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Review Article

An Overview of Status and Development Trend of Aquaculture and Fisheries in Nepal

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Although Nepal is a landlocked country, it has abundant water resources that enhance its potential for fisheries and aquaculture activities. But, only a few percentages of the total water resources have been utilized properly. Despite a satisfactory growth in pond fish production over the last 15 years with 73,693 Mt. of fish produced in the fiscal year 2020/21, there has not been much significant advancement in the fisheries sector as expected. Some of the major challenges encountered by farmers are lack of technical knowledge, lack of capital, scarcity of good quality fingerlings, quality feed, diseases, and lack of good market infrastructure. We recommend government authorities to address the problems as aquaculture and fisheries are important sectors that contribute to nutrition for rural people and employment opportunities for many individuals.

1. Introduction

Aquaculture is one of the fastest growing activity in the world [1], and also the fastest emerging food-producing sector that plays a significant role in the economy [2]. According to Food and Agriculture Organization FAO [3], aquaculture and fisheries are responsible for supplying 17% of total animal protein globally for human consumption. The increasing competition for land and water with other sectors has induced a reduction in feed resources for aquaculture [4]. It has been assumed that the total global fish production would expand up to 204 million tons by 2030 [3]. As a result, the primary issue for policymakers and development agents is to establish an enabling environment for the aquaculture industry that is capable of flourishing while satisfying societal demands and conserving the natural resources it requires. This environment has many facets and needs strong political will, long-term policy, public sector assistance, and investment [5].

Asia is the biggest contributor in the sector of aquaculture and China secures its position at the top of the producers' list in both Asia, as well as the world [6]. Aquaculture and fisheries are not a major agricultural activities in Nepal but they are important supplements to daily food [7]. Although Nepal ranks quite lower in terms of production, the impact exerted by aquaculture on the national Gross Domestic Product (GDP) cannot be ignored as 2.47% of the nation's agricultural GDP is contributed by fisheries and aquaculture [8]. Fish is a rich source of dietary nutrients having a diverse utility in food value and medicinal importance [9, 10]. Ever since the health benefits of fish foods have been known to the general public, national and international demand for fishery products has risen in these recent years. The increasing population and the inevitable need to solve the crisis of food hunger have confirmed that this trend is supposed to continue in upcoming decades as well [11]. An increase in the production of fish and advancement in the fisheries sector are the prerequisites for the improvement of fish-based industries. Despite the fact that Nepal is rich in natural water resources, the freshwater bodies have not been utilized to their full potential. Even though fish farming holds tremendous prospects in elevating the nation's economy, there are lots of setbacks hindering success of fish farming.

Thus, these issues must be addressed sincerely to promote economic and technological advancements in the aquaculture and fisheries sector.

The future prospects of fisheries and aquaculture can be predicted through a detailed analysis of the developmental trends and the current situation [12]. So, this article is focused on exploring such trends to offer a comprehensive portrayal of the present scenario of the aquaculture and fisheries sector in Nepal that would possibly help researchers in introducing the most suitable approaches for its development. It also attempts to shed light on the important issues to be addressed that are revolving around the sectors of fish production, marketing, and trade. This review highlights the various opportunities offered by aquaculture and fisheries that would lend a helping hand in ameliorating the economic state of the country. It will be helpful to policymakers and other concerned organizations in finding intervention areas and formulating appropriate programs, plans, and policies for the development of the aquaculture and fisheries sector in Nepal.

2. The State of World Aquaculture and Fisheries

Aquaculture continues to expand faster than other food-producing industries [13] playing a crucial role in achieving sustainable development goals (SDGs) and determining progress toward this goal [3]. According to global aquaculture data provided by FAO, the world aquaculture output reached a record of 114.5 million tonnes in live weight in 2018, with a total farm gate selling value of USD 263.6 billion [3]. Total world fish output (capture plus aquaculture, excluding aquatic plants) is anticipated to continue growing during the forecast period, reaching more than 200 million tonnes in 2030, because of increasing demands and technical advances [14]. However, there are significant barriers to aquaculture's future expansion as both land and water resources are already scarce in many locations [15].

In terms of production techniques and farmed species, Asia's aquaculture is considerably more diversified than in other areas and has an 89% share in the last two decades [3, 16]. Because of its rapid rise in economy and domestic seafood consumption, China has retained its position as the world's top producer, processor, and trader of fish, crustaceans, and mollusks since 2000 [16–18]. The estimated fish consumption per capita in 2019 is shown in Figure 1. Africa has the lowest consumption rate of fish and fish products. The fisheries and aquaculture sector are one of the key source of employment [21]. In 2020, the primary fisheries and aquaculture sector employed an estimated 58.5 million people [22]. Figure 2 shows the general predictions on the future of aquaculture and fisheries as suggested by the State of Fisheries and Aquaculture: Towards Blue Transformation, published by FAO in 2020. The COVID-19 pandemic has affected most countries in the world, with severe impacts on the global economy of which Nepal is not an exception. These projections were based on the assumption that there will be a significant disruption in the short run for production, consumption, and trade, with a recovery in late 2020 or early 2021.

3. General History of Aquaculture in Nepal

Aquaculture started in Nepal in the 1940s with the introduction of the indigenous Indian major carp seed from the neighboring country India on a small-scale pond. In 1946/47, aquaculture development was institutionalized by establishing a fisheries unit in the Agriculture Council. It was followed by the introduction of the exotic species common carp (*Cyprinus carpio* L.) in the late 1950s. In the mid-1960s, monoculture practice was followed by the successful breeding of common carp. Rice fish culture was also initiated at the same time in the hills and valleys. Rearing of three exotic Chinese carp species was done in the early 1970s, followed by their successful induced breeding in the mid-1970s. The Chinese carp included silver carp [*Hypophthalmichthys molitrix* (Valenciennes, 1844)], bighead carp [*Hypophthalmichthys nobilis* (J. Richardson, 1845)], and grass carp [*Ctenopharyngodon idella* (Valenciennes in Cuvier & Valenciennes, 1844)]. With support from Food and Agriculture Organisation (FAO)/United Nations Development Programme (UNDP) and later International Development Research Center (IDRC) Canada in the 1970s, there was an initiation of cage fish culture with herbivorous carps (major species: silver carp and bighead carp).

The establishment of breeding techniques of three major indigenous carps, namely, Rohu [*Labeo rohita* (Hamilton, 1822)], Mrigal [*Cirrhinus mrigala* (Hamilton, 1822)], and Catla [*Catla catla* (Hamilton, 1822)] in the late 1970s led to a significant success in aquaculture sector that provided momentum to the polyculture system in Nepal [23]. Later in the 1980s, commercial fish farming was developed with the launch of the Aquaculture Development Project supported by the Asian Development Bank (ADB) and the United Nations Development Programme (Figure 3).

4. Natural Water Resource in Nepal

Although Nepal is a landlocked country, it is rich in natural water resources. The most dominant water resources in Nepal are low land irrigated paddy fields and rivers and streams which occupy 48.14% and 47.77% of the total water resources, respectively (Table 1). Snow covers, lakes, marginal swamps, and groundwater are other major sources of water as presented in Table 1. According to [26], only 2% of the total water resource present in the country has been utilized for aquaculture production while there is an extreme scope for culture in the available resources.

