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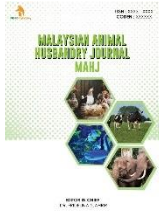

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REVIEW ARTICLE

COBB-DOUGLAS PRODUCTION MODEL OF DEVELOPMENT TREND OF AQUACULTURE AND FISHERIES IN NEPAL

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ABSTRACT

Nepal's inland freshwater resources provide immense potential for aquaculture and fisheries to contribute significantly to food security, employment, and economic growth. This paper assesses the economic and ecological importance of the sector using the Cobb-Douglas production function and Logistic Growth Model. National fish production has shown a consistent rise from 24,295 Mt in 2007/08 to 82,161 Mt in 2022/23, with aquaculture accounting for over 72%. The logistic growth model indicates a carrying capacity of 151,484 Mt, suggesting potential for further expansion. However, regional disparities and input constraints remain. Empirical results show that water surface area (capital input) plays a more dominant role than pond area (labor). The study recommends targeted investment in infrastructure, green technologies, training programs, and community-based management to ensure sustainable growth and equity. The paper emphasizes the need for policy integration, investment in green technology, and participatory resource governance.

KEYWORDS

Aquaculture, Fisheries, Cobb-Douglas Model, Logistic Growth, Employment, Productivity, Nepal

1. INTRODUCTION

Nepal, though a landlocked country, is endowed with rich and diverse inland water resources, including rivers, lakes, ponds, and man-made reservoirs, which present substantial potential for the development of aquaculture and fisheries. This sector has emerged as one of the fastest-growing agricultural subsectors, driven by favorable climatic conditions suitable for both warm and cold-water species. Aquaculture currently contributes over 80% of the country's total fish production, underlining its integral role in Nepal's evolving agricultural landscape (DFD, 2023).

In the face of mounting challenges such as climate change, land degradation, and agricultural fragmentation, aquaculture and fisheries offer a resilient alternative for rural livelihoods. These practices are not only ecologically sustainable but also economically viable, especially in a country where agriculture continues to support 27% of the GDP and employs nearly 66% of the workforce (World Bank, 2022). The shift toward fisheries, particularly aquaculture, is seen as a promising strategy for economic diversification and improving national food security.

Historically rooted in cultural traditions, fisheries in Nepal were initially dependent on wild capture from rivers and lakes. The formalization of aquaculture began in the early 1950s with the introduction of carp species (Woynarovich, 1975). Over the decades, the government has prioritized this sector in its national development agenda, recognizing its potential for poverty reduction, inclusive growth, and nutritional enhancement (MoAC, 2009; NARC, 2010). As a result, both public and private sectors have actively contributed public institutions ensuring regulation and quality control, and private actors focusing on seed production and distribution.

Despite contributing only about 1.2% to the agricultural GDP, the sector's annual growth rate exceeds 9%, suggesting underexploited opportunities for rural economic development (FAO, 2020; FPP, 2000). Nepal's extensive aquatic network, which includes more than 6,000 rivers and numerous lakes and reservoirs, positions the country to adopt environmentally friendly and sustainable aquaculture practices. Furthermore, Asia's dominance in global aquaculture accounting for over 93% of the global aquaculture workforce emphasizes Nepal's strategic alignment within this growing industry.

Currently, fish farming is practiced in 55 districts and provides direct employment to approximately 585,000 people. National production stands at about 113,736 metric tons, 80% of which comes from aquaculture. However, the per capita fish availability remains low at just 3.9 kg, far below the average of 11 kg for least-developed countries, indicating the need to scale up domestic production and encourage fish consumption for nutritional security.

The decentralized nature of Nepal's fish supply chain allows small-scale producers to directly access markets, while government and donor-supported programs continue to expand fish farming into new regions. Moreover, aquaculture is increasingly linked to strategies aimed at poverty alleviation and inclusive economic development, offering low-barrier entry for marginalized communities and consistent income opportunities throughout the year.

Considering climate change, aquaculture emerges not only as an economic opportunity but also as a climate-resilient and sustainable livelihood strategy. Its contributions to food security, employment, and ecological stability make it a pivotal element of Nepal's rural development agenda. The global trend further reinforces this, with aquaculture production reaching 114.5 million tonnes in 2018 and expected to exceed 200 million tonnes by 2030, driven by rising demand and technological advancements (FAO, 2018; 2020; 2021). Nepal must now capitalize on its untapped potential through inclusive policy reforms, investment in green technologies, and community-driven approaches to ensure the sustainable growth of its aquaculture and fisheries sector.

