Open Journal of Ecology, 2023, 13, 516-523
https://www.scirp.org/journal/oje
ISSN Online: 2162-1993
ISSN Print: 2162-1985

Impacts of Climate Change on Economic Performance of Tilapia Pond Operations in Minalin, Pampanga: A Case of Intensive Large-Scale Pond Culture

Edilyn V. Lansangan, Jairus Jesse M. Tubal

Department of Agricultural Management, College of Agriculture, Nueva Ecija, Philippines
Email: edilynlansangan@clsu.edu.ph

How to cite this paper: Lansangan, E.V. and Tubal, J.J.M. (2023) Impacts of Climate Change on Economic Performance of Tilapia Pond Operations in Minalin, Pampanga: A Case of Intensive Large-Scale Pond Culture. *Open Journal of Ecology*, **13**, 516-523.
https://doi.org/10.4236/oje.2023.137031

Received: June 15, 2023
Accepted: July 17, 2023
Published: July 20, 2023

Abstract

Pampanga is the top tilapia-producing province in Philippines. One of its municipalities, Minalin, is considered as one of its major centers of production. This study aims to determine the impacts of climate change hazards on the economic performance of tilapia-intensive pond culture in Minalin, Pampanga considering the threats to the industry, livelihoods, and food security. Results revealed that the economic performance of tilapia pond operations using semi-intensive large-scale culture was affected by climate change, as reflected in the reduction of yield among tilapia pond operators. This makes intensive tilapia pond farming in Minalin still a viable venture but will now require more than a year to pay for investment (variable and fixed) costs if under climate change risks. The study recommends strengthening capacity building related to climate-smart tilapia farming technologies for pond operators and to implement appropriate technologies to address climate change risks.

Keywords

Climate Change, Economic Performance, Intensive Pond Culture, Tilapia, Tilapia Pond Culture

1. Introduction

Fisheries and aquaculture play important roles in food supply, food security, and income generation [1]. Like other developing countries, Philippines has a high dependence on both fisheries and aquaculture to provide trade, employment opportunities, and food security [2]. Grown in more than 140 countries in different cultural systems, tilapia is patronized by consumers due to its taste, freshness, and affordable price. It is a widely accepted fish species consumed by people across almost all income groups. In Philippines, the trend of tilapia consumption reflects its popularity over other fish species, with an increase in per capita consumption of 3.81 kilograms per year (kg/year) in 2009 to 4.41 kg/year in 2021 [3]. Fisheries, therefore, have always been a potential for growth and a noteworthy source of employment opportunities, especially for households near coastal and inland water resources. On the contrary, the major tilapia-producing regions in Philippines are now experiencing significant impacts from the progressing negative effects of climate change. Tilapia pond aquaculture farmers are alarmed at the recurrent decline in farm productivity, mass mortality, and fish kill brought about by prolonged dry seasons, increasing air and water temperature, critical dry spells and droughts, frequency of strong typhoons, and heavy rainfalls and thunderstorms, which induce flooding and overflows of aquaculture farms [4]. The continuous change in the various ecosystems of the tilapia population imperils the whole industry, which has implications on how the species must be protected and be made able to adapt to the changing environment [5].

This study sought to estimate the effects of climate change hazards on the economic performance of tilapia-intensive pond culture in Minalin, Pampanga, taking into account threats to the industry, food security, and livelihoods.

2. Methods

2.1. The Study Area

The province of Pampanga is located in Central Luzon Region, Philippines, with its capital being the City of San Fernando, Pampanga. It is composed of 22 municipalities with approximately 16491.07 ha of fishponds used both for brackish and freshwater pond production [6]. Pampanga contributed 64 percent (191302.27 metric tons) to total regional fisheries production and 9 percent to total national production (2246315.78 metric tons) in 2021. The province remains the nation's top producer of tilapia, with a production of 131895.78 metric tons in 2021 which contributes 46.92 percent to total national tilapia production [7]. The study was conducted in the municipality of Minalin, one of the leading tilapia producers in province, and one of the coastal municipalities in the province (**Figure 1**).

