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Productivity and profitability of small-scale aquaculture in Malawi

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ABSTRACT

Small-scale aquaculture in Malawi contributes to nutrition and food security, and serves as a rural income diversification strategy. Nevertheless, its adoption is low. Drawing on a recent survey of 732 small-scale fish farms across the country, this study assesses the production, yield, profit, and profit per square metre of small-scale fish farms and explores their determinants using regression analysis. Most fish farms are owned and managed by individual farm-households, though communally owned farms are also present. Small-scale aquaculture is found to be profitable, though the gross margins are slim. Regression results reveal that production and profit are positively associated with the use of farms for both fingerling and grow-out production and the number of years the farm has existed, while yield and profit/m^2 are positively associated with the use of high-quality inputs such as commercial feed and inorganic fertilisers. These results suggest that small-scale fish farmers in Malawi and other similar settings should adopt improved technologies and follow best on-farm management practices to increase production and profits. This study contributes to the discourse on the pathway through which aquaculture in Malawi can best contribute to the country's development.

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1. Introduction

1.1 Background

The agriculture sector remains the core engine of Malawi's economy, employing 80% of the national workforce, contributing approximately 30% to the national gross domestic product (GDP), and accounting for over 80% of total export earnings (Benson and Hartley 2020; Tuni, Rentizelas, and Chipula 2022). The sector is dominated by smallholder farmers (Chinsinga and Chasukwa 2018). However, it is impeded by a number of challenges, including soil degradation, weak linkages to markets, poor infrastructure, low adoption of agricultural technologies, vulnerability to internal and external shocks, and limited access to quality and affordable inputs, extension services, and credit (Jew et al. 2020; Muyanga et al. 2020; Tufa et al. 2021; World Bank 2021, 2018).

Malawi's long-term development agenda, *Malawi2063,* aims to transform the country into a wealthy and self-reliant nation by the year 2063. The vision has identified urbanisation, industrialisation, agricultural productivity, and commercialisation as the key pillars to bring about this desired transformation. The country's agricultural policy focuses heavily on maize as a staple food and tobacco as a cash crop, though international demand for the latter is declining (Shah, Ricker-

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Gilbert, and Khonje 2021). In response to these challenges, there has been a call to diversify the country's agriculture sector by investing in alternative value chains. Along these lines, fisheries and aquaculture (fish farming) have been identified as one such alternative that can help Malawi meet its *Malawi2063* goals (Government of Malawi 2020). The fisheries value chain is also highlighted in the National Agriculture Investment Plan (NAIP).

Aquaculture has the potential to improve household food and nutritional security in Malawi and can be a climate-resilient adaptation strategy in the face of extreme weather events such as drought and floods (Abisha et al. 2022; Limuwa, Singini, and Storebakken 2018; Maulu et al. 2021; Pant, Shrestha, and Bhujel 2012; Perez et al. 2015; Shava and Gunhidzirai 2017; Troell et al. 2014). Nevertheless, it is not widely practiced in the country (Kapanda et al. 2005; Limuwa, Singini, and Storebakken 2018). This may be partly due to high start-up costs, limited technical knowledge and the limited promotion of aquaculture, which, in turn, may reflect a dearth of information about its profitability.

The present study aims to ascertain the patterns of production, yield, profit, and profit/m^2 of small-scale aquaculture in Malawi. The study evaluates fish farming across management systems (individually owned vs. communally owned farms), production systems (production cycles vs. continuous production), and other farm characteristics. The study also assesses the factors that influence the farm outcomes. Understanding the production, yield, profit, and profit/m^2 of fish farming, as well as their drivers, is essential for the development of effective strategies and policies to enhance the development of aquaculture in Malawi.

This study makes several contributions to the literature. First, while there is a rich literature on the profitability of aquaculture across Africa (Aheto, Acheampong, and Odoi 2019; Ali et al. 2016; Hyuha et al. 2011; Yassien et al. 2022), relatively little evidence seems to come from Malawi. Among the available studies conducted in Malawi, the focus has been on Tilapia enterprises and not aquaculture more holistically (Mussa et al. 2020; Phiri and Yuan 2018). This enables us to take note of promising yet less commonly produced species, such as *Clarias gariepinus* (mlamba/catfish). Second, many studies of aquaculture are at the household level – capturing only farm-households – while the present study is at the farm level (inclusive of communally managed farms, which are found in Malawi). Third, most studies of aquaculture in Malawi have used small samples of up to about 200 observations (Mussa et al. 2020). Moreover, the data was collected in just a few districts. In this study, we draw on a relatively large survey of 732 farms conducted in areas of concentrated fish farming in all three regions of Malawi. This provides a broader view of aquaculture in the country and allows for cross-region comparison. Fourth, as noted earlier, the government of Malawi is calling for agriculture diversification into more competitive and high-value products. Toward this end, our findings contribute to the current policy debate in Malawi around identifying priority agricultural value chains.

1.2 Overview of the fisheries and aquaculture sector in Malawi

The fisheries sector in Malawi encompasses both the capture fisheries (inclusive of ornamental fish) and aquaculture sub-sectors. The sector contributes about 4 percent to the country's GDP (Government of Malawi 2016). In 2020, its contribution to GDP was US$230 million for capture fisheries, US $30 million for aquaculture, and US$0.2 million for ornamental fish (Government of Malawi 2021). The sector provides jobs to over 150,000 fishers and about 15,000 fish farmers, and indirectly employs over half a million people engaged in ancillary activities, such as fish processing, fish marketing, boat building, and engine repair.

Data obtained from the Department of Fisheries indicate that aquaculture production has increased twelvefold from 813 metric tonnes in 2005 to 9,399 metric tonnes in 2020 (Figure 1). This increase in aquaculture production may be attributed to the decline in capture fisheries and fish consumption per capita, an increase in domestic fish demand as well as changing diets such as rising demand for protein (Munthali et al. 2021; Nankwenya, Kaunda, and Chimatiro 2017; Tran et al. 2022). Over the past decade, there have been various investments in aquaculture on the

