol. 26, 2033-2044.

Sanon, V.-P., Ouedraogo, R., Toé, P., El Bilali, H., Lautsch, E., Vogel, S., & Melcher, A.H. (2021). Socio-Economic Perspectives of Transition in Inland Fisheries and Fish Farming in a Least Developed Country. Sustainability 13, 1–34. https://doi.org/10.3390/su13052985

Sanon, V.P., Toé, P., Revenga, J.C., Bilali, H.E., Hundscheid, J.L., Kulakowska, M., Magnuszewski, P., Meulenbroek, P., Paillaugue, J., Sendzimir, J., Slezak, G., Vogel, S., & Melcher, A.H. (2020). Multiple-Line Identification of Socio-Ecological Stressors Affecting Aquatic Ecosystems in Semi-Arid Countries: Implications for Sustainable Management of Fisheries in Sub-Saharan Africa. Water 12, 1–29. https://doi.org/10.3390/w12061518

Sirima, O. (2004). Etude des peuplements piscicoles du bassin de la Comoe : inventaire, parametres de croissance des principales espèces et modes de gestion de trois (03) retenues d'eau. Mémoire d'Ingénieur du Développement Rural, Université Polytechnique de Bobo-Dioulasso, Burkina Faso.

Susfish Consortium (2015). Sustainable Management of Water and Fish Resources in Burkina Faso - a synthetic overview of the SUSFISH project. Vienna, Austria.

Thorpe, A., Pouw, N., Baio, A., Sandi, R., Ndomahina, E.T., & Lebbie, T. (2014). Fishing Na Everybody Business: Women's Work and Gender Relations in Sierra Leone's Fisheries. Fem. Econ. 20, 53–77. https://doi.org/10.1080/13545701.2014.895403

Troell, M., Naylor, R.L., Metian, M., Beveridge, M., Tyedmers, P.H., Folke, C., Arrow, K.J., Barrett, S., Crépin, A.S., Ehrlich, P.R., Gren, Å., Kautsky, N., Levin, S.A., Nyborg, K., Österblom, H., Polasky, S., Scheffer, M., Walker, B.H., Xepapadeas, T., & De Zeeuw, A. (2014). Does aquaculture add resilience to the global food system? Proc. Natl. Acad. Sci. USA. 111, 13257–13263. https://doi.org/10.1073/pnas.1404067111

UR-ABAQ (2017a). Développement d'une filière pilote de production de poisson-chat (*Clarias gariepinus*) au Burkina Faso : Amélioration et mise en place d'un système d'élevage pilote en circuit fermé. Université Nazi Boni, Burkina Faso.

UR-ABAQ (2017b). Développement d'une filière de production de semences améliorées de poissons, tilapia du Nil (*Oreochromis niloticus*) et poisson-chat (*Clarias gariepinus*). Université Nazi Boni, Burkina Faso.

Zakaria, A.-R., & Matsui, K. (2021). Assessing Awareness about Volta Basin Authority, Code of Conduct and Water Governance Challenges in the Volta Basin. Int. J. Environ. Agric. Biotechnol. 6, 59–68. https://doi.org/10.22161/ijeab

Table S1. Definition of the BSTs used to track the relevant literature

Search focus	Detailed boolean search term
Aquaculture legislation and gender	legislation OR politic*OR aquaculture OR "fish* farm*" OR develop* OR "Burkina* faso" OR sahel*
Aquaculture initiatives and gender	finance* OR project OR initiative OR "fish* farm*" OR aquaculture OR partner* OR facilit* OR "burkina* faso" OR sahel*
Limiting forces for aquaculture development	limit* OR constraint* OR challeng* OR aquaculture OR aqua* constraint* OR aqua* challeng* OR develop* OR burkina* OR sahel* gender* OR gender implication*
Environmental sustainability of aquaculture	sustainab* OR environment* OR climat* OR biolog* OR chemi* OR manag* OR gender OR gender implication*
Aquaculture management	gender OR "women empower*" OR "youth empower*" OR govern* OR economic* OR "economic empower*" OR manag* OR sociolog*