2.2. Data Analysis

The study was conducted to determine the impacts of climate change hazards on the economic performance of tilapia-intensive pond culture. Specifically, the study aimed: 1) to provide an overview of the tilapia industry and profile of tilapia pond operators, 2) to describe production costs and economic benefits of intensive tilapia pond operations, 3) to validate and assess the impacts of climate change hazards among intensive tilapia pond operators and the extent to which these hazards affect their income, and 4) to identify potential adaptation strategies and how these can address the adverse impacts of climate change among tilapia

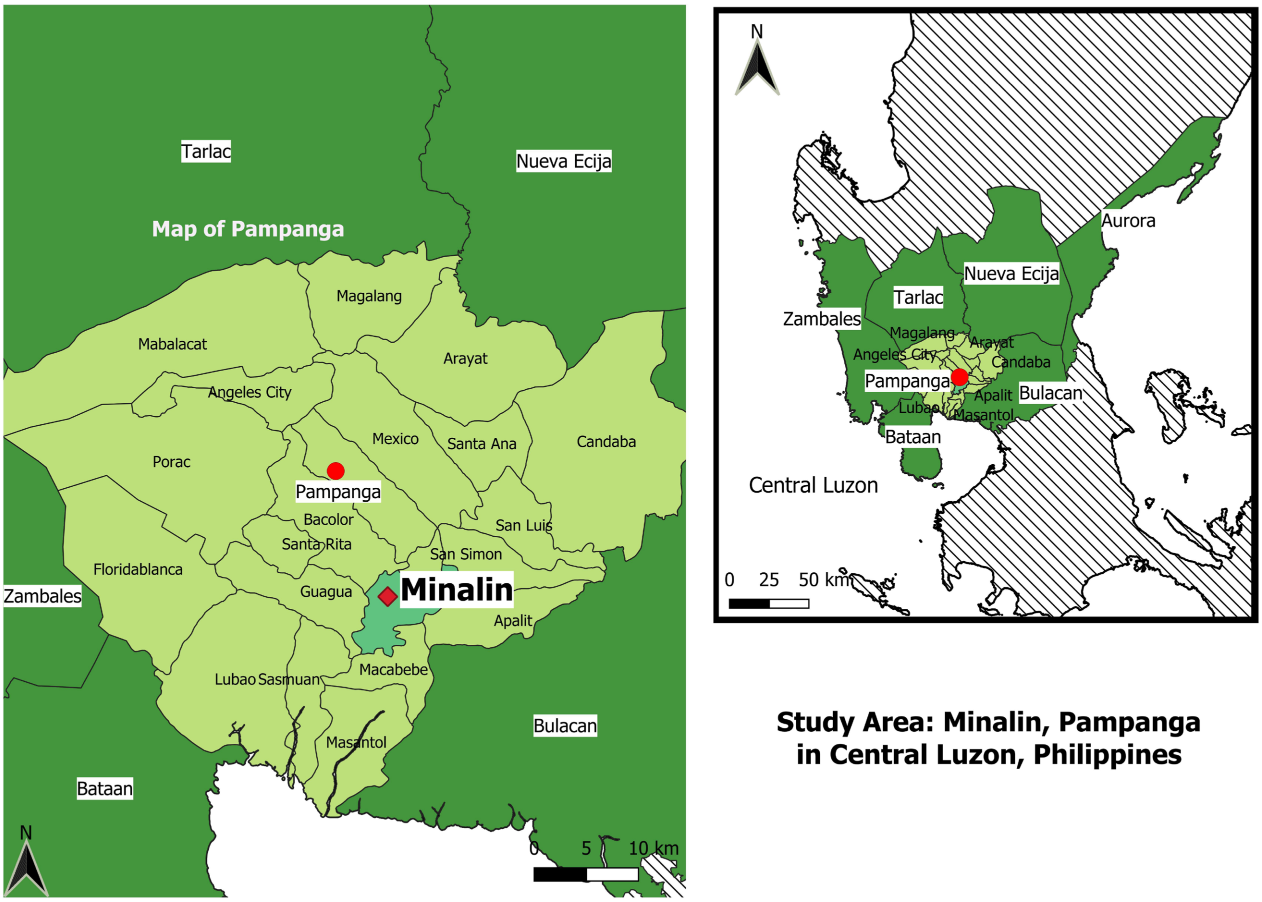

Figure 1. The study area.

pond operators. The sample used in this study consisted of eight tilapia producers whose combined area of tilapia pond operations totaled to 1462 hectares representing about 54 percent of total pond area in the municipality.

The study utilized a semi-structured survey to get the response of the tilapia pond operators on their culture operations, climate change hazard had affected their activities, and production performance indicators such as survival rate (SR), feed-conversion ratio (FCR), average culture period and yield per hectare. These indicators were compared without and with the occurrence of the climate change hazard. The costs and returns of tilapia production as affected by the occurrence of the identified climate change hazard were analyzed as well. A number of key informant interviews among industry players were also conducted to determine the possible adaptation measures to address the adverse impacts of climate change.