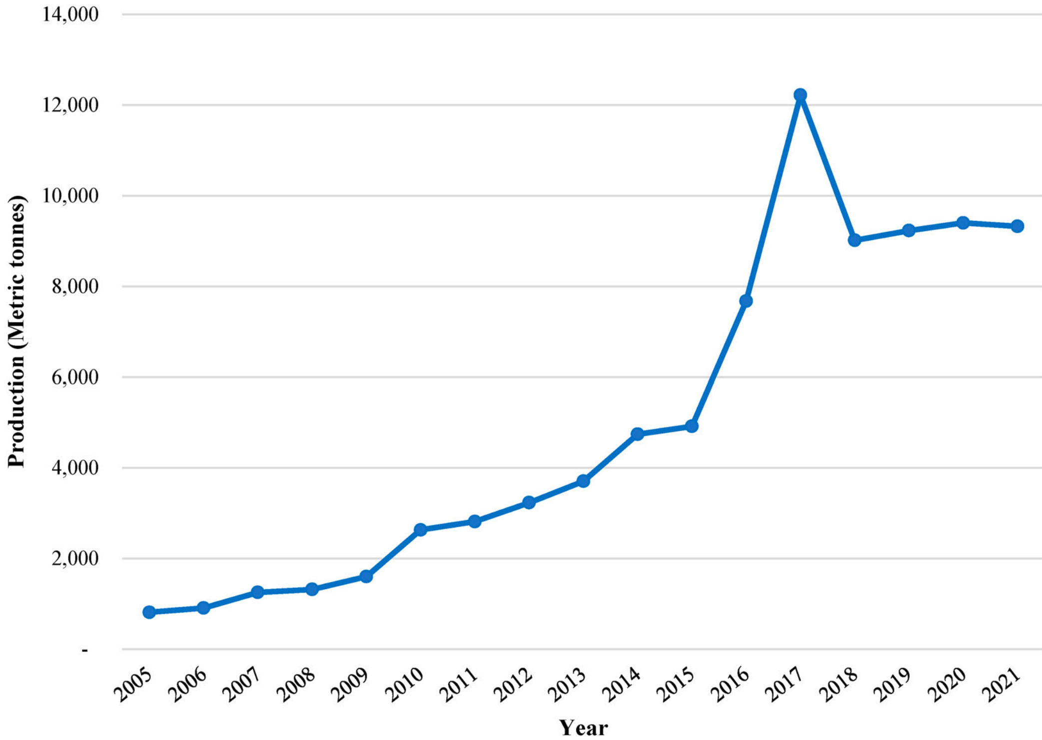

Figure 1. Aquaculture production between 2005 and 2021.
Source: Department of Fisheries, Malawi.

part of the government (through the Department of Fisheries), academic partners such as Lilongwe University of Agriculture and Natural Resources (LUANAR), development partners, and the private sector. These have ranged from efforts to improve fingerling supply, develop feed, provide extension services, and promote processing (CASA 2020; Government of Malawi 2021). Despite this activity, aquaculture production is low compared to other countries in sub-Saharan Africa (Adeleke et al. 2021). The growth of aquaculture in Malawi has been limited by a lack of access to extension services, credit, structured markets, and quality fish feed and fingerlings, as well as predation and fish diseases (CASA 2020; Munthali 2021; Munthali et al. 2022; Njera et al. 2017).

Fish consumption in Malawi stands at 9.5 kg per person per year (Government of Malawi 2021). This is lower than the world average of 18.9 kg (Mapfumo 2015) and the recommended World Health Organization (WHO) and Food and Agriculture Organization (FAO) level of 17 kg (Mwima et al. 2012). While fish supply from the wild has increased over the years, this increase is mainly of small pelagic species such as *Engraulicypris sardella*, while catches from traditional Tilapia species have fallen (Tran et al. 2022). It is estimated that the supply gap is around 20,000 tonnes per year, and this is filled mainly through imports (CASA 2020; FAO 2020). The bulk of fish imports are of Tilapia species, such that imports and domestically produced fish products are substitutes (Chikowi, Ochieng, and Jumbe 2021; Mussa et al. 2017; Nankwenya, Kaunda, and Chimatiro 2017). In order to increase per capita fish consumption, expanding aquaculture production is seen as a viable option in a country endowed with suitable natural resources for fish farming (SADC 2019; Tran et al. 2022). Additionally, aquaculture has been found to rank highly among 17 agricultural value chains in Malawi in terms of attainment of inclusive growth and attainment of agricultural transformation (Pienaar et al. 2023). Further, aquaculture has a very high potential to promote exports. It ranks fourth in a list of seventeen value chains that were ranked by Pienaar et al. (2023).

The aquaculture sector in Malawi is predominantly small-scale, with over 15,000 small-scale farmers practicing fish farming (Government of Malawi 2021). There are also two main commercial farms, namely MALDECO and Chambo Fisheries. Small-scale farmers operate either individually (individually owned farmers) or through clubs (community fish farms) (CASA 2020). As already highlighted, access to quality fingerlings is a challenge in the sector, such that most farmers tend to use recycled fingerlings either from their own farms or sourced from fellow farmers. Small-scale fish farms in Malawi can choose to produce just one fish species (monoculture) or several species (polyculture). At the end of the production season, some farmers completely drain their ponds and harvest all the fish before the start of another production cycle (complete harvest). Other farmers choose to partially harvest only the large fish and leave the small ones to continue growing for the next harvest (continuous/recycled production).

1.3 Conceptual framework

Aquaculture productivity and profitability depend on bio-physical, socio-economic, and demographic factors.

1.3.1 Biophysical factors

The use of quality inputs, including fingerlings, feed, and fertilisers, has been found to positively influence aquaculture productivity and profitability (Antwi et al. 2017; Duodu, Boateng, and Edziyie 2020). In Malawi, aquaculture production is particularly constrained by low-quality feed and fingerlings. Most smallholder farmers use sinking feed, which usually has a low protein-conversion ratio compared to floating feed (CASA 2020). Other determinants of Tilapia output in Malawi include fingerling quality, fertiliser use, and farm size (Mussa et al. 2020). Further, the use of high-quality inputs needs to be coupled with good farm management practices related to stocking density, water quality, water pH, and temperature (Moyo and Rapatsa 2021; Sharma and Leung 2008). In Bangladesh, Mitra et al. (2019) found that farmers practicing polyculture were more efficient and productive than those practicing monoculture. Other farm management-related factors such as farm use (whether it is solely for fingerling production or both fingerling and out-grower production) and production systems followed (production cycles vs. continuous production) may also influence farm outcomes. However, these have not been extensively studied.

1.3.2 Institutional factors

Previous studies have found that a lack of access to credit and extension/training can be a constraint to aquaculture productivity (Antwi et al. 2017; Khan et al. 2021). In the case of Malawi, the most common source of aquaculture extension is government extension officers. However, extension services are challenged in terms of the number of extension officers (particularly for aquaculture) and their technical capacity (CASA 2020). In Zambia, access to extension services is recognised as a driving factor in the impressive growth of the aquaculture sector, while a lack of financial support from banks eventually limits access to key production inputs (Avadí et al. 2022; Moyo and Rapatsa 2021). Additionally, Onumah, Brümmer, and Hoerstgen-Schwark (2010) show that fish farm ownership matters, with cooperatively-operated farms being less efficient than individually owned farms. For the former, a consensus has to be reached by the members of the executive management, whereas for the latter, decision-making is usually left to the owner, who can swiftly make and implement a decision.

1.3.3 Demographic factors

Demographic characteristics of farmers are also key determinants of aquaculture productivity and profitability. For example, farming experience has sometimes been found to positively affect aquaculture productivity (Aripin et al. 2020), though others have found that the productivity of commercial Tilapia farms decreased with more experience (Antwi et al. 2017; Mussa et al. 2020). In the latter cases, the authors concluded that novice (and often younger) farmers were more open to adopting innovations that increase productivity.