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2. Literature Review Summary

An expanding collection of works underscores the potential and intricacy of using big data for official statistics in developing nations. Research in various regions of Africa, Asia, and Latin America has examined the potential of non-traditional data sources like mobile phone records, satellite imagery, and social media to augment or serve as alternatives to expensive and infrequent household surveys. For instance, research conducted in Rwanda and Ghana has leveraged call detail records to assess population movements and urban activity patterns, offering real-time alternatives to conventional census methods (De Montjoye et al., 2013; Blumenstock et al., 2015). Likewise, satellite data has been utilized to assess agricultural productivity in South Asia and deforestation rates in Brazil, facilitating more adaptive environmental and economic policy measures (Jean et al., 2016).

Scholars have employed machine learning, spatial analysis, and econometric techniques methodologically to derive insights from big data sources. Because conventional surveys are expensive and time-consuming, the combination of remote sensing and AI-based classification models has demonstrated notable effectiveness in tracking changes in land use, urbanization, and crop health. Nevertheless, these methods frequently encounter difficulties regarding replicability, validation, and representativeness, especially in low-resource environments. Researchers stress the necessity of hybrid models that integrate big data with ground-truthing and conventional statistical methods to enhance accuracy and legitimacy (Letouzé et al., 2016; Taylor and Schroeder, 2015). In summary, although regional experiences demonstrate considerable potential, they highlight the necessity for national strategies that connect technological innovation with ethical and institutional safeguards.

2.1 Current State of Aquaculture and Fisheries

Nepal's aquaculture production reached 80,000 metric tons in 2022, dominated by carps (65%) and trout (15%) (DoFD, 2022). However, overfishing, pollution, and poor management threaten wild fish stocks. The introduction of cage farming in reservoirs and polyculture systems has shown promise, yet adoption remains limited due to inadequate technical knowledge and financing. Nepal encompasses approximately 808,500 hectares of natural water bodies, including rivers, canals, lakes, reservoirs, and paddy fields, ideal for fish production. These resources collectively yield 21,000 metric tons (Mt) of fish annually. Additionally, there are 14,745 hectares of ponds for aquaculture. In the fiscal year 2079/080, total fish production from both natural and pond systems reached 113,736 Mt, with pond culture accounting for 81.5% of the total. The Terai region has the highest production, with Madhesh province contributing over 50% of the total fish production. Nepal has immense potential for the sustainable development of its aquaculture and fishery sector. Recognizing its importance to food security, employment generation, and social inclusion, the Government of Nepal has endorsed the National Fishery Development Policy 2079. This policy aims to sustainably develop the fisheries and aquaculture sector, emphasizing employment generation and aquatic biodiversity conservation for future prosperity. It will guide the sector's development, ensuring that all programs, plans, and activities align with this policy.

3. Material and Method

3.1 Data

The data used were secondary data derived from Statistics of Fisheries and aquaculture in Nepal from 2007/2008 to 2022/2023, Central Bureau of Statistics and Statistics of Fisheries and aquaculture in Nepal 2022/2023

3.2 Economic Significance of Aquaculture and Fisheries in Nepal

This study integrates econometric and ecological modeling techniques to assess both the economic significance and sustainability of aquaculture and fisheries in Nepal. The Cobb-Douglas production function was utilized to measure how labor (pond area) and capital (water surface area) contribute to fish production. To support this, log-transformed regression analyses were conducted using STATA 18.0.

In parallel, a Logistic Growth Model was employed to estimate the maximum sustainable yield or carrying capacity of Nepal's fish production. This was based on historical data from 2007 to 2022, with nonlinear regression used to fit the model parameters such as initial production, growth rate, and carrying capacity. Data sources included the Ministry of Agriculture and Livestock Development, Central Bureau of Statistics, and district-level fishery reports. To aid interpretation, tables, graphs, and trend analyses were generated using STATA 18.0. This dual-model approach posed comprehensive insights into yield efficiency, production trends, and the potential for sustainable aquaculture in Nepal. Aquaculture plays a vital socioeconomic role in the country, directly employing over 500,000 people and indirectly supporting around 1 million others (MOALD, 2022). It also contributes significantly to nutrition security by providing affordable animal protein. From 2010 to 2022, Nepal's fish production grew from 60,000 to over 100,000 metric tons annually (CBS, 2022), supporting national GDP and helping to reduce dependence on fish imports.