5. Number of Ponds and Their Area

People are more attracted to aquaculture as it has become a good money-returning sector. Out of all the aquaculture practices of Nepal, pond fish culture is the most common and popular. In 2020/21, among the 3 geographical regions, the Terai region has the highest number of ponds (45,169) with a large area occupancy (13,404 ha), followed by the Hilly region (ponds: 4,491, area: 430 ha) and

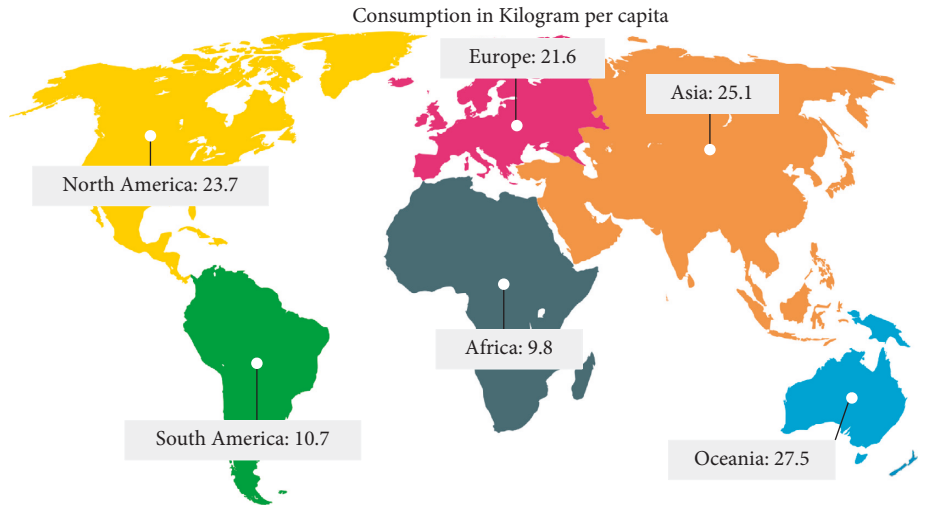

Figure 1: Global world map showing estimated fish consumption per capita in 2019 (kilograms per capita), information obtained from [19]. The shapefile of the world map required for Arc GIS Ver. 10.8 was obtained from [20].

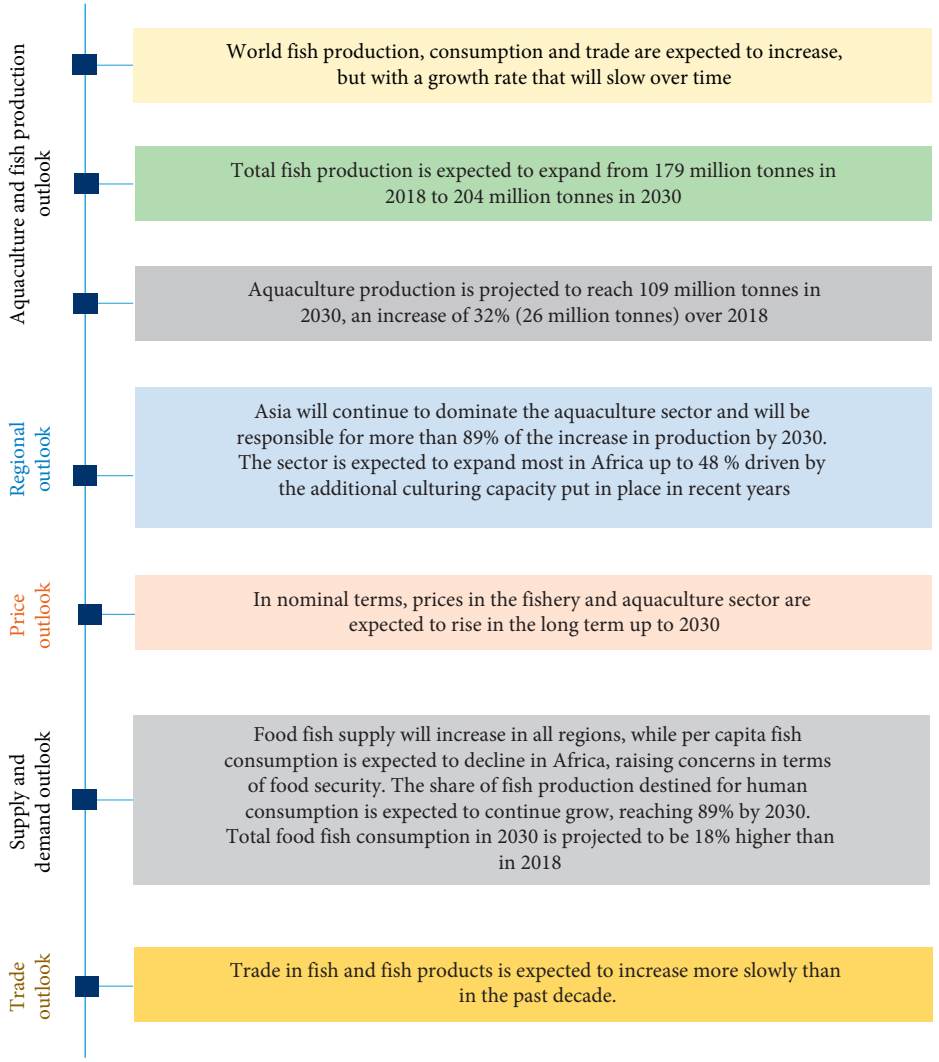

Figure 2: General prediction on future of world aquaculture and fisheries sector as published by FAO. Reference [3].

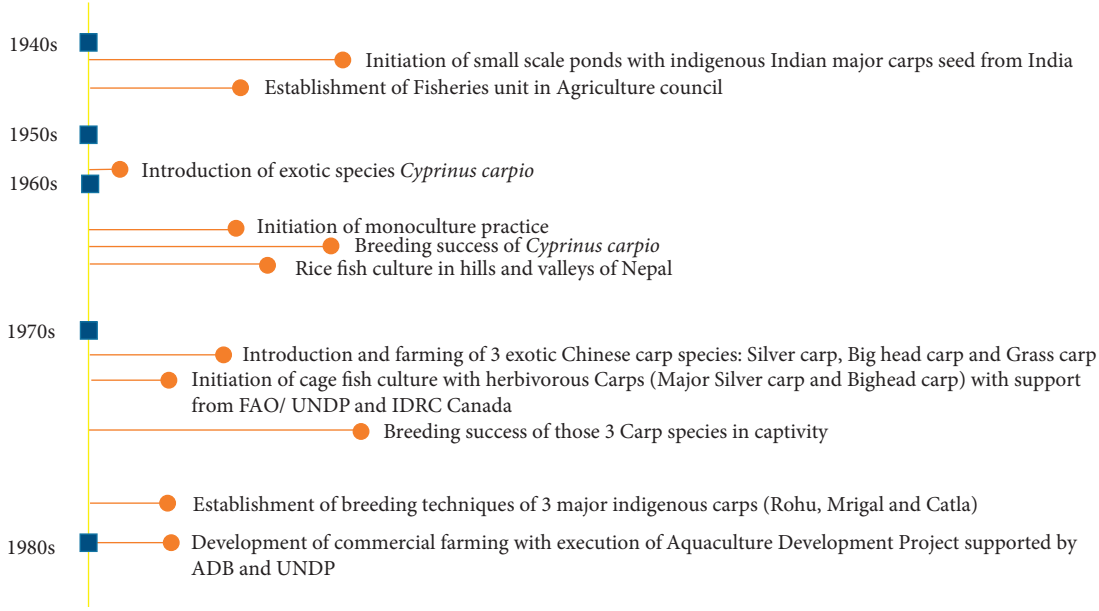

Figure 3: General overview of aquaculture history in Nepal, source: information obtained and modified from [24, 25].

Table 1: Natural water sources in Nepal.

SN	Water Resources	Estimated area (ha)	Coverage Percentage	Total number	Remarks
1.	Rivers and streams	395000 ha	47.77%	6000	45000 km length
2.	Lakes	5000 ha	0.60%	5358	
3.	Reservoirs	1500 ha	0.18%		Future potential 78000 ha
4.	Ponds	12794 ha	1.38%	44725	
5.	Marginal swamps	12500 ha	1.51%		
6.	Low land irrigated paddy field	398000 ha	48.14%		Total paddy area 1551000 ha
7.	Irrigation canal	3160 ha	0.38%		Irrigation canal length 7900 KM (assuming 4 m average width of the canal)
8.	Highway side ditches	262 ha	0.03%		Approximate highway length in Terai area 3500 KM (assuming 15% of the highway has the side ditches with 2.5 m average width)

Note: SN 7 and 8 are general prediction data; authentic verification is still not done, source: [26].