2. Materials and methods

2.1 Data

This study draws on the MwAPATA Aquaculture Survey (MAS), conducted in May – June 2021. The survey was conducted in 10 districts where fish farming is most common in each of the country's three regions, as determined by the Malawi Department of Fisheries and through consultation with district fisheries officers (DFOs). These include Nkhatabay and Mzimba (Northern region);

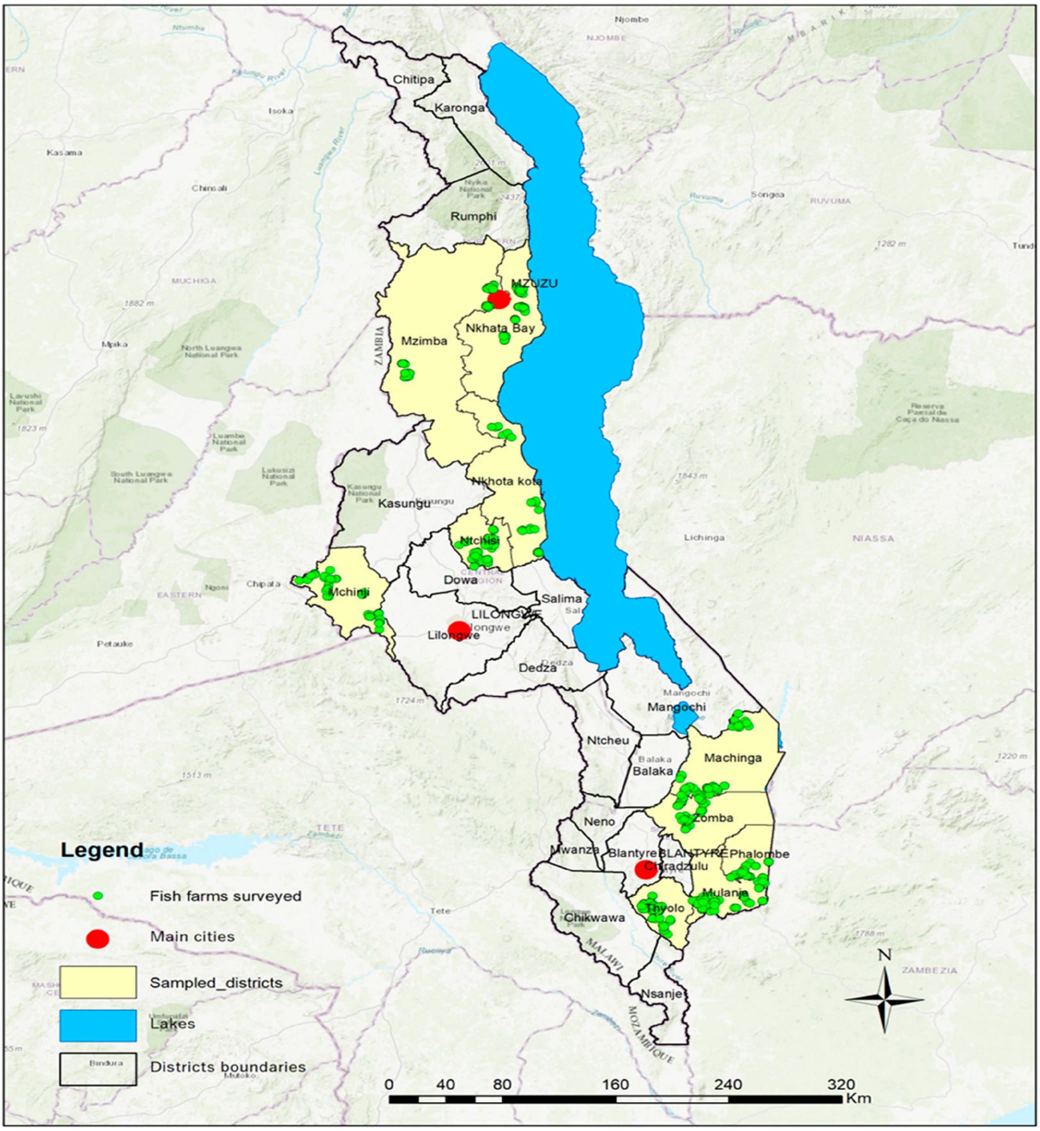

Figure 2. Districts and fish farms surveyed.

Source: Authors.

Ntchisi, Nkhotakota, and Mchinji (Central region); and Phalombe, Thyolo, Mulanje, Machinga, and Zomba (Southern region) (Figure 2).

The study employed a three-stage approach to selecting respondents:

i In the first stage, the team identified the districts in each region with the greatest number of fish farmers, selecting five in the Southern region, three in the Central region, and two in the Northern region.
ii In the second stage, the Extension Planning Areas (EPAs) in each of the ten selected districts were ranked based on the number of fish farms, and we selected three EPAs in each district with the highest number of fish farms.
iii In the third stage, a list of all fish farms in each of the selected EPAs was created. This list included all types of fish farms (e.g., pond farms and cage farms). Then, 30 fish farms were drawn randomly from the list. In cases where there were fewer than 30 fish farms in an EPA, we interviewed all farms in the manner of a census.

This resulted in a sample size of 732 (606 individually owned and 126 community-owned/managed) fish farms. According to the data collected from the Department of Fisheries, Malawi has approximately 9,000 fish farms, therefore, our sample covers about 8 percent of the total population of fish farms. It should be emphasized that this is not a nationally representative sample, though the sample is intended to represent the population of fish farms in the areas of the country where fish farming is most common.

A structured questionnaire was administered to fish farmers and community farm leaders to elicit information on the characteristics of their households (in the case of individually owned farms) or of community farm membership (in the case of community-owned farms), characteristics of the fish farms, management, fish production, and income realised from fish farming between December 2019 and December 2020.[1] Survey weights were applied in all the statistical analyses to generate statistics that loosely represent the population of fish farms in the areas of the country where fish farming is most common.[2]

2.2 Analytical methods

2.2.1 Measuring fish farm outcomes

In this study, we consider four key outcomes for small-scale fish farms, namely production, yield, profit, and profit/m^2. Production of fish farms is defined as the quantity produced on the farm in kilograms during the reference period, while yield is defined as the quantity produced per m^2. The profit and profit/m^2 of fish farms are determined with a Gross Margin (GM) analysis, a simple measure of financial performance that has been widely employed in other studies of aquaculture (Akegbejo-Samsons and Adeoye 2012; Hyuha et al. 2011; Issa et al. 2014; Namonje-Kapembwa and Samboko 2020). The GM is computed by deducting the total variable costs (TVC) from the total revenue (TR) of a farm. It should be noted that fixed costs are not accounted for in the GM analysis, though the scale of farm establishment costs will be addressed in the results section. In our study, the value of production is inclusive of all the fish harvested, with a monetary value imputed for what is consumed, gifted out, or otherwise not sold.

The data contained a small number of outliers, which could have strongly influenced the analysis. To address these outliers, we winsorized the gross margins at the 2nd and 98th percentile and the measure of production (kgs harvested) at the 98th percentile.