3.3 Cobb-Douglas Production Model

To estimate the contribution of inputs to aquaculture productivity, the Cobb-Douglas production function can be used:

$Q = A \cdot L! \cdot K"$

Where:

Q = Total fish output

A = Total factor productivity

L = Labor input

K = Capital input (e.g., ponds, feed, technology)

α, β = Output elasticities of labor and capital

This model helps estimate the returns to scale and efficiency of resource use. Empirical studies in Nepal have shown $\alpha + \beta < 1$, indicating decreasing returns and the need for technical innovation (Shrestha and Dhakal, 2020).

Model Specification

The Cobb-Douglas production function used is: $\log(Q) = \log(A) + \alpha\log(L) + \beta\log(K)$

3.4 Logistic Growth Model Overview

The logistic growth model is represented by the equation:

$Q(t) =$ K

$1 +$ $K - P\#6$ $e\$\%$and

3 $P\#$

Where:

$Q(t)$: Fish production at time t

K: Carrying capacity (maximum sustainable production)

$P\#$: Initial production at $t = 0$

r: Intrinsic growth rate

Table 1: Yearly Summary of Pond Aquaculture Fish Production

Year	Pond's No.	Pond's Area	Water Surface Area (Ha)	Total Fish Production (Mt.)	Yield (Mt./Ha.)
2007/08	23,884	10,362	6,735	24,295	3.61
2008/09	23,790	10,308	6,700	23,780	3.55
2009/10	24,418	10,615	6,900	24,869	3.60
2010/11	26,036	11,195	7,277	26,941	3.70
2011/12	29,270	10,718	7,939	29,999	3.78
2012/13	32,020	12,338	8,020	31,221	3.89
2013/14	34,400	13,231	8,600	37,427	4.35
2014/15	36,666	14,154	9,200	41,481	4.51

Table 1 (cont): Yearly Summary of Pond Aquaculture Fish Production

2015/16	39,308	15,283	9,934	48,543	4.89
2016/17	44,725	17,532	11,396	55,842	4.90
2017/18	45,327	18,310	11,889	58,433	4.91
2018/19	45,936	19,620	12,749	62,725	4.92
2019/20	48,369	20,732	13,476	66,906	4.96
2020/21	50,122	21,313	13,854	73,693	5.32
2021/22	49,862	21,443	14,137	77,320	5.47
2022/23	50,326	22,684	14,745	82,161	5.57

Table 2: Summary of Fish Production (2079/080)

Fish Production (Aquaculture and Capture Fisheries)	2022/23		
Particulars	Total Area (Ha.)	Fish Production (Mt.)	Yield (Mt./Ha.)
A. Fish Production from Aquaculture Practices		92736	
A1 Pond Fish culture (Carps)	14745	82161	5.572
Mountain	48.96	82	1.67
Hill	1452.85	6787	4.67
Terai	13243.3	75292	5.69
Total Fish Production (Mt.)		113,736	
B. Fish Seed Production/Distribution		569,070	
B1 Public Sector (000)		131,239	
a. Hatchling		335,600	
b. Fry		17,158	
c. Fingerling		16,869	
B2 Private Sector (000)		437,831	
a. Fry		437,831	
Fish import (Mt.)		3732	
Per capita fish production(kg)		3.8	
Per capita fish availability(kg) (Production+ Import)		3.9	
Households in Aquaculture		62,397	
Employment from Aquaculture		158,720	
Employment in Capture Fisheries		362,244	

Table 3: Import and export of fisheries in Nepal

Year	Import Value (US$)	Export value	Import value growth	Export value growth YOY (%)
2010	2,788,282.00	1,587.00	12.54	–42.87
2011	4,286,729.00	5,139.00	53.74	223.82
2012	5,059,269.00	21,416.00	18.02	316.73
2013	5,373,479.00	9,869.00	6.21	–53.91
2014	7,993,753.00	48,778.00	48.76	394.25
2015	7,491,385.00	5,184.00	–6.28	–86.37
2016	9,322,883.00	17,820.00	24.22	243.75
2017	11,290,872.00	9,684.00	21.10	–45.65

Source: T. Economy, 2021.

The table shows that Nepal's fishery imports steadily increased from 2010 to 2017, rising from US$2.79 million to US$11.29 million, indicating growing domestic demand. In contrast, exports remained low and unstable, peaking at US$48,778 in 2014 but declining afterward. Import growth was generally positive, while export growth fluctuated sharply, reflecting weak export performance and market inconsistency. Overall, Nepal's fishery trade balance is heavily import-driven, highlighting the need to boost local production and develop stronger export capacity.