Mountain region (ponds: 462, area: 20 ha) [27]. There has been an increase in the number of ponds and the pond area every year (Figure 4). The increasing trend in pond numbers and area might be due to the subsidy programs for pond construction launched by the government of Nepal. After the pond expansion programs from the fiscal year 2011/12 in the mid-hill region, the development of pond fish culture has been accelerated.

6. Diversity of Aquatic Organisms

A diverse aquatic ecosystem is prevalent in Nepal that includes various fin fish, frogs, mollusks, water birds, and many others. Details on aquatic organisms and the number of their species found in Nepal are presented in Table 2. Fish are the most consumed aquatic organisms in Nepal. Two hundred fifty-two different species of fin fish are found throughout the country (Table 2). Out of them, 236 are indigenous fish species, whereas 16 species are exotic.

6.1. Major Fish Species Cultured in Nepal. Two hundred fifty-two species of fish are found in various water bodies in Nepal inhabiting from a few hundred meters above sea level to as high as 4000 meters [26]. The details on the major fish species in Nepal are shown in Tables 3–7, which were extracted from [26, 29–32]. Seven carp species such as Bighead carp, Grass carp, Rohu, Naini/Mrigal, Silver carp, Common carp, and Catla/Bhakur are the most cultured fish species in Nepal. In addition to them, Pangas, African catfish, and Nile tilapia are also produced. However, in case of mangur [*Clarias gariepinus* (Burchell, 1822)] was permitted for scientific studies but it got established in illegal way. Mahseer is also popular for sport fishing. Besides these fish species, exotic ones such as rainbow trout of superior commercial value have been introduced in the country over the years. The crustacean species Giant fresh water prawn, which is locally known as "Jhinge Maccha," is also cultured in Nepal. In order to import any fish other than indigenous one, permission should be taken from government authority.

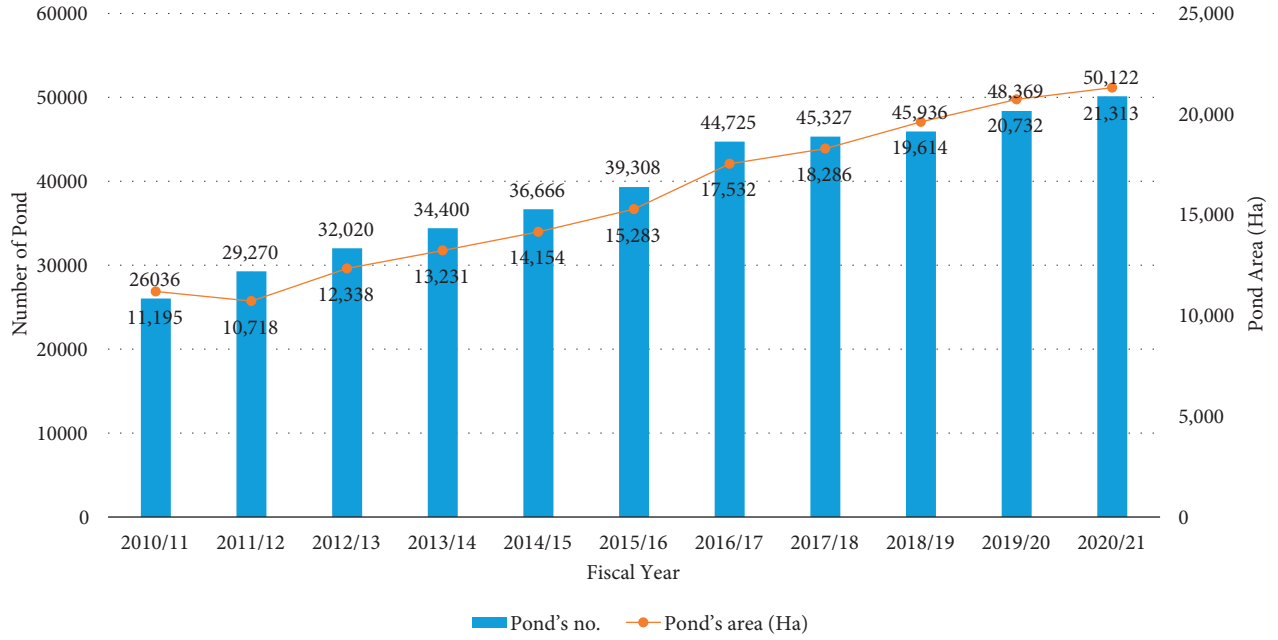

Figure 4: Number of ponds and their area from the fiscal year 2010/11 to 2020/21 in Nepal. Data obtained from [27, 28].

Table 2: Aquatic diversities in Nepal.

SN	Aquatic diversities	Number of species
1.	Finfish	252 (indigenous: 236, exotic: 16)
2.	Frogs	53
3.	Mollusks	50 (edible: 25)
4.	Crabs	9
5.	Prawns	3
6.	Water birds	193
7.	Aquatic plants	84
8.	Reptiles	47

Source: [26]

Table 3: Species that are technically recommended to the rear for commercial purposes in Nepal.

Scientific Name	Common Name	Domain
Labeo rohita (F. Hamilton, 1822)	Rohu	Warm water
Cirrhinus mrigala (Hamilton, 1822)	Naini/Mrigal	Warm water
Labeo catla (F. Hamilton, 1822)	Bhakur/Catla	Warm water
Cyprinus carpio var. communis, *C. carpio* var. specularis	Common carp	Warm water
Hypophthalmichthys molitrix (Valenciennes, 1844)	Silver carp	Warm water
Aristichthys nobilis (Richardson, 1845)	Bighead carp	Warm water
Ctenopharyngodon idella (Valenciennes in cuvier & Valenciennes, 1844)	Grass carp	Warm water
Oncorhynchus mykiss (Walbaum, 1792)	Rainbow trout	Cold water
Pangasianodon hypophthalmus (Sauvage, 1878)	Pangasius	Warm water
Oreochromis niloticus (Linnaeus, 1758) (mono-sex)	Nile tilapia	Warm water
Puntius gonionotus (Bleeker, 1850)	Silver barb	Warm water

6.2. Mollusks Species. Although the climatic region from 65 m to 4800 m altitude is suitable for 70 species of mollusks, the edible ones are found in the valleys and the Terai region of Nepal. Twenty species of mollusks: Pila (2 spp.), Bellamya (3 spp.), Brotia (1sp.), Lamellidens (4 spp.), Parreysia (9 spp.), and Peludomus (1 sp.) are found in Terai which are generally consumed by ethnic people with low income. *Pupilla eurina* (Benson, 1864) was the first-ever mollusk reported from Nepal [33]. Mollusks are consumed as delicious energy food and natural collection is their only source of production [34]. The scarcity of the database on mollusk diversity in Nepal shows that many endemic species are yet to be discovered [33]. The demand for mollusks is not fulfilled by local production as it covers only 30–40% of the total demand. The remaining demand is fulfilled by importing from the neighboring country India. So, the only

Table 4: Finfish species that are allowed to culture after taking legal authority in Nepal.

Scientific name	Common name	Local name	Domain
Clarias gariepinus (Burchell, 1822)	African catfish	Mangur	Warm water
Pampus chinensis (Euphrasén, 1788)	Butter fish	Rupchanda	Warm water

Table 5: List of commercially important indigenous fin fishes (artificially bred) in Nepal.