2.2.2 Econometric model specification

Multiple linear regression was used to determine the factors that influence the production, yield, profit, and profit per square metre of small-scale fish farms in Malawi. The multiple linear regression model has been widely used to identify factors that affect the productivity and profitability of aquaculture enterprises (Aheto, Acheampong, and Odoi 2019; Ali et al. 2016; Antwi et al. 2017; Bimbao et al. 2000; Hyuha et al. 2011; Musaba and Namanwe 2020; Yassien et al. 2022). The model is specified as follows:

$$Y = \boldsymbol{F\alpha} + \varepsilon \tag{1}$$

where Y is alternately a measure of logged[3] production, yield (quantity produced/m^2), profit, or profit/m^2; $\boldsymbol{F}$ is a vector of fish farm attributes/variables indicated in Table 1, and ε is a random error term. Y is estimated as a function of farm ownership structure, species farmed, production system followed, input usage, farm size (only included when Y is not scaled to farm size), labour endowment, fish farming experience, the intensity of contact with extension, access to credit, and record-keeping practices. The variables and their definitions are presented in Table 1.

It should be noted that our use of an ordinary least squares (OLS) regression assumes that decisions around input usage are not correlated with the error term representing unobserved shocks. If farmers use more or higher-quality inputs when they expect fewer negative shocks (and, conversely, use less inputs when they anticipate greater risk), the OLS estimates would be biased. Our regression results should be interpreted as correlations and not necessarily causal relationships.

Table 1. Definitions of key variables.

Variable	Definition
Dependent variables	
Production	Total quantity of fish harvested (kg)
Yield	Quantity of fish harvested per square meter (kg/m^2)
Farm profit	Total profit generated from the farm (MK)
Farm profit/m^2	Profit per square meter (MK/m^2)
Independent variables	
Individually-owned farm	1 = Farm owned and managed by an individual household, 0 = Otherwise
Community-owned farm	1 = Farm owned and managed by community, 0 = Otherwise
Species	
Orichromis karongae	1 = *Orichromis karongae*, 0 = Otherwise
Orichromis shiranus	1 = *Orichromis shiranus,* 0 = Otherwise
Tilapia rendalli	1 = *Tilapia rendalli*, 0 = Otherwise
Clarias gariepinus	1 = *Clarias gariepinus*, 0 = Otherwise
Culture type	
Monoculture	1 = Monoculture (practice of culturing one species on a farm), 0 = Otherwise
Polyculture	1 = Polyculture (practice of culturing more than one species on a farm), 0 = Otherwise
Farm area	Summed area of fish ponds (m^2)
Number of ponds	Number of ponds on the farm
Use of the farm	
Grow-out production	1 = Grow-out production, 0 = Otherwise
Fingerling production	1 = Fingerling production, 0 = Otherwise
Continuous/recycled production system	1 = Continuous production cycles (farm used recycled fingerlings and produced fish continually without pond maintenance), 0 = Otherwise
Feed	
Homemade feed	Quantity of homemade feed used in kg or kg/m^2
Commercial feed	Quantity of commercial feed used in kg or kg/m^2
Fertilizer	
Inorganic fertilizer	Quantity of inorganic fertilizer used in kg or kg/m^2
Organic fertilizer	Quantity of organic fertilizer used in kg or kg/m^2
Labor endowment	Number of adult household members or communal farm members
Farming experience	Years the fish farm has been in operation
Location (region)	
Northern region	1 = Northern region, 0 = Otherwise
Southern region	1 = Southern region, 0 = Otherwise
Central region	1 = Central region, 0 = Otherwise
Extension services	Number of interactions with extension services in past year
Access to credit	1 = Took out a loan for the fish farm
Record keeping	1 = Farm maintains written records, 0 = Otherwise

A diagnostic test of the Variance Inflation Factor (VIF) was conducted to ensure there is no serious multicollinearity among independent variables, applying a threshold of 10 to determine whether variables are "highly" collinear (Abrha, Emanna, and Gebre 2020; Gujarat 2003). The VIF for the models in this analysis was less than 10, indicating an acceptable level of multicollinearity. We corrected heteroskedasticity by obtaining robust standard errors, which are clustered at the district level.

3. Results

3.1 Descriptive analysis

3.1.1 Characteristics of fish farms

The general characteristics of fish farms in Malawi are presented in Table 2. Fish farms in the areas of Malawi with concentrated aquaculture activity are predominantly owned and managed by

Table 2. Characteristics of fish farms in Malawi.

Variable	Share of farms (%)[a]
Farm ownership structure	
Individually owned	86.8
Communally owned	13.2
Type of rearing facility	
Ponds	94.5
Dams	5.5
Source of water	
Groundwater	75.1
River	24.0
Irrigation scheme	0.9
Primary use of the farm	
Grow-out production	96.2
Hatchery operations (fingerling production)	0.3
Both grow-out and fingerling production	3.4
Species farmed	
Tilapia rendalli (chilunguni)	53.3
Oreochromis shiranus (makumba)	57.2
Oreochromis karongae (chambo)	18.8
Clarias gariepinus (mlamba/catfish)	1.8
Culture type	
Monoculture	71.1
Polyculture	28.9
Fish-rearing system	
Continuous production	73.2
Production cycles	26.8
Sources of new fingerlings[b]	
Fellow farmers	54.0
Recycled (own production)	20.0
Government hatchery	13.9
NGO/Project	9.0
Private hatchery	2.2
Other sources	0.7
Wild (caught in open water)	0
Type of feed	
Homemade feed only	92.4
Commercial/floating feed only	1.2
Both homemade and commercial feed	6.2
Type of fertilizer	
Organic fertilizer only	41.1
Inorganic fertilizer only	3.9
Both organic and inorganic fertilizer	45.5
None	9.5
Access to extension services	72.8
Access to credit	6.2
Record keeping	37.5

Source: MAS 2021; [a] Summary statistics should be understood to reflect the population of fish farms in the areas of Malawi where fish farming is most common; [b] Values can sum to over 100% as farms can access multiple sources of fingerlings

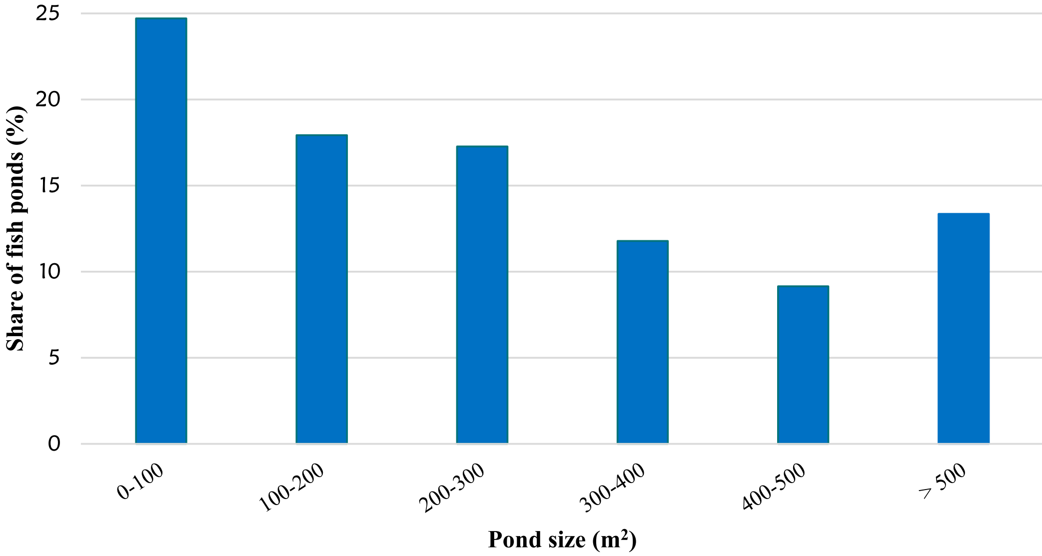

Figure 3. Distribution of pond size on fish farms in Malawi.
Source: MAS 2021

individual fish farming households (86.8%), though communally owned farms are also present. Most of the farms are pond-based (94.5%), with the most common water source being groundwater (75.1%), followed by river water (24.0%). The average number of ponds per farm is 1.4, with a mean pond size of 299.5 m^2, although about half of the ponds (50.1%) have a size of $\leq$200 m^2 (Figure 3). Out of their total land holdings, fish farming households allocate nearly 3% to fish farming, on average.