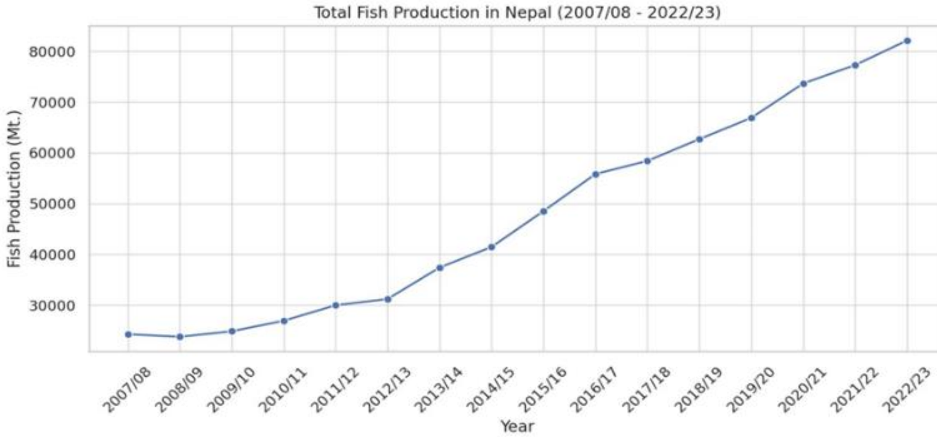

Figure 1: Trend of fish production

Figure 1 shows a consistent upward trend in fish production from 24,295 Mt to 82,161 Mt. Indicates growing productivity and expansion of aquaculture activities in Nepal

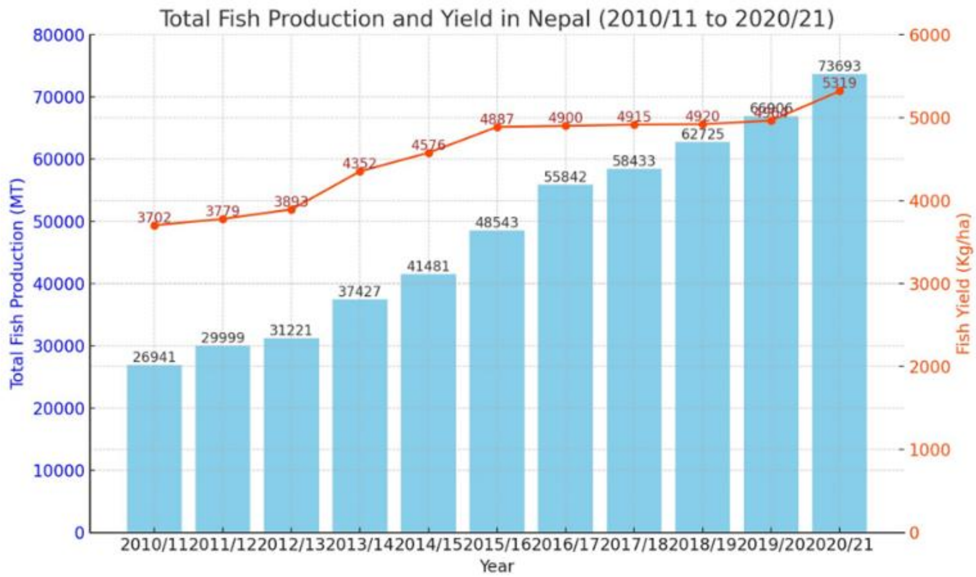

Figure 2: Fish production and yield in Nepal

4. Results and Discussion

Yield per hectare has increased steadily even with the expansion in pond area. This implies improved efficiency and possibly better technology and management practices. The trend of fish production in Nepal from 2007/08 to 2022/23 can be effectively analyzed using the logistic growth model. This model posits that production begins with a slow growth phase, accelerates during a middle phase, and then gradually tapers off as it nears the maximum sustainable limit known as the carrying capacity (K). The data indicates that the fish production (P_0) at the outset of 2007/08 was 24,295 metric tons. Production rose consistently over the years, culminating in a total of 82,161 metric tons by the 2022/23 period. This pattern displays the classic S-shaped curve that is characteristic of logistic growth. We can estimate the model parameters by using the nonlinear regression methods of the `nl` command.

With an estimated carrying capacity (K) of about 85,000 metric tons and an intrinsic growth rate (r) of roughly 0.13, this suggests that production grows by 13% each year in the growth phase. The model aligns closely with the actual production data, suggesting that the residuals are probably small and randomly distributed. The trend indicates that fish production in Nepal is approaching its ecological and infrastructural limits. To sustain or boost production beyond this threshold, it is essential for policymakers and stakeholders to invest in enhancing aquaculture practices, increasing pond areas, or developing innovative technologies to raise the effective carrying capacity.