Scientific name	Common name	Local name	Domain
Schizothorax plagiostomus (heckel, 1838)	Blunt-nosed snow trout	Bucche Asala	Cold water
Schizothoraichthys progastus (McClelland, 1839)	Point-nosed snow trout	Chuchhe Asala	Cold water
Tor putitora (F. Hamilton, 1822)	Golden Mahseer	Pahelo Sahar	Cold/Warm water
Tor tor (Hamilton, 1822)	Deep-bodied Mahseer	Falame Sahar	Cold water
Neolissochilus hexagonolepis (McClelland, 1839)	Copper Mahseer	Katle	Cold water
Labeo dero (Hamilton, 1822)	River carp	Gardi	Cold/Warm Water
Labeo pangusia (Hamilton, 1822)	River carp	Hade	Cold/Warm water
Labeo angra (Hamilton, 1822)	River carp	Thend	Cold/Warm water
Chagunius chagunio (Hamilton, 1822)	Chaguni	Rewa	Cold/Warm water
Labeo calbasu (F. Hamilton, 1822)	Calbusa	Calbusa	Cold/Warm water
Heteropneustes fossilis (Bloch, 1794)	Singhi	Singhi	Warm water

Table 6: List of ornamental finfishes in Nepal.

Scientific name	Common name
Exotic	
Carassius carassius (Linnaeus, 1758)	Goldfish
Cyprinus carpio (Linnaeus, 1758)	Koi carp
Poecilia reticulate (W. Peters, 1859)	Guppy
Xiphophorus hellerii (Heckel, 1848)	Swordtail
Xiphophorus maculatus (Günther, 1866)	Platty
Native	
Colisa lalia (F. Hamilton, 1822)	Kolisa

way forward to discourage importing is to initiate mollusk culture in Nepal. The list of mollusks species that can be promoted for rearing in Nepal is shown in Table 8. On account of crustacean species, its study has been conducted in a very limited, non-research, and non-professional manner. Commercialization production should be initiated by providing incentives to farmers in a collaborative fashion.

6.3. Aquatic Plants. Aquatic plants in aquaculture are of great importance as they absorb dissolved minerals and enrich the water with oxygen produced during photosynthesis, thus assisting in the maintenance of clean water [35]. Furthermore, submerged aquatic plants stabilize bottom sediments which reduces turbidity. So, aquatic plants are to be grown as part of aquaculture. The list of plants that can be promoted in the coming days by including them in aquaculture is presented in Table 9.

7. Practices/Systems of Fish Culture

The fish production in Nepal is all dependent on inland water resources. Fish are raised in the floating enclosure of the water bodies in the cage fish culture system [36]. It was first started in Nepal at Phewa lake in 1972 [37]. According

Table 7: Suitable local fish species that can be domesticated in the coming days in Nepal.

Scientific Name	Local Name
Garra annandalei (Hora, 1921)	Lahare
Garra gotyla (J. E. Gray, 1830)	Buduna
Botia lohachata (B. L. Chaudhuri, 1912)	Baghi
Pseudeutropius goonawaree	Jalicapoor
Bagarius yarrelli (Sykes, 1839)	Gonch
Anguilla bengalensis (J. E. Gray, 1831)	Raj bam
Monopterus cuchia (Hamilton 1822)	Andha bam
Wallago attu (Bloch & Schneider, 1801)	Buhari
Barilius bendelisis (F. Hamilton, 1807)	Faketa
Labeo dyocheilus (McClelland, 1839)	Gardi
Labeo gonius (Hamilton, 1822)	Kursa
Chitala chitala (F. Hamilton, 1822)	Mohi
Notopterus notopterus (Pallas, 1769)	Golhi
Clupisoma gaura (Hamilton, 1822)	Jalkapoor or Pottasi
Aorichtyhs oar (Hamilton, 1822)	Kanti
Aorichtyhs seenghala (Sykes, 1839)	Tengra
Ompok bimaculatus (Bloch, 1794)	Pabata
Eutropiichthys vacha (Hamilton, 1822)	Bachwa
Channa marulius (F. Hamilton, 1822)	Bhura
Channa striata (Bloch, 1793)	Saura
Mastacembelus armatus (Lacepède, 1800)	Chusi bam
Macrognathus aral (Bloch & J.G Schneider, 1801)	Gaichi

Table 8: Mollusk's species that can be promoted for rearing in Nepal.

SN	Scientific Name	Protein %
1.	*Bellamya bengalensis* (Lamarck, 1822)	57.46
2.	*Lamellidens marginalis* (Lamarck, 1819)	52.59
3.	*Pila globosa* (Swainson, 1822)	60.52

Source: [26, 30].

Table 9: Plants that can be promoted in the coming days by including them in aquaculture in Nepal.

SN	scientific name	Common name	Local name	Family	Edible parts	Protein %
1.	*Euryale ferox* Salisb.	Fox nuts/Gorgon nuts	Makhana	Nymphaeaceae	Seeds	14.5
2.	*Ipomoea aquatica* Forssk.	Water Spinach	Pani Palungo	Convolvulaceae	Almost all parts of the young plant tissue (preferred parts are tender shoot tips and younger leaves)	8.0
3.	*Neptunia oleracea* Lour.	Water Mimosa	—	Fabaceae	Young leaves, shoot tips, and young pods	6.4
4.	*Trapa bicornis* Osbeck, *T. natans* L., *T. bispinosa* Roxb	Indian water chestnut/cattrop	Singhara/ Simal Kande	Lythraceae	Fruits, seeds	3.4
5.	*Nelumbo nucifera* Gaertn	Lotus	Kamal	Nelumbonaceae	Leaves, stems, flowers, seeds, rhizome	5.0

Source: [26, 30, 32].

to the data of 2020/21, cage fish culture is carried out in 73,706 m^2 area [27]. Mainly herbivorous carps (Bighead carp and Grass carp), Silver carp, Rohu, Bhakur, Naini, and Common carp are cultured in cages [38].

Small-scale fish farms are abundantly found more than the large ones as most farmers are not trained in the improved technology. Ghol culture, cage culture, paddy cum fish culture, and trout culture are some commonly adopted fish culture systems of Nepal [39, 40]. Among these, pond fish culture is common practice for the commercial production of fish and contributes 68.30% of total fish production in Nepal [28].

Rice is the most important staple food cultivated in Nepal. Fish farming can be integrated with rice cultivation that would increase the productivity of both sectors and reduce the production cost at the same time [40]. The Department of Fisheries initiated paddy cum fish farming in Nepal in 1964 [41]. Common carp and Tilapias are examples of species being cultivated in the paddy fields of Nepal [40].

For optimum utilization of pond productivity, an integrated farming system was introduced. It combined polyculture of rearing carps in ponds with livestock like ducks, pigs, poultry, etc., and horticulture (bananas). But due to management complexities, it failed to expand to a larger scale. Rearing of high-value cold water fish, i.e., rainbow trout in raceways has not been adopted on a big scale and is an ongoing activity in intensive culture for some years. The Nepal Agriculture Research Council (NARC) has stated its intention to further develop the private aquaculture sector and enhance facilities after the successful introduction of trout aquaculture into the remote hills. By 2016, 85 private farms were present in 16 hill and mountain areas, totaling 13,161 square meters of raceway area. The output peaked at 400 metric tons of fish production [42]. In some snow-fed rivers in Nepal, ranching and open stocking of economically important cyprinids have been initiated but its viability has not been evaluated for further extension.

8. National Fish Production and Yield of Different Years

With the increment in the number of ponds and their area every year, fish production seems to be flourishing. The status of aquaculture in Nepal is at a growing stage. Although fish production is relatively low as compared to other large countries, the level of progress achieved in recent years shows promising remarks.