Overall, a majority of the fish farms (96.2%) are grow-out farms (producing adult fish and not only fingerlings). Farmers produce various fish species either in monoculture or polyculture (production of more than one fish species) systems, with 71.1% practicing monoculture. Just over half of the fish farms culture chilunguni (*Tilapia rendalli*); over half culture makumba (*Oreochromis shiranus*); and 18.8% produce chambo (*Oreochromis karongae*). A much smaller share of farms (1.8%) stock their ponds with mlamba/catfish (*Clarias gariepinus)*. Just under three quarters of the fish farms practice continuous production in which farmers produce fish continually without interruption for pond maintenance. Just 26.8% of the farms adhere to one or two distinct production cycles (with each production cycle having a duration of about six months, followed by pond drainage). Farmers obtain their fingerlings from various sources. More than half of the fish farmers (54.0%) obtain their fingerlings from fellow farmers, followed by recycled (20.0%), government hatcheries (13.9%), NGOs/projects (9%), and private hatcheries (0.7%), with almost no farms catching fingerlings from wild/open waters.

With regard to inputs for aquaculture production, nearly all the fish farms (98.6%) use homemade feed (made from maize bran, soyabean, groundnuts, common beans, usipa (*Engraulicypris sardella*), kitchen waste, and vegetables), while 7.4% use commercial/floating feed. Some farms use both types. While 86.6% of farms use organic fertiliser, 49.4% use inorganic fertiliser, and 9.5% of the farms did not apply fertiliser at all.

Nearly three-quarters of fish farms in Malawi have access to extension services. Just 37.5% of the fish farms maintain written records of their farm operations, and 6.2% access some credit.

3.1.2 Level of fish farm production, yield, profit, and profit/m^2

A summary of the level of production of small-scale fish farms in Malawi is presented in Table 3. Over 98% of farms harvested some fish, and the annual fish production ranged from 0 to 1,779

Table 3. Production, yield, profit, and profit/m² of small-scale fish farming in Malawi.

	(1)		(2)		(3)		(4)		(5)		(6)
	Share of profitable farms		Profit (10,000s MK)		Profit per square meter (MK/m²)		Production (kg)		Yield (kg/m²)		Number of farms (obs.)
Category	%	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*N*
All	81.5	0.4	9.0	20.4	322.9	767.7	153.3	326.5	0.8	2.1	732
By farm ownership structure											
Individually owned	81.4	0.4	9.4	21.2	356.5	806.6	147.0	316.6	0.8	2.0	606
Community farm	81.9	0.4	6.4	13.1	103.5	369.0	194.5	384.5	0.8	2.0	126
By primary use of the farm											
Grow-out production	81.1	0.4	7.1	16.3	314.8	775.3	131.8	289.9	0.8	2.0	707
Fingerling production	58.4	0.6	1.8	2.3	61.8	96.6	23.0	20.7	0.1	0.1	3
Both grow-out & fingerling production	100	–	65.5	37.6	595.5	480.3	774.1	610.5	1.7	3.3	21
By fish rearing system											
Continuous production	84.1	0.4	6.7	14.1	325.9	809.6	124.0	287.6	0.7	1.7	562
Production cycles	74.3	0.4	15.4	30.9	314.5	638.4	234.0	405.5	1.1	3.0	170
By species											
Tilapia rendalli	83.2	0.4	11.6	24.0	290.3	638.1	183.2	354.2	0.9	2.5	364
Oreochromis shiranus	82.5	0.4	10.6	21.2	336.9	760.5	163.4	324.5	0.7	1.6	410
Oreochromis karongae	80.9	0.4	7.7	18.6	357.2	962.9	136.4	307.5	0.8	1.7	142
Clarias gariepinus	100	-	34.8	46.2	303.0	254.9	599.0	741.5	1.6	3.4	14
By culture type											
Monoculture	79.3	0.4	6.3	16.6	319.2	813.3	125.8	295.2	0.8	2.2	546
Polyculture	87.0	0.3	15.7	26.4	332.3	643.2	220.8	385.7	0.7	1.7	186
By region											
Southern Region	81.9	0.4	7.8	18.9	379.1	816.4	189.8	364.0	1.0	2.4	400
Central Region	77.0	0.4	4.9	12.6	254.5	916.6	104.5	285.5	0.6	2.0	176
Northern Region	3.5	0.4	10.4	22.2	206.9	400.0	80.7	195.9	0.2	0.4	156
By farm size											
0–200 m²	78.7	0.4	3.5	6.6	430.6	1002.7	110.5	274.5	1.2	2.8	349
200-1,000 m²	84.2	0.4	9.3	18.2	214.4	417.3	168.9	365.3	0.4	1.0	321
>1,000 m²	87.2	0.3	40.6	42.9	227.8	254.0	320.6	326.0	0.2	0.2	58

Source: MAS 2021.

kg per farm, with a mean of 153.3 kg (column 4). Some farmers from districts such as Mchinji did not produce anything due to an outbreak of Epizootic Ulcerative Syndrome (EUS), which was first reported in July 2020 (SADC 2020). However, just 1.4% of the farms were affected by EUS, and just 0.1% (three of the 19 farms that reported EUS) did not harvest any fish during the reference period.[4] A disaggregated analysis shows that community-owned farms have a higher level of production, on average, than individually owned farms; farms that follow production cycles have a higher level of production, on average, than farms that practice continuous production; farms that practice polyculture have a higher level of production, on average, than farms that practice monoculture; large farms of between 200 and 1000 m^2 have a higher level of production, on average, than smaller farms; and farms in the Southern region have a higher level of production, on average, than farms in the Central or Northern regions.

Results for yield (kg/m^2) reveal somewhat different patterns. For example, farms that produce in monoculture have a greater average yield relative to farms that produce in polyculture. Moreover, consistent with the widely observed inverse relationship between farm size and productivity, farms that are small (<200 m^2) have the highest average yield, while farms that are large (>1,000 m^2) have the lowest average productivity.