3. Results and Discussion

3.1. Overview of the Tilapia Industry and Profile of Tilapia Pond Operators

Tilapia culture is widely undertaken in the country. Because of research and development programs on product attributes and factor productivity of tilapia started in the mid-1980s, tilapia production has been a dynamic aquaculture enterprise in the country [8].

The tilapia industry in Philippines is composed of various key players along its value chain. Figure 2 shows the operators at each level of the chain that have different tasks.

For pre-production activities, there are hatchery & nursery operators; fish feed dealers and retailers; and fish culture assets and other inputs-provider. There are two major types of intensive culture systems in Philippines. Minalin belongs to the grow-out pond operators while those that are usually found in Southern Luzon are into grow-out cage operations. The succeeding operators along the chain that will perform the distribution and marketing includes the harvester-traders which will consequently sell the tilapia to broker-middlemen, assembler-wholesalers, institutional buyers and retailers in various product forms like live tilapia, chilled and fresh.

Tilapia production has been steadily increasing from 2001 to 2006 with 13.75 percent growth; however, the tilapia production growth from 2006 to 2021 has been slow at about 2.37 percent (from 202040.54 metric tons to 281114.30 metric tons) with an average annual increase in volume of 5271.58 metric tons.

3.2. Tilapia Pond Production in Central Luzon

Grow-out operators are the main "production center" of the tilapia industry. From the farm, tilapia reaches the market through a series of middlemen; from traders to *consignacion* (a group of wholesaler-retailers that caters to other retailers and restaurants) wholesalers, processors, institutional buyers, retailers, and the final consumers.

Generally, grow-out operators in the region stock fingerlings with size no. 22

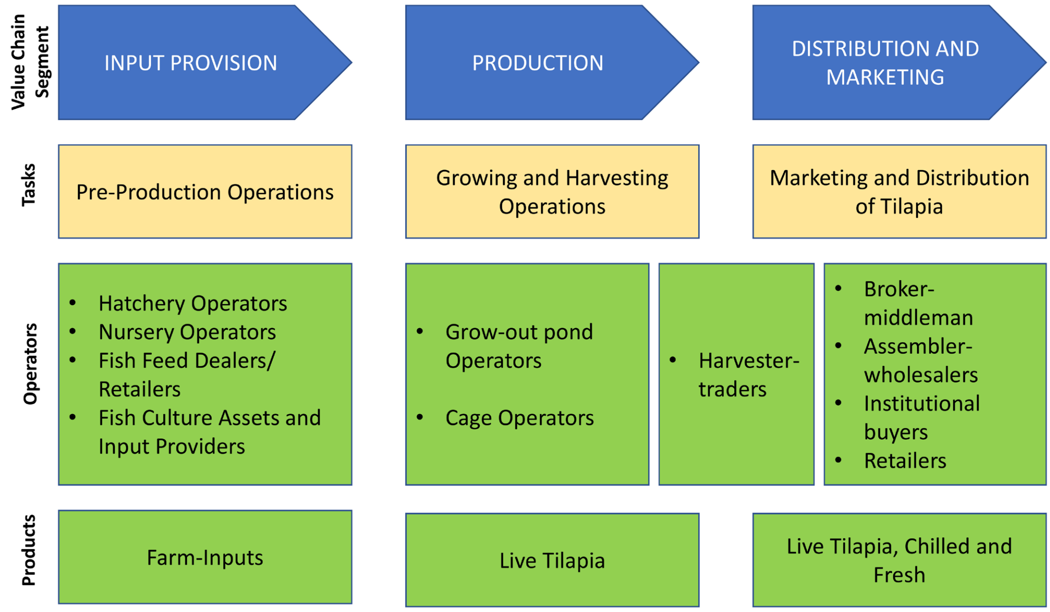

Figure 2. Overview of Philippine tilapia industry.

which are purchased from hatcheries within the province of Pampanga. Operators usually follow a stocking rate of either 5 or 10 pieces per square meter (m^2) which is equal to 50,000 or 100,000 pieces per hectare.

In a study conducted by [9], majority of the tilapia pond operators in Central Luzon preferred to feed tilapia with commercial feed. The regular production cycle of tilapia growers usually takes six months to reach the marketable size of 200 - 300 grams per piece or 3 - 5 pieces per kg. The number of cycles in a year depends on the availability of water but most have two production cycles/year.