The production and fish yield in Nepal from the fiscal year 2010/11 to 2020/21 are shown in Figure 5. Figure 5 shows that the total fish production has increased much in these 11 years. The production was 26,941 Mt. in 2010/11 which spiked up to 73,693 Mt. in the year 2020/21. The same is the case for yield, where the yield has increased from 3,702 kg/ha to 5,319 kg/ha from the year 2010/11 to 2020/21.

This increase in pond fish productivity is a result of good management practice, training, control over fish disease, and proper manuring and feeding. The districts with maximum fish yield in 2020/21 were Bara (5800 kg/ha), Rupandehi (6799 kg/ha), Sarlahi (6506 kg/ha), Dhankuta (6000 kg/ha), and Rautahat (5798 kg/ha). Bajhang, Bhojpur, Taplejung, and Panchthar were the ones with low fish yields [27]. Figure 6 shows that the Terai region of Nepal has a higher yield than other parts of the nation. The per capita fish consumption has significantly increased to 3.11 kg in 2018/19 from 330 g in 1981/82 but this is still lower than the global per capita consumption [26].

9. Fish Market and Fish Marketing in Nepal

Different types of fish and fish products sold in Nepalese markets are live fish, dried/smoked fish, fish fillets, canned fish (department stores), vacuum-packed fish (trout fishes), and wet fish preserved in iced form from India and Nepal. Live and fresh fish are found to fetch a higher market price than the ones imported from India due to consumers' demand for native fresh fish [44]. From place to place and species to species, the prices of fish vary. Rainbow trout are sold at the rate of NRS 900–1100/kg, while Common carp, Rohu, Mrigal, Catla, and grass carp are sold at the rate of NRS 300–450/kg, and Silver carp, Bighead carp, Nile tilapia, and striped catfish are sold at NRS 200–350/kg. In Pokhara valley, sukuti (the dried fish) are sold at the rate of 1500–2000/kg, while the price of dried smoked fish ranges from NRS 3000–5000/kg [45].

In Nepal, the fish marketing system varies from place to place. Some farmers sell their fish directly from their site of production or send their produce to local markets. In some places, large intermediaries are involved in distribution. There

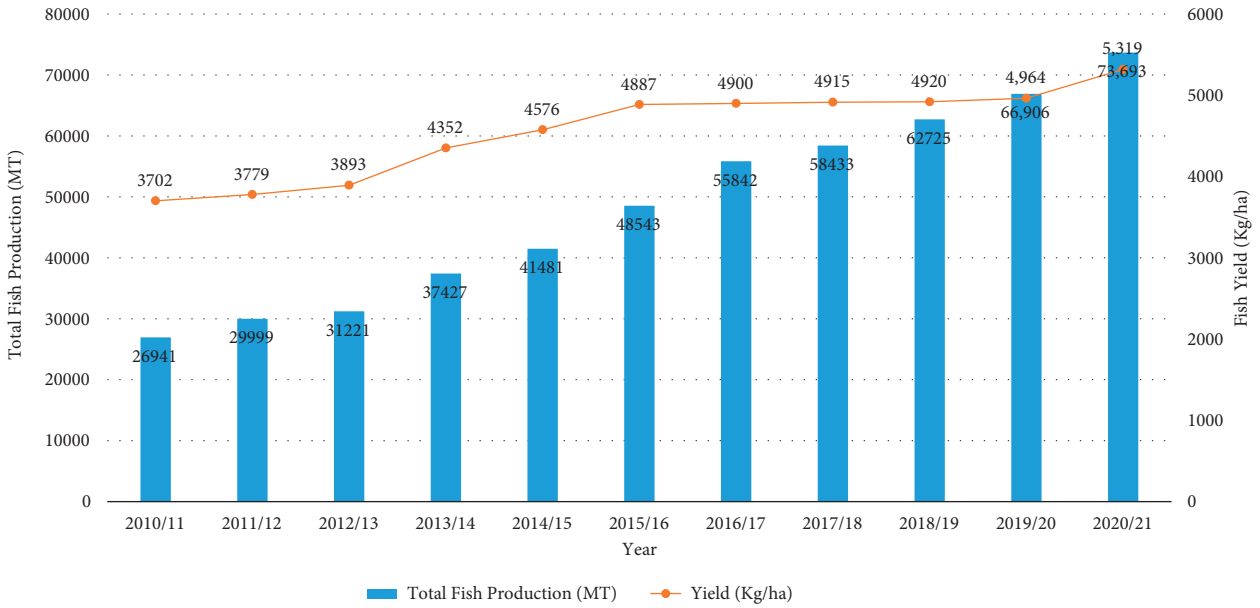

Figure 5: Total pond fish production (Mt) and fish yield (Kg/ha) from the fiscal year 2010/11 to 2020/21 in Nepal, source: [27, 28].

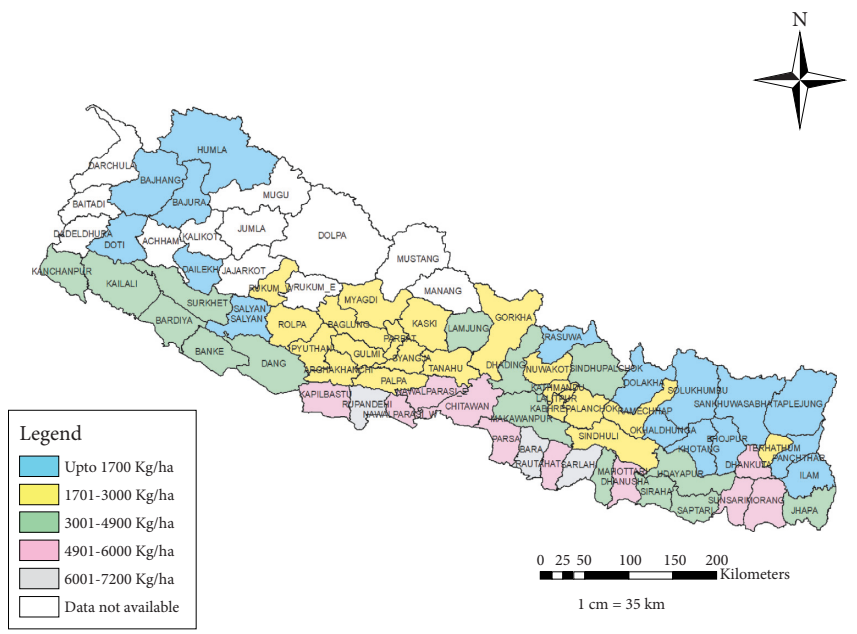

Figure 6: District-wise fish yield in Kg/ha in the fiscal year 2020/21 in Nepal, data obtained from [27]. The shapefile of Nepal required for Arc GIS was obtained from [43].

are some farmer's organizations such as Begnas Fish Entrepreneur Committee, The Rupa Lake Restoration and Fishery Cooperative Ltd., and Harpan Fewa Fish Cooperative that produce and sell through cooperatives [44]. The different marketing channels existing in Nepalese fish markets are as follows:

(1) Fish farmer- middleman/collectors/contractors- commission agents- wholesalers- retailers- consumers

(2) Fish farmer- retailers- consumers

(3) Fish farmer- middleman/collectors/contractors- retailers- consumers

(4) Fish farmer- middleman/collectors/contractors- wholesalers- retailers- consumers

(5) Fish farmer- fish cooperative/fish entrepreneur committee- consumers

(6) Fish farmer- middleman/collectors/contractors- consumers, source: [44]

10. Import and Export

Fish should be marketed as soon as possible due to its perishable nature, but it can be preserved a bit longer by

Table 10: Fish and crustaceans, mollusks, and other aquatic invertebrates' import and export value (US$) and value growth, YoY (%) in Nepal, YoY = year over year.