On average, farmers spend MK42,574.5[5] (US$52.3) annually to run their fish farms. A detailed analysis of production costs reveals that feed (homemade and commercial) accounts for more than half of the total fish production costs, on average (Table A1 and Figure 4). Note that household labour is not valued in this calculation of production costs.

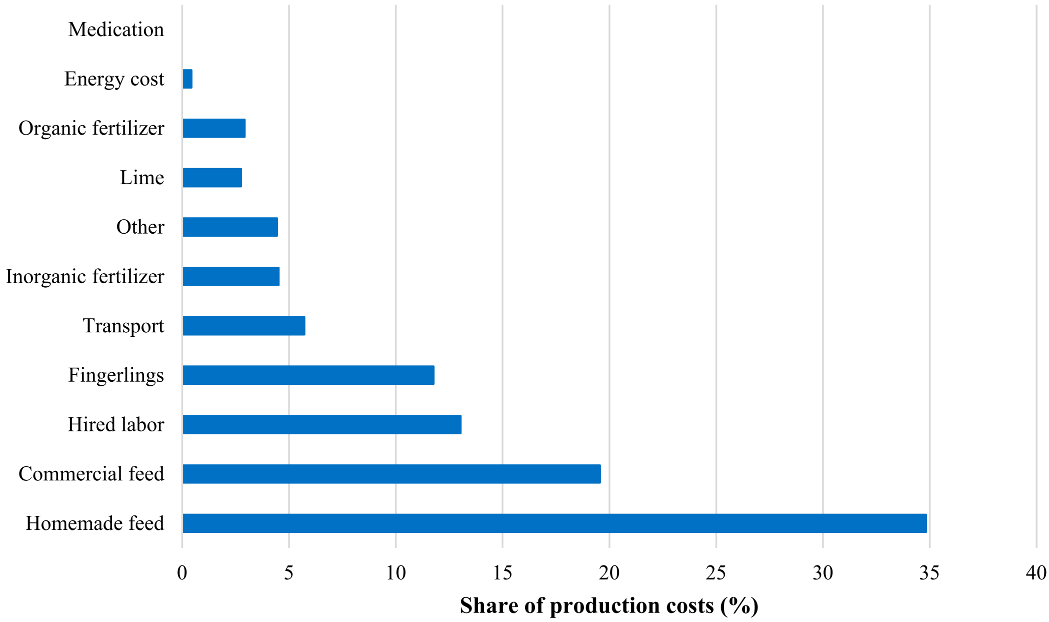

Figure 4. Distribution of production costs (average values) on fish farms in Malawi.
Source: MAS 2021.

In terms of profit, over 80% of the fish farms report positive profits, with an average of MK90,285.2 (US$111.0) gross margins per farm per year (Table 4). The level of profit varies considerably depending on the farm ownership structure, production system, species farmed, region, and farm size. From the average profit per square metre of MK322.9, the profit per hectare of fish farming is equivalent to MK 3,229,100 (US$3,969). On a per-hectare basis, this is higher than other important crops, such as maize (US$396), groundnuts (US$274), soyabeans (US$242), and tobacco (US$1,150) (Shah, Ricker-Gilbert, and Khonje 2021).

On average, communally owned fish farms see a higher profit than farms owned by individual farm-households. Farms that rear fish through production cycles (i.e., maintained their ponds after six months) have much higher average gross margins than those that continuously produce fish without pond maintenance. A regional disaggregation also shows that farms in the Northern region experience higher profits than the Southern and Central regions. In terms of species, it is worth noting that fish farms that produce catfish (*Clarias gariepinus*) have higher average gross margins than farms that culture other fish species. (Recall, however, that only 1.9% of farms produce any catfish.) An inadequate supply of fingerlings hinders the adoption of catfish species for aquaculture in Malawi (Sinyangwe et al., 2017).

3.1.3 Farm establishment costs

As noted earlier, our analysis of gross margins does not account for fixed costs, such as pond construction. However, because information on the cost of farm establishment was gathered, we can compare the annual gross margins in the reference year to the cost of farm establishment. This provides a very loose estimate of the number of years necessary to earn back the cost of farm establishment. On average, farms required MK91,692.3 (US$112.7) in start-up costs. Across all farms with a positive gross margin, it would seem to require 3.8 years, on average, for the farms to recoup their start-up expenditures. This value is 2.2 years for individually-owned farms and 14.3 years for communally owned farms. As will be discussed in section 4, this suggests that an analysis of profits over the life cycle of a typical farm, inclusive of fixed costs, may add value.

Table 4. Factors affecting fish farm production and profit in Malawi.

Variables	(1) Production (kg, ln)	(2) Profit (10,000s MK, ln)[a]
1 = Individually owned farm	−0.26	−0.11
	(0.226)	(0.801)
1 = Species: *Oreochromis karongae* (chambo)	0.06	−0.66
	(0.914)	(0.105)
1 = Species: *Oreochromis shiranus* (makumba)	0.26	−0.53
	(0.653)	(0.288)
1 = Species: *Tilapia rendalli* (chilunguni)	0.34	−0.59
	(0.505)	(0.175)
1 = Species: *Clarias gariepinus* (mlamba/catfish)	1.05	0.51
	(0.174)	(0.263)
1 = Polyculture	−0.19	0.98
	(0.765)	(0.111)
Number of ponds	0.22**	0.31**
	(0.022)	(0.010)
Farm area (hectares)	0.02*	0.03
	(0.080)	(0.293)
1 = Fingerling production only	−1.31	−0.11
	(0.215)	(0.877)
1 = Both fish and fingerling production	0.97**	1.92***
	(0.011)	(0.002)
1 = Continuous production system	−0.05	0.25
	(0.776)	(0.108)
Commercial feed (tons)	−0.72	−1.86*
	(0.319)	(0.100)
Homemade feed (tons)	0.56	1.16*
	(0.374)	(0.099)
Inorganic fertilizer (tons)	1.29	−3.08
	(0.530)	(0.465)
Organic fertilizer (tons)	0.00	−0.06***
	(0.935)	(0.004)
Labor endowment (workers)	0.01	0.01
	(0.520)	(0.616)
Number of years the farm has existed	0.02***	0.03***
	(0.001)	(0.009)
Number of contacts with extension in past year	0.00	0.00
	(0.399)	(0.422)
1 = Accessed credit	0.39**	0.22
	(0.048)	(0.443)
1 = Maintain records	0.25*	−0.27
	(0.057)	(0.152)
1 = Northern region	−0.00	0.41***
	(0.988)	(0.006)
1 = Southern region	0.68***	0.44***
	(0.002)	(0.010)
Constant	3.25***	0.74
	(0.001)	(0.249)
Observations	731	731
R-squared	0.233	0.190

Source: MAS2021; Note: ***, ** and * means 1%, 5% and 10% levels of significance, respectively and robust *p*-values in parentheses; standard errors clustered at district level.

[a]The unit of 10,000s MK was selected before applying the inverse hyperbolic sine transformation (IHST) because this choice yielded a higher R-squared value than either MK or 1,000s MK. According to Aihounton and Henningsen (2020), magnitude of the R-squared value is a suitable decision rule for selecting a unit for values to be transformed when those values are large.

