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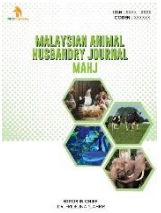

RESEARCH ARTICLE

TREND AND GROWTH RATE ANALYSIS OF POND NUMBER, WATER SURFACE AREA, PRODUCTION AND PRODUCTIVITY OF FISH FARMING IN BARA DISTRICT, NEPAL

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ABSTRACT

Eastern terai of Nepal carries a great potential for fish farming. A study was conducted to assess the trend of pond number, water surface area, production, and productivity of fish in Bara district. For the study secondary data were collected from "Statistical Information on Nepalese Agriculture" published yearly by MoALD from 1999/2000 to 2018/19. Microsoft Excel program and XLSTAT, add in for Ms. Excel were used for analysis of data. Mann-Kendall test and Sen's slope method were used for identifying and quantifying the trends. Inferences from Mann-Kendall test concludes that the monotonic trend is present in pond number, water surface area, production and productivity at 95% level of significant. Pond number, water surface area, production, and productivity had jumped by 266.98%, 343.05%, 662%, and 72.01% respectively during the study period. The result from Sen's slope showed that the number of ponds, water surface area, production, and productivity were increasing at the rate of 179.15 ponds per year, 57.823 ha per year, 360602.94 kg per year and 144.667 kg/ha per year respectively. Annual growth indicate that highest annual growth rate for all variable occurs in 2011/12. Compound Annual Growth Rare indicate growth rate of production (10.69%) was highest followed by water surface area (7.73%) and growth rate for productivity (2.74%) was lowest. The district have basic infrastructure for fish farming and the findings from this study will aid in policy formulation and program implementation for strengthening production and marketing strategies of fish in Bara.

KEYWORDS

Mann-Kendall, Status, Fish Production, Trend, Bara

1. INTRODUCTION

Nepal is a landlocked country, deprived of any oceanic resource and 83% of the total area of the country is occupied by mountainous topography. About 3 percentage area of Nepal is covered with water and 500,000 ha of this area is available for fish farming (Shrestha, 1999). The abundant availability of water resource from the himalaya, monsoon rainfall, different freshwater habitat and suitable agro-climatic condition makes the eastern terai of Nepal potential for different fisheries and aquaculture activities (Budathoki and Sapkota, 2018). Carp can adapt to temperature from 4ºC to 35ºC (Amin and Khan, 2016). The optimum temperature for the growth of the most carp is between 28ºC to 32ºC (Bhatnagar and Singh, 2010). Bara is an eastern Terai district with total area of 1190 square kilometer located between altitude of 152 m to 915 m above sea level with geographical and climatic diversity suitable for fish farming. The district is famous for its hot and humid climate which is suitable to produce warm water fish species. There are 4290 fishponds in Bara which is 9.33% of total fish pond of Nepal, producing 7886 mt which is 12.57% of the total fish production of Nepal from pond fish culture (CFPCC, 2018/19). The average pond size of Bara 0.32 ha. The productivity for pond fish culture in the Bara district is 5298 kg/ha which is slightly above national productivity, which is 4920 kg/ha (CFPCC, 2018/19).

The rate of increase in the demand for the fish is greater than the rate of increase in fish production in Nepal (Kafle, 2016). To fill the gap between demand and production a lot of fish is being imported from neighboring countries (Ranjan, 2019). About 10957.3 mt of table fish is imported in Nepal with an estimated price of NRs. 1,935,728,000 and the estimated price for exported fish was NRs. 13,096,000 which is very low compared to that of import (Ranjan, 2019). Apart from this, the food poverty of Nepal is 27.6 % and there is a prevalent of 37.4 % stunting, 30.1 % underweight, 11.3 % wasting and 18.1 % women with low BMI (ADS, 2015). 29.9% of the total population of Bara are living below the poverty line which is higher than the national average (Sapkota, 2013). Aquaculture plays a great effort on food security and poverty alleviation than any other crops in developing countries (Ahmed and Lorica, 2002). Groundwater resources and suitable climatic condition favors eastern terai region to be developed as fishery hub of the country. With technological adoption, fisheries can play a significant role to alleviate poverty in Bara.

Although the fish production activities exhibited a very positive growth, overall productivity had not been satisfactory (Budathoki and Sapkota, 2018). Despite the tremendous potential for fish production in Bara District and continuous effort from governmental and non-governmental sectors, farmers are facing the production constraints. The predominant reason is lack of optimum use of resources. Resources like fry and fingerlings, feed, fertilizer, lime and medicine are being under used in Bara (Adhikari et al., 2019). In addition to this, timely unavailability of inputs, frequently occurring fish diseases, lack of refrigeration facilities and efficient marketing channels are problems faced by fish farmers of Bara

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district (Bhandari et al., 2021). The temporal growth in pond number, water surface area, production and productivity in Bara has not been assessed and short and long-term plans are prepared based on limited information, and as a consequence, governmental and non-governmental bodies are being hindered in formulating relevant policies, plan and implementation of the interventions.

Bara is the major fish producing district of Nepal with great possibilities for further expansion. Understanding the temporal variation in the fish production is imperative for aiding effective policy formulation for short-term and long-term plans to fuel up the fish production. It is of utmost requirement to identify the periods when growth has been inadequate and further study on the respective government policies and programs. However, no any studies had been conducted for temporal analysis of pond number, water surface area, production and productivity of fishery sub-sector of Bara district, despite its major role in household economy. Inadequate study on the trend and growth rate of pond number, water surface area, production and productivity of fish in Bara has obstruct the policy makers to develop effective policies and plans for augmenting the fish production. Therefore, this study was conducted with a view to analyze trends in fish pond number, water surface area, fish production, productivity and growth pattern of fish subsector in Bara District over the past 20 years and generate useful information for policy makers, governmental bodies, researchers and student.