Year	Import value (US$)	Export value (US$)	Import value growth YoY(%)	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: [47].

chilling or deep cooling, which is also quite acceptable in the market [46]. At each level from producers to collectors/middlemen to suppliers and wholesalers to retailers and vendors, fish traders have developed and operated through organized marketing networks. In Nepal, fish traders are divided into two groups: those from Nepal and those from India. Indian traders are well established and organized, with larger fish size and consistent supply while fish from Nepal possess superiority in quality and freshness.

Nepal still imports fish to meet public demand despite being endowed with abundant water resources. The possible reasons for this could be lack of production technology and marketing infrastructures, low pricing of Indian fish, the influence of a large share of the national border with India in the South, and inappropriate marketing channels of product distribution in Nepal. As the internal production is not enough to satisfy the country's demand, import is higher than export. The trend of fish and crustaceans, mollusks, and other aquatic invertebrates' imports and exports are expressed in Table 10. In order to meet the internal demand and promote export, these problems need to be addressed in a coordinated manner.

11. Institutional Framework for Aquaculture and Fisheries Development in Nepal

After the restructuring of the entire governmental organization by the Constitution of Nepal, 2072 BS (2015 AD), the Directorate of Fisheries Development (DoFD) was changed into the Central Fisheries Promotion and Conservation Center (CFPCC) which is the commodity-specific national focal body. The illustration showing the institutional framework for aquaculture and fisheries development in Nepal is presented in Figure 7. CFPCC works under the Department of Livestock Services (DLS) which is under the Ministry of Agriculture and Livestock Development (MoALD). Central level policy issues, planning, monitoring, and supervision, in coordination with national and international fisheries- and aquaculture-related institutes are the main responsibilities and objectives of CFPCC [39]. CFPCC operates three centers in three districts of Nepal (Dhanusha, Makwanpur, and Rupandehi). Each province of Nepal has one provincial Directorate of Livestock and Fisheries Development (DLFD) to regulate development activities and maintain coordination among the local, institutional, and federal governments.

For carrying out extension programs related to aquaculture and fisheries within their respective district, there are Veterinary Hospital and Livestock Expert Centers (VHLECs) and Livestock service centers. Similarly, there are provincial Fisheries Development Centers (FDCs) for the production, distribution, technical support, and laboratory services of fish seeds (Figure 6). Agriculture and Forestry University (AFU) and Tribhuvan University (TU) are two main universities providing aquaculture and fisheries education program to students interested in studying aquaculture and fisheries sector in Nepal. Likewise, Nepal Agriculture Research Council (NARC, Fisheries Research Centers), Nepal Academy for Science and Technology (NAST), Purbanchal University, Pokhara University, Kathmandu University, and Far-Western University are also involved in the research and development of the fisheries and aquaculture sector. National Parks under the Department of National Parks and Wildlife Conservation are carrying out conservation of aquatic resources. As Nepal has only a few handfuls of expertise in the fisheries and aquaculture sector, there is a dire need for an increase in the number of extension workers, technicians, and researchers to use the maximum potential of natural resources [48].

12. Fisheries Development Program under the Prime Minister's Agriculture Modernization Project (PMAMP)

With a clear roadmap to increase the production and productivity of the agricultural sector through the delivery of necessary technology, materials, and mechanization for agricultural production, processing, and marketing, the Prime Minister's Agriculture Modernization Project (PMAMP) was launched to help the 20-year Agriculture Development Strategy (ADS) [50]. It is the largest existing project of 10 long years under the Ministry of Agriculture and Livestock Development that started in the fiscal year 2016/17. The four components of this project are pocket, block, zone, and super zone. Super zones comprise commercial areas of more than 1,000 ha, zones over 500 ha, blocks over 50 ha, and pockets over 10 ha [29]. This project

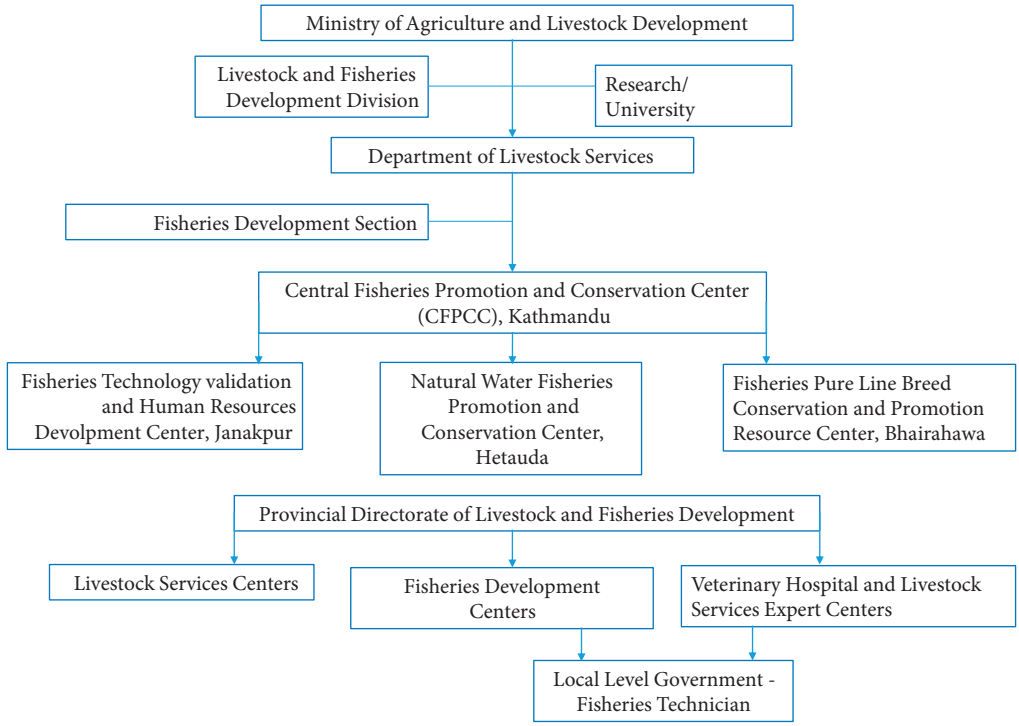

Figure 7: Institutional framework for aquaculture and fisheries development in Nepal, source: [48, 49].

considers the fisheries as a rapidly growing commodity and adopts a problem and demand-based program for suitable and feasible areas [51]. The details of the operating super zone and zone under the PMAMP project for fisheries development are shown in Figure 8. Dhanusha, Bara, and Rupandehi districts are fish super zones whereas Morang, Sunsari, Mahottari, Kapilbastu, Siraha, and Bardiya districts are the fish zones. There are several blocks and pocket areas across the country working under government support to induce fish commercialization. Through the grant assistance, this project helps in the construction, maintenance, and repairing of ponds, fisheries hatchery establishment, technical, laboratory support, and other various programs to support fish farmers. In the fiscal year 2019/20, with grant assistance from the project implementation unit, the construction of a 242 ha new pond and the maintenance of a 46 ha old pond was done [53]. Out of the entire national fish production (62,725 Mt.) in 2018/19, 43.60% (27,351 Mt.) was from the project implementation area [54].

13. Human Resources Involved in Aquaculture and Employment Generation

Globally fisheries and aquaculture, a crucial sector of the world economy, is responsible for sustaining the livelihood of millions of people by generating employment in the fishing, processing, transport, retailing, boat and net manufacturing industry [55]. Likewise, aquaculture is also aiding the nation's economy by employing thousands of individuals in Nepal. It has been estimated that about 122,772 people are employed directly and indirectly in the aquaculture sector of Nepal. Among them, 40,499 are female with 33% of involvement, whereas males cover 67% as shown in Figure 9(a). About 462,067 individuals depend on captured fisheries for their livelihood. More females are involved in capture fisheries in contrast to aquaculture as shown in Figure 9(b). Females account for 60% of the population participating in capture fisheries, while only 40% are males (Figure 9(b)) [46].