The different criteria for categorizing tilapia culture systems were presented in a study conducted by [10]. Depending on the stocking density and feeding practice, tilapia fishpond production can either be extensive, semi-intensive or intensive. It is considered an intensive culture system when the stocking density is more than 20,000 fingerlings per hectare and feed cost is about 60% - 70% of the production cost. This culture system uses high level of inputs and is dependent to commercial feeds while natural food production plays a minor role. These practices were evident among the eight pond operator-respondents in Minalin, Pampanga, hence classified as intensive pond culture system.

3.3. Production Costs and Economic Benefits of Tilapia-Intensive Pond Operations

Tilapia pond production entails a number of costs which are classified either as variable or fixed cost. Variable costs are those cost from production inputs than increase as the quantity of tilapia grown increases. This includes fingerlings, feeds, fertilizer, agricultural lime, and labor to perform field activities. On the other hand, fixed costs involve depreciation for farm equipment and pond construction and interest on investment. Fixed costs are cost from items that remain constant within a given period (say, per culture cycle) regardless of the stocking level/level of production.

3.4. Impacts of Climate Change Hazards in Tilapia-Intensive Pond Operations

Extreme heat was identified to be the climate change hazard (CCH) which affected the tilapia pond producers in Pampanga. Being higher than 32˚C, it inhibits the growth of tilapia thru slow growth, reduced feeding and increased in mortality. *O. niloticus* can tolerate high temperatures: up to 40˚C - 42˚C [11]. Their growth however is negatively affected by drastic changes in the temperature because of the inverse of increasing temperature with dissolved oxygen. It is a known fact that the level of dissolved oxygen has direct effect to aquaculture production. In addition, the temperatures above 32˚C may significantly results to slow growth, reduced feeding efficiency and increased mortality [12].

In Philippines, since 1971, the mean, maximum, and minimum temperatures have increased 0.14˚C per decade [13]. Studies by [14] and [15] support this finding, showing departures from the annual mean (0.61˚C), maximum (0.89˚C), and minimum (0.34˚C) temperatures in recent years, compared to the 1961-1990 normal values). The frequency of hot days and warm nights has also increased, and the number of cold days and cool nights decreased. According to climate change projections from the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA), there will be a seasonal temperature increase of about 1˚C by 2020 and 2˚C by 2050. There is an increasing trend in the annual mean maximum temperature in the province.

Table 1 presents a comparison of the average production performance of a 1-hectare tilapia pond grow-out farm per cycle under "without" and "with" climate change hazard scenarios. With the occurrence of extreme heat, among the direct effects to production were the following; a decrease in survival rate of 29%. Feed conversion ratio increased by 30% due to higher mortality and ultimately, the yield per hectare decreased by 23.25%.

Direct adverse impact to production consequently means direct negative effect to profitability of the farm. The impacts are evident in both the revenues and costs components of production. Table 2 presents the cost and return analysis for a 1-hectare intensive pond tilapia production.

As shown in Table 2, the major decline in net income under the "with" CCH scenario is due to the lower estimated mean revenue despite the (almost) same production expenses incurred by the tilapia farmers. The reduction in revenue by 22.8% is attributed to decrease in the volume harvested by 23.25%.

The costs and benefits included in the operation of the different tilapia production were analyzed to understand the extent of impact of climate change hazards on the production. Due to the occurrence of extreme heat, net income

Table 1. Average production performance of a 1-hectare tilapia grow-out farm per cycle in Minalin, Pampanga without and with climate change hazard.

Item	Production performance		
	Without CCH	With CCH	% change
Survival rate	48%	34%	29
Feed-conversion rate	2.52	3.28	30
Culture period	6 months	6 months	Nil
Yield per hectare	9166.67 kg	7035.71 kg	23.25

Table 2. Cost and return (USD) of a 1-hecatre tilapia grow-out farm per cycle in Minalin, Pampanga without and with climate change hazard.

Item	Income and cost values		
	Without CCH	With CCH	% change
Mean revenue	10764.29	8308.33	22.82
Mean cost	5960.89	5770.00	3.20
Net income before tax	4803.40	2538.33	19.62
Return on invenstment	80.58%	43.99%	45.41

before tax decreased by 19.62% (from USD 4803.40 to USD 2538.33). Return on investment measures the gain or loss generated on an investment relative to the amount of money invested. ROI computed was 80.58% under without climate change condition and decreased to 43.99% during with climate change conditions. This makes intensive tilapia pond farming in Minalin still a viable venture but will now require more than a year to pay for investment (variable and fixed) costs if under climate change risks.

4. Conclusions and Recommendations

The extreme heat reduced the productivity of tilapia culture. Moreover, additional costs were incurred by each actor to mitigate the effects of extreme heat. All these factors have resulted in lower income among tilapia grow-out operators.