- K (Carrying Capacity)**:** 85,000 Mt. This is the theoretical maximum under current aquaculture capacity and technologies.
- P_0 (Initial value)**:** 24,295 Mt
- r (Growth Rate)**:** ~0.13 (i.e., about 13% annual growth rate)

Table 3: The output of STATA

Source | SS df MS Number of obs= 16

-------------+---------------------------------- F(2, 13) = 957.89

Model | 3.80241251 2 1.90120625 Prob > F = 0.0000

Residual | 0.02581897 13 .001986074 R-squared = 0.9933

-------------+---------------------------------- Adj R-squared= 0.9918 Total | 3.82823148 15 .255215432 Root MSE = 0.04458

----

log_Q | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+-- log_L | 0.3711 0.3170 1.17 0.263 -0.313 1.056

log_K | 1.1662 0.3250 3.59 0.003 0.465 1.867

_cons| -3.6042 0.3340 -10.78 0.000 -4.326 -2.882

Table 3 is the regression analysis evaluates a Cobb-Douglas production function, where the natural logarithm of output (log_Q) is modeled as a function of the natural logarithms of labor (log L) and capital (log_K). The model demonstrates an excellent fit, with an R-squared value of 0.9933, indicating that approximately 99.33% of the variation in output is explained by the combination of labor and capital inputs.

The adjusted R-squared, which accounts for the number of predictors, remains high at 0.9918, confirming the model's reliability and robustness. Furthermore, the F-statistic value of 957.89 with a p-value of 0.0000 suggests that the model is highly statistically significant overall, meaning that the independent variables jointly have a strong influence on the dependent variable.

Looking at the individual coefficients, capital (log_K) has a statistically significant and positive effect on output, with a coefficient of 1.1662 and a p-value of 0.003. This means that a 1% increase in capital is associated with a 1.17% increase in output, holding other factors constant. The confidence interval for this estimate ranges from 0.465 to 1.867, reinforcing its significance. In contrast, the coefficient for labor (log_L) is 0.3711, suggesting a positive relationship between labor and output; however, it is not statistically significant, as its p-value is 0.263 and the 95% confidence interval includes zero. This implies that, within this dataset, labor does not have a statistically meaningful impact on output at the conventional significance level.

The constant term, or intercept, is -3.6042 and is statistically significant with a p-value of less than

0.001. This value represents the expected log output when both labor and capital are zero, which, while not practically interpretable, is necessary for model estimation. Using the estimated coefficients in the Cobb- Douglas functional form, the production equation becomes: Q = e^(-3.6042) · L^0.3711 · K^1.1662.

Importantly, the sum of the output elasticities (0.3711 for labor and 1.1662 for capital) is 1.5373, which is greater than one. This indicates increasing returns to scale, suggesting that a proportional increase in both labor and capital inputs would result in a more than proportional increase in output. From a policy or managerial perspective, this implies that capital investment is likely to yield substantial returns in terms of output growth. In contrast, the role of labor appears less influential in this specific model and context.

Based on the regression results from your Cobb-Douglas model, the estimated Cobb-Douglas production function equation is:

Q = e$'.)#*+ · L#.',-- · K-.-))+

and in logarithmic form (used in your regression):

$\log(Q) = -3.6042 + 0.3711 \cdot \log(L) + 1.1662 \cdot \log(K)$

This function shows that Output increases by approximately 0.37% for every 1% increase in labor (though not statistically significant). Output increases by approximately 1.17% for every 1% increase in capital (statistically significant). The returns to scale are increasing since 0.3711 + 1.1662 = 1.5373 > 1.

Provincial Analysis revealed major disparities in fish production. Madesh Province leads with 58% of national output (47,640 Mt) from 20,318 ponds and 7,273 Ha of water area and has the highest yield (6.55 Mt/Ha). In contrast, Karnali Province contributes just 0.1% of production (82 Mt) from only 32 Ha, with the lowest yield (2.54 Mt/Ha), indicating inefficiencies. Provinces like Gandaki and Bagmati also underperform in yield compared to the national average (5.57 Mt/Ha), while Koshi, Lumbini, and Sudurpaschim show moderate performance (4.76–4.91 Mt/Ha).