3.2 Econometric results

Multiple linear regression analysis was carried out to examine the determinants of production (total fish harvested in kg), profit, yield (quantity harvested in kg/m^2), and profit/m^2 of small-scale fish farms in Malawi. Factors that influence these farm outcomes are presented in Tables 4 and 5. Holding all other variables constant, an additional year of farm existence is associated with a 2%

Table 5. Factors affecting fish farm yield and profit per m^2 in Malawi.

Variables	(1) Yield (kg/m^2, ln)	(2) Profit per m^2 (MK/m^2, ln)[a]
1 = Individually owned farm	0.19**	−0.25
	(0.021)	(0.625)
1 = Species: *Oreochromis karongae* (chambo)	0.08	−1.50**
	(0.672)	(0.048)
1 = Species: *Oreochromis shiranus* (makumba)	0.06	−1.54
	(0.722)	(0.131)
1 = Species: *Tilapia rendalli* (chilunguni)	0.11	−1.70**
	(0.478)	(0.012)
1 = Species: *Clarias gariepinus* (mlamba/catfish)	0.40	0.59
	(0.224)	(0.422)
1 = Polyculture	−0.13	2.37**
	(0.475)	(0.020)
Number of ponds	−0.03	0.20
	(0.411)	(0.400)
1 = Fingerling production only	−0.27**	−1.47
	(0.017)	(0.658)
1 = Both fish and fingerling production	0.37	2.18**
	(0.160)	(0.047)
1 = Continuous production system	−0.06	0.93*
	(0.364)	(0.087)
Commercial feed (kg/m^2)	0.24*	−1.25
	(0.095)	(0.404)
Homemade feed (kg/m^2)	0.12	0.66
	(0.302)	(0.134)
Inorganic fertilizer (kg/m^2)	1.43	44.60*
	(0.688)	(0.099)
Organic fertilizer (kg/m^2)	4.14	−52.06*
	(0.562)	(0.068)
Labor endowment (workers/m^2)	3.21**	−4.05
	(0.016)	(0.555)
Number of years the farm has existed	0.00	0.04**
	(0.424)	(0.039)
Number of contacts with extension in past year	−0.00	−0.00
	(0.661)	(0.536)
1 = Accessed credit	0.04	0.43
	(0.727)	(0.465)
1 = Maintain records	−0.03	−1.13**
	(0.596)	(0.036)
1 = Northern region	−0.12*	0.78**
	(0.077)	(0.036)
1 = Southern region	0.23***	1.03**
	(0.001)	(0.024)
Constant	0.04	3.89***
	(0.736)	(0.008)
Observations	728	728
R-squared	0.176	0.079

Source: MAS 2021; Note: ***, ** and * means 1%, 5% and 10% levels of significance, respectively and robust *p*-values in parentheses; standard errors clustered at district level.

higher value of the total quantity harvested (Table 4, column 1). Similarly, an additional pond, using the farm for both grow-out and fingerling production, maintaining farm records, accessing credit, and farms from the Southern region are associated with higher values of the total quantity harvested of 22%, 164%, 28%, 48% and 97% respectively.[6]

With reference to correlates of farm profits (Table 4, column 2), an additional pond, use of fish farms for both grow-out and fingerling production, use of an additional ton of homemade feed, farms in the Northern region, and farms in the Southern region are associated with higher farm profits by 31%, 582%, 116%, 51%, and 55%, respectively. On the other hand, the use of an additional ton of organic fertiliser and commercial feed is associated with lower farm profits by 6% and 186%, respectively. This may be an indication that these inputs are not a lucrative investment, given the prices received for the farm output. However, an examination of outcomes that are scaled to farm size can shed further light on the use of inputs.

Results pertaining to yield (Table 5, column 1) reveal that an additional kg/m^2 of commercial feed, an additional worker/m^2, and a location in the Southern region are associated with 24%, 321%, and 26% higher yields. Meanwhile, the use of the farm for only fingerling production and location in the Northern region are associated with 24% and 11% lower yields. Profit/m^2 (Table 5, column 4) is positively influenced by polyculture, use of the farm for both fish and fingerling production, continuous production system, use of inorganic fertiliser, years of farm experience, and location in the Northern or Southern regions. Meanwhile, profit/m^2 seems to be negatively influenced by the production of *Oreochromis karongae* (chambo), the production of *Tilapia rendalli* (chilunguni), the use of organic fertiliser, and maintenance of records. While the coefficient on *Clarias gariepinus* (mlamba/catfish) is not statistically significant, a Wald test of the equality of the coefficients on *Clarias gariepinus* (mlamba/catfish) and *Tilapia rendalli* (chilunguni) indicates that these coefficients are significantly different from one another ($F = 16.72$, $P = 0.0027$).

4. Discussion

This study provides empirical evidence on the production, yield, profit, and profit per square metre of small-scale aquaculture in Malawi. Results indicate that small-scale fish farming is profitable, although the gross margins are small; these findings are in line with other studies in sub-Saharan Africa (Adelesi and Baruwa 2022; Aheto, Acheampong, and Odoi 2019; Hyuha et al. 2011; Namonje-Kapembwa and Samboko 2020). Key among the determinants of farm outcomes of small-scale aquaculture in Malawi are farm characteristics such as location and number of ponds; production inputs such as labour endowment, feed, and fertilisers/manure; and other socio-economic factors such as experience in fish farming and access to credit.

The use of high-quality feed is found to be a key factor in yield (though not necessarily profit) in Malawi, and this is well-documented (Aktar et al. 2018; Aung et al. 2021; Prodhan and Khan 2018; Ragasa, Osei-Mensah, and Amewu 2022; Sarkar et al. 2015). Most small-scale fish farmers in Malawi are unable to consistently access high-quality commercial feed because it is usually imported from neighbouring Zambia and is therefore expensive (CASA 2020). As such, farmers tend to use homemade feed formulated from locally sourced raw materials such as maize bran. While homemade feed is profitable, farm profits are much lower than when commercial feed is used (Ansah 2014). Currently, the use of commercial feed in Malawi is estimated to be less than 10% (Imani et al. 2016; Munthali et al. 2022).

Applying the appropriate type and quality of organic and inorganic fertilisers is also key to ensuring the profitability of fish farms. In this study, the use of organic fertilisers is found to reduce profits (though not yield), while the use of inorganic fertilisers is associated with higher profit/m^2. Most small-scale farmers in Malawi rely on organic fertilisers (chicken manure and composite manure), which are available locally. The use of chicken manure is usually associated with higher returns for resource-poor fish farmers (Badawy, Zaki, and Kenawy 2009; Khan, Ahmed, and Ahmed 2001; Matsimbe and Kapute 2011). However, limited access to high-quality aquaculture extension services, the unavailability of guidelines on application rates of organic fertilisers, and the low nutrient composition of the organic fertilisers may contribute to low efficiency.