Since Nepal is an ethnically and culturally diverse country, people of different ethnic groups contribute to the aquaculture and fisheries sector of the nation as presented in Table 11. The Tharu community includes the highest number of individuals engaged in fish farming with 6.56% of the total population employed under it. Following the Tharu community are other caste groups such as Mushar, Pasi, Dalit, Mallah, Kewat, Kumal, Danuwars, Majhis, Bantar, Dhangar, Darai, Kachhare, Bote, and Barhamus. Some other unidentified ethnic groups of 1.02% are also involved in the occupation.

14. Opportunities and Future Prospects of Aquaculture in Nepal

The suitable climate, soil, and a huge number of underutilized water resources provide a good habitat for fish in Nepal [57]. Aquaculture and fisheries not only increase employment opportunities but also add nutrition such as protein, vitamin D, and omega-3 fatty acids into the diet of people. Both men and women can collaboratively participate in this farming and can run a family business. Demand increments, water availability, women empowerment, byproducts, and improved technologies are some of the opportunities and prospects for fish production in Nepal.

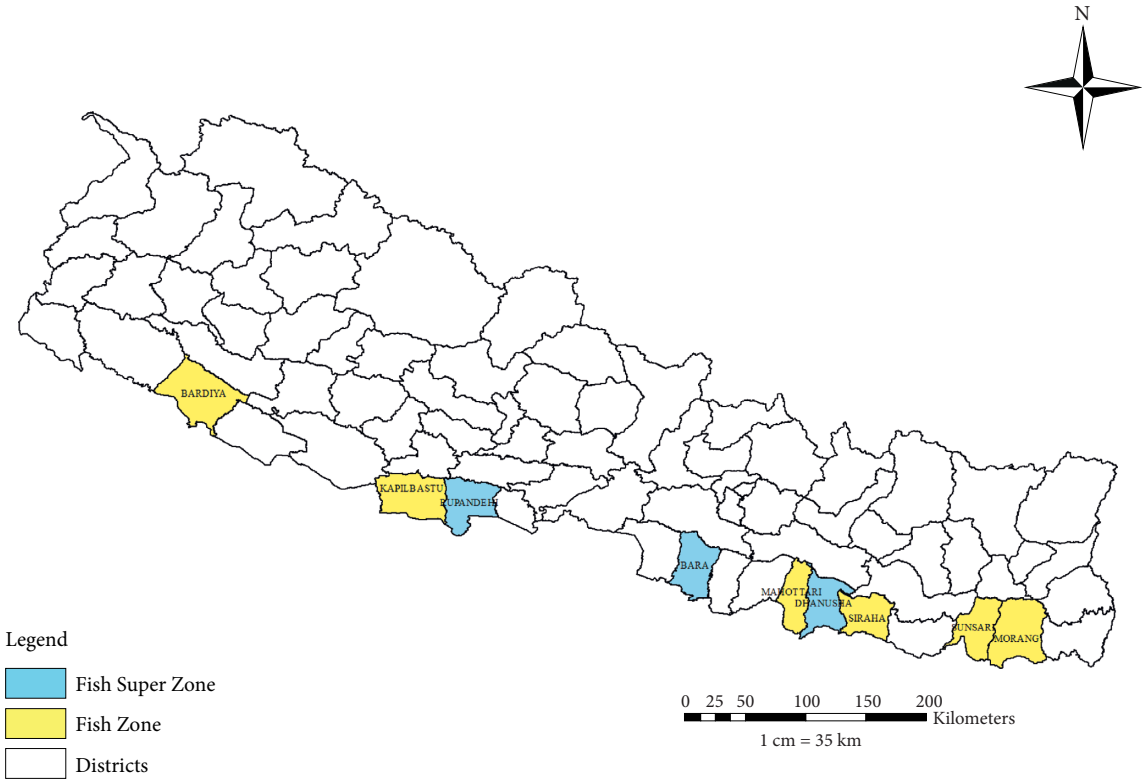

Figure 8: Map of Nepal showing fish super zone and fish zone. Map prepared from data available at [52].

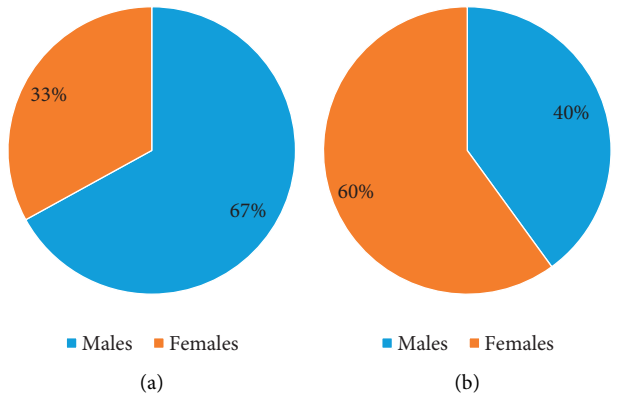

Figure 9: (a) Percentage of the male and female population involved in aquaculture in Nepal. (b) percentage of the male and female population involved in capture fisheries in Nepal, source: [25].

14.1. Increasing Demand. The global food fish market is experiencing an increasing trend in the demand of production. According to the report by FAO, it is speculated that by 2030, aquaculture will have 62% of all fish food production [58]. Nepal can strengthen its economy by taking advantage of this growing demand.

14.2. Contribution to GDP. In the case of Nepal, the contribution of captured fisheries to the nation's GDP adds up to 0.5% [59] whereas it contributes approximately 2.47% to agricultural GDP [8]. This number might appear quite trivial but holds huge potential due to its annual growth rate of 8-9% [60].

14.3. Availability of Water Resources. The rich water resources of Nepal, which include about 225 billion m^3 per annum of surface water, provide immense opportunities for the fish farming sector within the country [61]. Water bodies such as rivers, lakes, reservoirs, irrigated paddy fields, and swamps/ditches are suitable for the cultivation of captured fisheries. These water bodies make for an annual production of 16,700 metric tons of captured

Table 11: Ethnic groups involved in traditional fish farming with their populations and population percentage in Nepal.

SN	Ethnic/Caste groups	Population	Percentage of the total population
1	Tharu (Rana/Dangaura)	1,737,470	6.56
2	Mushar	234,490	0.89
3	Dusadh/Paswan/Pasi	208,910	0.79
4	Dalit/unidentified Dalit	201,358	0.76
5	Mallah	173,261	0.65
6	Kewat	153,772	0.58
7	Kumal	121,196	0.46
8	Danuwars	84,115	0.32
9	Majhis	83,727	0.32
10	Bantar	55,104	0.21
11	Dhangar/Jhagar	37,424	0.14
12	Darai	16,789	0.06
13	Kachhare Pahari	13,615	0.05
14	Bote	10,397	0.04
15	Barhamus/Baramu	8,140	0.03
16	Unidentified caste/ethnic group	270,244	1.02
	Total	**3,410,012**	**12.87**

Source: [56].

Table 12: Uses derived from fish byproducts along with the nutrient obtained from them.