Table 4: Province Wise Fish Production (2079/080)

Province	Pond's No.	Water Surface Area (Ha.)	Total Fish Production (Mt.)	Yield (Mt./Ha.)
Koshi	11,047	2,019	9,919	4.91
Madesh	20,318	7,273	47,640	6.55
Bagmati	35,477	1,263	5,210	4.13
Gandaki	2,547	391	1,409	3.60
Lumbini	9,878	3,338	15,885	4.76
Karnali	290	32	82	2.54
Sudurpaschim	2,699	429	2,018	4.71
Total	**50,326**	**14,745**	**82,161**	**5.57**

Table 5: Ten Topmost Districts based on productivity of pond fish farming (FY 2079/80)

Province	District	Pond's No.	Water Surface Area (Ha.)	Yield kg. /Ha.	Total Fish Production (Mt.)
Madhesh	Bara	4571	1569	7416	11635
Madhesh	Dhanusha	3052	1271	7050	8960
Madhesh	Rautahat	1345	601	6963	4185
Madhesh	Siraha	2623	814	6905	5621
Madhesh	Sarlahi	1430	558	6817	3804
Lumbini	Rupandehi	4856	1487	5746	8545
Madhesh	Saptari	2940	965	5715	5515
Lumbini	Arghakhanchi	13	1.51	5629	9
Lumbini	Dang	619	112	5455	611
Koshi	Sunsari	2058	582	5407	3147

As illustrated in Tables 4 and 5, Nepal's aquaculture fish production exhibited a consistent rise over five years, escalating from 70,832 metric tons in 2075/76 to 92,736 metric tons in 2079/80. The primary contributor continued to be pond fish culture (carps), with production rising from 62,725 to 82,161 metric tons and yield enhancing from 4.92 to 5.572 tons per hectare. The Terai region consistently topped the production charts, while the Hill region experienced considerable growth, particularly in the later years. Production in the mountain region remained low but saw a gradual increase. In general, production volume and yield both increased across regions, signaling advancements in aquaculture practices.

The figure 2 illustrates the regional distribution of fish production from aquaculture in Nepal for 2022/23. The Terai region dominates, contributing over 91% of the total production, while the Hill region accounts for about 8.3%, and the Mountain region contributes only 0.1%. This clearly highlights the Terai's crucial role in national aquaculture due to its favorable environment and infrastructure.

4.1 Employment generation by fisheries sector

Like other developing nations, Nepal faces a significant issue with employment. Many young people emigrate each year looking for work. In this context, the fisheries sub-sector can serve as an alternative means of reducing youth migration by offering them employment opportunities in various fisheries and aquaculture-related activities. In Nepal, aquaculture is a major contributor to job creation. Aquaculture engages individuals of various ages and genders, from preparing equipment and caring for fish to marketing fish and fisheries products. The number of people directly employed in aquaculture during the 2018/19 fiscal year was 143,241. The economy of Nepal greatly relies on remittances. This type of economy can collapse at any moment and cannot be sustained. Thus, developing aquaculture could be a viable option to address the issue of outmigration, generate employment opportunities within the country for young people, and engage them in national development efforts. Though aquaculture in Nepal is a small and primitive sub-sector, it plays a significant role in generating employment. Aquaculture engages individuals of various ages and genders, from preparing equipment and caring for fish to marketing fish and fisheries products. Approximately 122,772 individuals are employed directly or indirectly in this sub-sector, with males accounting for 67% and females for only 33% (Figure 3).

2.57% of the world's freshwater is shared by Nepal. Of the total water resources, rivers, lakes, and reservoirs account for 48.55%, irrigated paddy fields for 48.14%, marginal swamps for 1.4%, ponds for 1.38%, irrigation canals for 0.38%, and highway-side ditches for 0.03% (CFPCC, 2019). Currently, 143,241 individuals are directly engaged in aquaculture, while 421,345 are involved in capture fisheries in Nepal. Several ethnic communities, including Bhote, Darai, Majhi, Gurung, and Kunwar, rely on fisheries for their sustenance. Currently, the contribution of fisheries to Nepal's Gross Domestic Product is 1.13%, while its contribution to Agricultural Gross Domestic Product stands at 4.18%.