Poor growth and survival rates of indigenous Tilapia species are the most common complaints from small-scale fish farmers in Malawi (Kassam and Sangazi 2016). In our study, we found that farming *Oreochromis karongae* and *Tilapia rendalli* are associated with lower profit/m^2 (Table 5). Most farmed species in Malawi are not genetically improved, and an inadequate supply of quality fingerlings constrains their production. The challenge of accessing high-quality fingerlings from hatcheries forces farmers to use recycled fingerlings, thereby reducing farm profits. Some authors have recommended the hybridisation of local Tilapia species (Kassam and Sangazi 2016; Nzohabonayo, Kang'ombe, and Kassam 2017). Nevertheless, the growth rate of *Clarias gariepinus* (mlamba/

catfish) is far greater than that of Tilapia species (Maluwa *et al.*, 1995), suggesting that more research and policy attention might be given to *Clarias gariepinus*.

Our results also indicate that farm location has an influence on farm outcomes, with location in the Southern region associated with greater production, yield, profit, and profit/m^2, while farms in the Northern region showed increased profits but lower yield relative to farms in the Central region. An outbreak of Epizootic Ulcerative Syndrome (EUS) fish disease a year prior to the study may have contributed to the geographic patterns seen in this study. Specifically, EUS was reported in some districts in the Central region and part of the Northern region but not the Southern region (Munthali 2021; Munthali et al. 2022). EUS results in some fish fatalities. Further, fish affected by EUS usually have ulcerative lesions on their skin, and it is recommended that they are not consumed unless they are thoroughly and adequately cooked (FAO 2009).

Some small-scale fish farmers in Malawi make use of their farms for both grow-out and hatchery operations, which is found in this study to be associated with greater production, profit, and profit/m^2. Plausibly, integrating grow-out farms with hatchery operations reduces production costs and raises the output from a single pond, as the farmer can harvest table-sized fish at the end of the growing season and can also sell fingerlings from the stocked fish to other farmers. Additionally, small-scale fish farms that practice polyculture have higher profit/m^2 than those that practice monoculture. Similar findings have been reported in Bangladesh (Khor et al. 2022), where polyculture has been found to improve input use efficiency and increase yield and farm profits.

The positive relationship between access to credit and production has also been well-documented (Mahmud et al. 2022; Mitra et al. 2019; Twumasi et al. 2021, 2023) and is consistent with our findings. While access to credit remains a challenge for most fish farmers, it is a key driver of commercial aquaculture growth as it enables farmers to acquire capital-intensive inputs such as inorganic fertilisers and commercial feed. Regarding the positive influence of a number of years of fish farming on farm production, profit, and profit/m^2, our results are consistent with Aripin et al (2020), who found that more farming experience positively affected the productivity of sea bass pond-based culture in Malaysia.

The intensity of access to agricultural extension was not found in this study to be a statistically significant correlate of any farm outcome. Access to aquaculture extension services is a key aspect of small-scale fish farming (Hasan 2020; Kleih et al. 2013; Mantey, Mburu, and Chumo 2020). However, the aquaculture extension service in Malawi is limited by a lack of well-trained government extension workers, and the existing extension workers have limited technical knowledge or expertise in aquaculture (CASA 2020).

5. Conclusion

The paper provides empirical evidence on the production, yield, profit, and profit/m^2 of small-scale fish farms in Malawi. We find that small-scale aquaculture is profitable, although the gross margins are slim. Various factors, such as the fish species farmed, the primary use of the farm, the production and culturing system followed by farmers, the use of commercial feed and organic fertilisers, years of farm existence, and geography, are determinants of farm outcomes.

Among the species farmed, descriptive results show that the slow-growing Tilapia species are associated with lower farm profits, while farming *Clarias gariepinus* (mlamba/catfish) is associated with relatively higher profits. Altogether, these results imply that Malawi should not only support investment in the farming of Tilapia species but should also increase efforts to scale up *Clarias gariepinus* farming. Further, the low profits and productivity associated with farming Tilapia species call for a strong commitment from the government to invest in genetic improvement programmes (GIPs) to enhance the profitability and performance of the slow-growing indigenous species.

Small-scale aquaculture in Malawi has the potential to achieve the transformational change envisaged in *Malawi2063* – but only if farm production, yield, profit, and profit/m^2 can be enhanced. Accordingly, this study has established that the use of high-quality inputs, such as high-quality fish feed and inorganic fertilisers, and following the best aquaculture management practices can improve the outcomes of small-scale fish farms. Our findings make an important contribution to the ongoing discourse in Malawi regarding the role of aquaculture in achieving the *Malawi2063* agenda.

The current study has several limitations, which point to areas for further research. First, the focus on gross margins shows the within-year profitability but does not account for the costs of farm establishment. A benefit-cost analysis that accounts for the durability of farm structures, discount rates, and variation in gross margins over time would be a worthy direction for future research. Second, while our analysis is at the farm-level, farmers may appreciate more pond-level analysis to understand how they should construct and manage their various ponds. Finally, the focus on farm-level experiences and outcomes does not tell us whether aquaculture has an impact on nutrition, consumer preferences and food security among both producers and those who access the product through the market. Further research is needed to determine whether this link premised partly on the affordability of farmed fish is observed.

Notes

1. This period of production overlaps with the start of the COVID-19 pandemic. However, aquaculture production in Malawi did not drop during the pandemic (Figure 1), with total production in 2020 and 2021 continuing a steady, upward trend. This suggests that a study during this somewhat unusual time period can yield insights that are broadly relevant.
2. In EPAs in which we sampled fish farms from within a larger population of fish farms, each farm received an initial weight of greater than "1" within the EPA, reflecting that it represents a larger number of farms in the EPA. In EPAs in which all fish farms were included in the sample, each fish farm received an initial weight of "1" within the EPA. Beyond this level of sampling, the final weights additionally account for the likelihood of selection at the level of EPA and district.
3. The dependent variables are transformed using an inverse hyperbolic sine transformation (IHST).
4. Dropping these farms from analysis did not have any noticeable effect on our results.
5. The exchange rate between the U.S. dollar and Malawian kwacha as of 30 June 2021 was US$1 = MK813.49.
6. In a semi-log model in which the dependent variable is logged, the effect of a 0–1 change in a binary regressor is $[100*(e^{\beta} - 1)]\%$.

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Consent for publication

Consent for publication has been obtained from all authors.

Consent to participate

The participants in this study were given a thorough explanation of the objectives of the study. The study adhered to confidentiality and informed consent from the participants.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The datasets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

Human and animal ethics

The study adhered to the confidentiality of the participants. No animals were handled.

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Annex

Table A1. Gross margins and productivity of fish farming in Malawi (mean values).

	All production	
	Mean (MK)	% of cost
Harvest value	122,637.0	
Fingerling revenue	10,270.4	
Total revenue	**132,859.7**	
Commercial feed	8,329.5	19.6
Homemade feed	14,827.9	34.8
Energy cost	186.0	0.4
Organic fertilizer	1,246.8	2.9
Inorganic fertilizer	1,922.9	4.5
Lime	1,172.8	2.8
Medication	0.0	0.0
Fingerlings	5,012.6	11.8
Hired labour	5,549.5	13.0
Other inputs	1,890.2	4.4
Transport	2,436.2	5.7
Total variable costs	**42,574.5**	
Gross margin	**90,285.2**	
Observations	732	

Source: MAS 2021.