SN	Fish byproducts	Nutrient content	Uses	References
1.	Fish meal	(i) High levels of lysine, methionine and cysteine (ii) Rich in minerals like ca, P, Cu and Fe (iii) Good source of vitamin B12, chlorine, niacin, pantothenic acidv and riboflavin	(i) Livestock feed (ii) Fish and shrimp feed	[65]
2.	Fish liver oil	Vitamins A and D	Therapeutic purposes in treatment of vitamin A and D deficiencies	[65]
3.	Fish body oil	Polyunsaturated fatty acids (PUFA), particularly η3 PUFA	(i) Control of heart ailments in humans (ii) Suitable as oil for diesel engine	[65] [66]
4.	Fish silage		Cattle feed	[65]
5.	Fish protein concentrate (FPC)	Fat content up to 3%	Protein supplement in human diet	[65]
6.	Chitin		(i) Growth promoter in animals and birds (ii) Feed ingredient (iii) Use of chitosan as natural flavouring material	[65]
7.	Prawn head meal and shell waste	Protein, Minerals and Chitin	Natural flavouring material	[65]
8.	Fish skin		To obtain collagen and gelatine	[67]
9.	Fish bone	Ca	(i) Important for bone health and, in combination with vitamin D (ii) Improves cardiac health along with a number of diseases including gastrointestinal diseases, diabetes, and hypertension	[67]
10.	Enzymes from fish viscera	Pepsin, trypsin, chymotrypsin, and Elastase	(i) Production of bioactive components in a large scale (ii) Production of fish protein hydrolysate and fish roe, fish sauce (iii) Enzymatic removal of fish skin (iv) As pearl essence	[67]

fisheries [62]. Improvement in the trade and market aspect and topography suitable technology can boost production [11]. Nepal can channel huge profits by making maximum use of these naturally available resources.

14.4. Means of Women Empowerment. In 2017, 60% of the total individuals involved in subsistence captured fisheries belong to the female demographic (Figure 9(b)). In such a scenario, the government can introduce fisheries-related programs and training targeted toward women's empowerment.

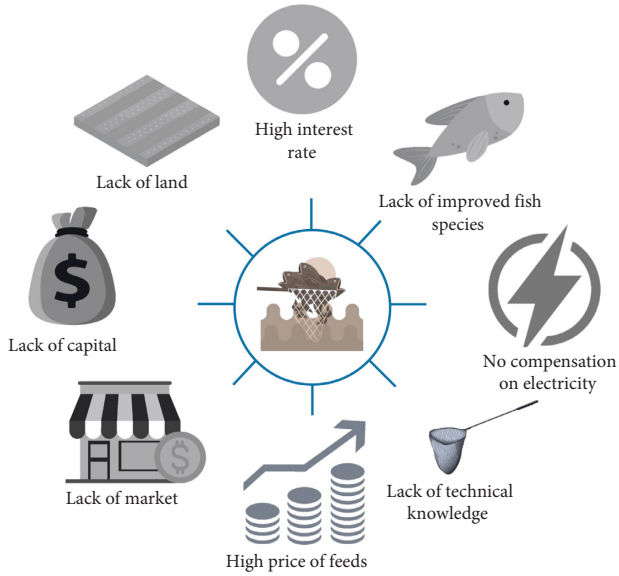

Figure 10: Major problems faced by fish farmers in Nepal.

Table 13: SWOT analysis of production and marketing of fish in Nepal.

	Strength	Weakness
Production	Agricultural family background, rising demands, higher yield, governmental backing and augmentation, easy and profitable, and favorable climatic and environmental condition	Difficulty in pond construction due to topographical constraints, lack of adoption of modern production technology, improper knowledge of fish cultivation among fish farmers, and undesirable quality of seeds
Management	High profit and prospects, involvement of more traders, middlemen, contractors, and sellers competitive market structure for the fish industry, low entry barriers	Seasonal price fluctuation, lack of postharvest storage facilities in rural areas, unsystematic and unorganized marketing channel and poor distribution network, and middlemen engagement in a faulty and inefficient way
	Opportunity	Threats
Production	Greater scope of expansion of the number of ponds, self-employment generation, and increase in supply-demand gap fish in Nepal	Climate change and global warming, increase in the price of inputs, restricted money limit of ranchers, and lack of youth's involvement in aquaculture
Management	Growing local and central markets, high demand for healthy and fresh fish	Inconsistent import-export quality, intense competition with the Indian market, improper government regulation and market management

Source: [57].

14.5. Use of Fish Byproducts. Fish byproducts or fish waste can be a good source of nutrients from fishes that have landed bycatch or those with less meat value, high quantity of fat, repulsive color, aroma, or unappetizing taste [63]. Low-cost processed and refined byproducts, such as fish-meal, fish oil, fish silage, fish protein concentrate (FPC), Prawn head meal and shell waste, and Chitin, help to add an extra source of income [64]. The uses obtained from various fish byproducts are presented in Table 12.

14.6. Improving Technology. Organizations like Central Fisheries Promotion and Conservation Center (CFPCC) and Nepal Agricultural Research Council (NARC) are working on various research studies to introduce innovative topography and farmers-suitable technologies in the aquaculture and fisheries sector with the aim of uplifting the livelihood of poverty-stricken rural areas [68]. The use of the Chinese model for polyculture fish farming in the Terai region is a good example of a successful adaptation of technology that has gathered a good response due to the integration of various food chains [69]. Biofloc is another promising technique. Farmers in Chitwan, Kathmandu, and Biratnagar have been able to garner profit through its successful implementation [70].

15. Challenges in the Aquaculture and Fisheries Sector

The results obtained from Fisheries Survey 2015 by [71] on major problem in fish farming are shown in figure 10. The majority of fish farmers reported lack of capital and poor scientific knowledge as the leading problems. The dominant challenges to the sustainable development of fisheries include poor technological implementations, lack

of infrastructures like transportation, land, and lack of timely supply of quality fish feed and fingerlings (Figure 10). In the intensive fish culture in Nepal, the incidence of the disease is higher [72]. And the major causes for the frequent occurrence of diseases in fish and the failure of commercial value aquaculture are poor management, unhygienic practices of fish farming, and lack of skilled and experienced manpower [73]. The lack of research on behavior, propagation, population dynamics, and biology of indigenous species which can be of great importance, commercially and economically, is another bottleneck of the Nepalese aquaculture and fishery system [46]. Indiscriminate use of antibiotics for fish growth is another wing to look out for [74]. On the local level, there are poor postharvest facilities with social problems like poaching and poisoning [32].

16. SWOT (Strengths, Weaknesses, Opportunities, and Threats) Analysis of Production and Marketing of Fish in Nepal

SWOT analysis is a powerful tool used in organizations for planning and managing strategically and concluding the capability and disability of the organization [75]. Strength and opportunities can be defined as enhancers whereas weakness and threats as inhibitors for desired performance [76]. SWOT analysis helps in considering better alternative solutions. The SWOT analysis of the production and marketing of fish in Nepal is shown in Table 13. In accordance with this, policymakers, researchers, and aquaculture agencies should focus on weaknesses and threats while designing a plan for sustainable production and marketing of fish and its products.

17. Conclusion

Nepal is a country with huge potential for aquaculture and fisheries production. The aquaculture and fisheries sector of Nepal, with its promising status and ever-evolving development trends, has shown satisfactory improvement in these recent years, mainly due to projects such as the fisheries development program under PMAMP. The production scenario is still at a critical phase as the concerned bodies are yet to explore the vast opportunities presented by these sectors and their undeniably prosperous future. A multitude of natural water resources paired with a diverse aquatic ecosystem is a boon to the Nepalese economy that has the immense capability of drawing huge profits through the aquaculture and fisheries sector. The abundant human resources available, especially in the rural areas, can work in favor of the goal of increasing the production that meets the internal demand and hopefully broadens the possibilities of export as well. Such a profit-guaranteed sector has not garnered mainstream attention since various drawbacks have halted the development trends. Nepal's present aquaculture condition may be improved with a long-term sustainable strategy, scientific and technological research on indigenous fish species, adequate hygiene management, and better disease control.

Thus, the authors suggest that researchers should direct their studies toward topography suitable aquaculture technologies that can be easily adopted by Nepalese farmers. More preference should be given to local level farmers in the marketing and distributing stage. And, the collaborative approach of the government in coordination with local farmers must be promoted to tackle the problems.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors have no conflicts of interest to disclose.

Authors' Contributions

Each author made a remarkable contribution to every step of manuscript preparation. The final manuscript is read and approved by all the authors.

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