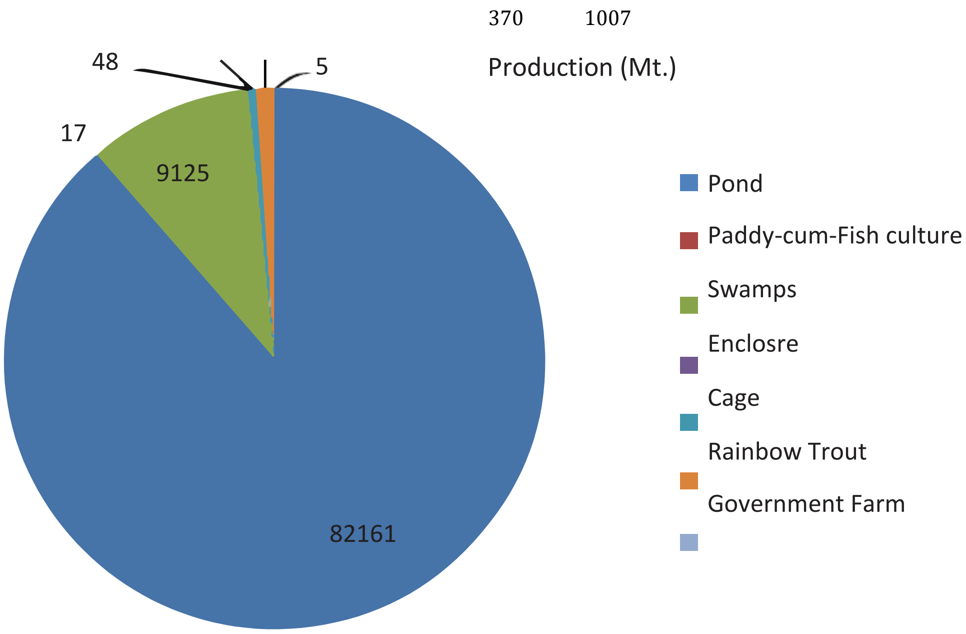

Figure 3: Fish production from natural and aquaculture systems (2079/80)

As illustrated in figure 3, various aquaculture systems yield differing levels of fish production, with the pond system accounting for the highest contribution. Data analysis reveals that while the water surface area of ponds has slightly increased and production has risen, it indicates a significant increase in productivity over time. The graph illustrates my productivity, which has risen over time; it was at least 4.35 tons per hectare, and it is now 5.57 tons per hectare. Data analysis shows that the private sector plays a greater role in fish seed production compared to the public sector, highlighting its ability to fulfill the demand for fish seed.

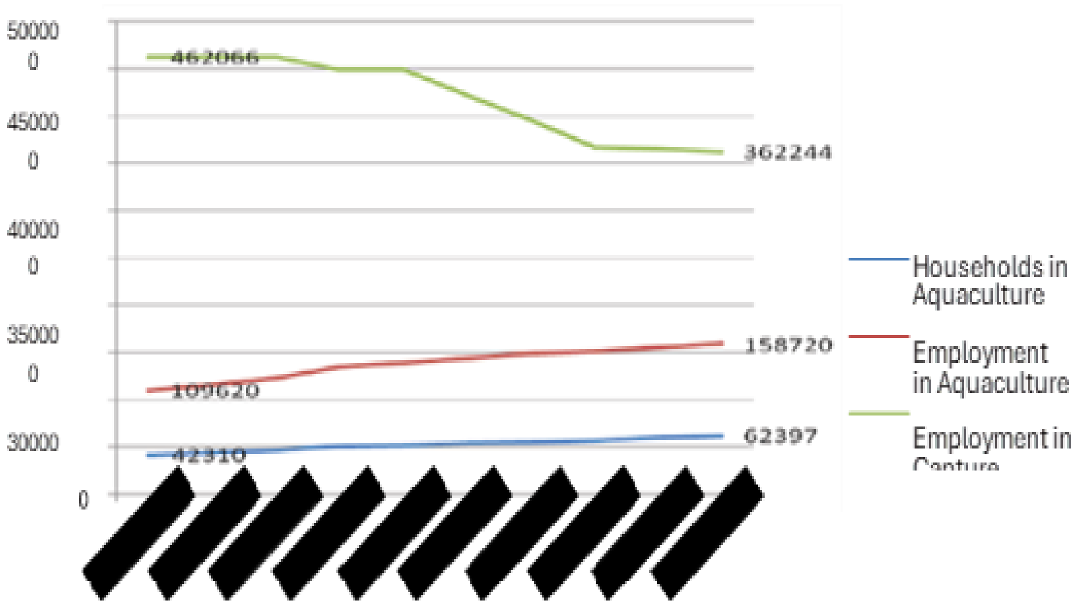

Figure 4: Employment from fisheries sector (10 years)

The figure demonstrates that employment in aquaculture has increased over me, whereas employment in capture fisheries has decreased over, indicating that aquaculture is one of the key industries that employ households

The figure shows that per capita fish production and availability have increased over the period, and per capita fish availability is slightly higher than that of production. It also reveals that the import of fish is not so high.