This scenario has drawn the need to build resilient tilapia pond production to climate change hazards and emphasize the critical importance of cooperation as a stepping stone to disaster risk reduction. The public and private sectors' roles will be crucial when deciding national priorities in reducing disaster risks and preparing for unpredicted, yet manageable disasters in years to come.

The risks from climate change hazards and capacity building related to climate-smart tilapia farming technologies for pond operators must be pursued. LGUs, in coordination with BFAR and other concerned agencies, may address productivity impacts caused by extreme heat using appropriate technologies.

Acknowledgements

This paper is based on a research project funded by the Department of Agriculture-Bureau of Agricultural Research (DA-BAR) and implemented by the World Fish-Philippine Country Office and Central Luzon State University (CLSU).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Cochrane, K., De Young, C., Soto, D. and Bahri, T. (2009) Climate Change Implications for Fisheries and Aquaculture. FAO Fisheries and Aquaculture Technical Paper, 530, 212.

[2] DA-BAR (Department of Agriculture-Bureau of Agricultural Research) (2016) Climate Change Research and Development and Extension Agenda and Program for Agriculture and Fisheries 2016-2022. https://bar.gov.ph/downloadables/rdeap/CC%20RDEAP%202016_final.pdf

[3] Department of Agriculture (2021) Philippine Fisheries Profile. https://www.bfar.da.gov.ph/wp-content/uploads/2022/11/2021-Fisheries-Profile-FINAL-FILE.pdf

[4] Bureau of Fisheries and Aquatic Resources (2017) Impact Management of Weather

Systems on Tilapia Pond Culture. BFAR Aquaculture Technology Bulletin Series No. 1.

[5] Bureau of Fisheries and Aquatic Resources (2017) Documentation of Practical Innovative Approaches on Impacts of Climate Change-Local Tilapia Farming Practices in the Philippines. BFAR Aquaculture Technology Bulletin Series No. 2.

[6] Bureau of Fisheries and Aquatic Resources (2021) Pampanga Fisheries Profile. https://region3.bfar.da.gov.ph/cmsFiles/region3/fisheriesprofile/pdf/7f141b9c-54ef-472f-bb26-fa1efe739274(01-24-2017).pdf

[7] Philippine Statistics Authority (2021). https://openstat.psa.gov.ph/PXWeb/pxweb/en/DB/DB__2E__FS/0092E4GVAP1.px/?rxid=bdf9d8da-96f1-4100-ae09-18cb3eaeb313t

[8] Jamandre, W., Hatch, U., Bolivar, R. and Borski, R. (2017) Improving the Supply Chain of Tilapia Industry of the Philippines. https://aquafishcrsp.oregonstate.edu/sites/aquafishcrsp.oregonstate.edu/files/09mer03nc_improving_supply__0.pdf

[9] Asian Development Bank (ADB) (2004) Farming Tilapia in Ponds in Central Luzon, Philippines. https://www.adb.org/sites/default/files/evaluation-document/35937/files/farming-tilapia-phi.pdf

[10] Dela Vega, A.M. (2014) Review Study on Status of Production, Marketing and Farm Application of Milkfish Feed in the Philippines. http://www.fao.org/fileadmin/user_upload/affris/docs/news/pres/Annex_F._Results_of_Rapid_Assessment.pdf

[11] Philippart, J.C. and Ruwet, J.C. (1982) Chapter: Ecology and Distribution of Tilapias. In: Pullin and Lowe-McConel, Eds., *The Biology and Culture of Tilapias*, *ICLARM Conference Proceedings*, International Center for Living Aquatic Resources Management, Manila, 15-59.

[12] Pandit, N.P. and Nakamura, M. (2010) Effect of High Temperature on Survival, Growth and Feed Conversion Ratio of *Nile tilapia*, *Oreochromis niloticus*. *Our Nature*, **8**, 219-224. https://doi.org/10.3126/on.v8i1.4331

[13] IPCC (Intergovernmental Panel on Climate Change) (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability. https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg2_full_report.pdf

[14] Tibig, L.V. (2004) Trends in Extreme Daily Temperatures and 24-hr Rainfall in the Philippines, Climatology and Agrometeorology Branch. Technical Report.

[15] Manton, M.J., Della-Marta, P.M., Haylock, M.R., Hennessy, K.J., Nicholls, N., Chambers, L.E. and Yee, D. (2001) Trends in Extreme Daily Rainfall and Temperature in Southeast Asia and the South Pacific: 1961-1998. *International Journal of Climatology*, **21**, 269-284. https://doi.org/10.1002/joc.610