The figure reveals the trend of annual growth rate of Aquaculture. Aquaculture growth rate is attained by different farming system like Pond aquaculture, cage aquaculture, raceway aquaculture etc. Among which pond aquaculture is the major contributor of the aquaculture production.

The figure presents the annual production and distribution of aquarium fish by Central Fisheries Promoon and Conservation Center five provisions.

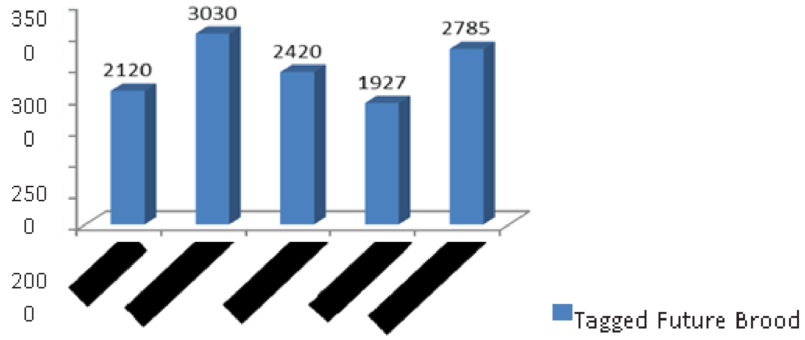

Figure 5: Province wise distribution of tagged future brood

4.2 Policy and Economic Interventions

Several crucial policy and economic measures are necessary to foster sustainability and economic growth in Nepal's aquaculture sector. Investing in green technologies like biofloc systems, integrated fish-livestock setups, and wastewater aquaculture can enhance yield and reduce environmental impact. Improving cold storage, transport, and market infrastructure to strengthen the value chain will decrease post-harvest losses and boost farmers' income. By involving local cooperatives, community-based resource management guarantees sustainable harvesting and equitable distribution. Access to subsidies and government-backed loans can help impoverished farmers adopt sustainable practices.

Infrastructure plays a major role in productivity; for instance, Madesh's 20,318 ponds support high yields (6.55 Mt/Ha), while underdeveloped provinces like Karnali lag with only 2.54 Mt/Ha. Bridging this yield gap through improved technology, quality feed, and training could boost total national production by 17.6%, reaching 96,632 Mt. Prioritizing the expansion and efficient use of surface water, adopting integrated systems, and improving water quality and feed technologies are crucial. Since labor (pond area) is showing diminishing returns, productivity gains should also focus on training and mechanization to enhance efficiency.

5. Future Research

Future studies should build on the current findings by including survey-based research that gathers micro-level data from stakeholders directly involved in aquaculture and fisheries, such as smallholder farmers, cooperatives, and local market actors. The primary data gathered would yield valuable insights into household-level decision-making, socio-economic impacts, the adoption of sustainable practices, and the challenges encountered in accessing technology, credit, or training

Moreover, it is crucial to conduct impact evaluations of ongoing and past fishery development projects in Nepal and similar developing contexts to determine the effectiveness of these interventions. Methods like difference-in-differences, randomized control trials (RCTs), or propensity score matching could aid in quantifying outcomes associated with productivity, income, employment, and environmental sustainability. Assessments of policy tools like subsidies for pond construction, fish feed initiatives, or cold chain enhancement would inform future investments and resource distribution. By bolstering the evidence base for policymaking, these empirical assessments would help ensure that the growth of the aquaculture sector promotes equitable and sustainable development.

6. Conclusion

Aquaculture in Nepal is expanding rapidly and holds strong potential to transform rural economies sustainably. Despite its growth, the sector faces several challenges. Provinces Karnali and Gandaki scrap with low yields due to harsh climates, limited resources, and poor market access. Resource allocation tends to favor already productive regions, increasing regional disparities. Climate issues such as floods and droughts disrupt pond-based farming, while high feed and input costs largely due to import reliance add financial pressure on farmers. Environmental threats like pollution from agriculture and industry also endanger aquatic life. Institutional inefficiencies from poor coordination among fisheries, agriculture, and water management sectors hinder policy implementation. Despite these hurdles, Nepal boasts a 15.6% aquaculture growth rate, the highest among SAARC countries, gaining government attention and budget support. Commercial fish farms are growing to meet rising demand but lack technical support and skilled manpower due to limited training opportunities. Addressing this skills gap through specialized training in fish breeding, disease control, nutrition, and water quality is essential. Ecological-economic models like Cobb-Douglas can guide sustainable decision-making. With water area being a dominant factor in production, future policies should prioritize efficient water use and improved infrastructure to enhance productivity and promote balanced regional development.

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