2. Materials and Methods

2.1 Study Site

The site of the study was Bara District, Nepal. The district was selected for the study based on data availability, popularity for fish production in Nepal and preferred by government and non-governmental organization for implementing fishery related projects. The study was conducted from April 2020 to July 2020.

2.2 Data Type and Collection

The time series secondary data on pond number, water surface area, total production, and total fish productivity of 20 years from 1999/00 to 2018/19 were extracted from "Statistical Information on Nepalese Agriculture" published by the Ministry of Agriculture and Livestock Development of Nepal. Information about the fish subsector of the district was collected from Prime Minister Modernization Project Fish Superzone, Bara, journal articles and authentic websites.

2.3 Data Analysis Techniques

2.3.1 Trend Analysis

Trend analysis is the widespread practice of collecting information and attempting to spot a pattern. It is based on the idea that what has happened in the past and gives an idea of what will happen in the future. Of the several statistical techniques available for the trend analysis Mann-Kendall test and Sen's slope method was selected for this study according to its feasibility for the data analysis. Mann-Kendall test is a statistical test initially developed (Mann, 1945; Kendall, 1975). Being a nonparametric test it works for all distribution. The Mann-Kendall test determine whether a given time series data has a monotonic upward or downward trend. It is a robust test for data which doesn't have any kind of distribution. The null hypothesis for this test is that there is no monotonic trend in the series. The alternate hypothesis is that a trend exist in the series. The trend can be positive, negative, or non-null. The Mann-Kendall test begin with arranging the data collected over the period of time in ascending order i.e. from earlier time period of time to later period of time. Then all the possible differences for a data set are calculated in which data of the earlier period are subtracted from later period viz.

$$x_j - x_i \quad (1)$$

Where j>i such that, x_j represent data from later period and x_i represent data from earlier time. So, all together n (n-1)/2 number of possible differences will be determined for "n" amount of data. Sign of n (n-1)/2 number of possible is determined as:

$$sign(x_j - x_i) = \begin{pmatrix} 1, & (x_j - x_i) > 1 \\ 0, & (x_j - x_i) = 0 \\ -1, & (x_j - x_i) < 1 \end{pmatrix} \quad (2)$$

Where each term carry usual meaning. Mann Kendall test is based on Mann Kendall Statistics "S". The "S" value is calculated as:

$$S = \sum_{j=1}^{n} \sum_{i=1+1}^{n} sign(x_j - x_i) \quad (3)$$

"S" is the sum of all the positive and negative differences. "S" is discriminated by unit value or zero, it doesn't account for the actual difference between the two data. If $S > 0$ then later observations in the time series tend to be larger than those that appear earlier in the time series and if $S < 0$, then later observation in the time series tend to be smaller. So, Mann-Kendall test is a nonparametric statistical test.

The variance of S is given by;

$$var = \frac{1}{18}[n(n-1)(2n+5) - \sum_t f_t(f_t - 1)(2f_t + 5)] \quad (4)$$

Where n is the number of time series observation, t is number of tie and f_t is the frequency of tie.

The Mann-Kendall Test uses the following test statistic:

$$z = \begin{cases} \frac{S-1}{se}, & S > 0 \\ 0, & S = 0 \\ \frac{S+1}{se}, & S < 0 \end{cases} \quad (5)$$

Where *se* = the square root of variance of S. For time series with more than 10 elements, Z has a standard normal distribution. The calculated value of Z can be compared to standard normal cumulative distribution probabilities to test the null hypothesis of no trend. If the Z value is positive the trend is increasing and if the Z value is negative trend is concluded decreasing. In this study p-value was used to determine the presence of monotonic trend in the given set of data. The p-value greater than 5% level of significance (p>0.05) suggest accepting null hypothesis i.e. absence of monotonic trend in the data and p-value less than 5% level of significance (p<0.05) conclude failure to accept the null hypothesis i.e. presence of monotonic trend in the data.

The Kendall's correlation coefficient (τ) is calculated as:

$$\tau = \frac{2S}{n(n-1)} \quad (6)$$

Where "S" is Mann-Kendall statistics. Kendall correlation coefficient is a non-parametric measure of strength and direction of association between two variables. It takes the value between -1 to +1. The absolute value of the Kendall's coefficient indicates the strength of association between two variable and the sign of the coefficient indicate the direction of association between two variables.

Mann-Kendall's tests give conclusion about the significance of trend, strength of association and direction of association between two variables. For this study, association of pond number, water surface area, production and productivity with time is calculated individually. Sen's slope talks about the magnitude of trend. Sen's slope is the non- parametric estimate of the slope, as the slope is based on the median. Sen's slope is defined as:

$$Sen's\ slope = Median\left\{\frac{x_j - x_i}{j-i}, i < j\right\} \quad (7)$$

As n (n-1)/2 difference calculated in the Mann-Kendall test, n(n-1)/2 slopes are computed in Sen's slope method. By arranging these slopes in the ascending order median of all the slope is calculated. The calculated median is the Sen's slope.

The intercept was computed according to Sen's method for each time step t as:

$$\alpha_t = Y_t - \beta t \quad (8)$$

The value of intercept is the median of all intercepts computed. From the value of the Sen's slope and intercept an equation of straight line is derived. The positive Sen's slope value indicates increasing trend and the negative value indicate decreasing trend. The regression line was plotted based on the Sen's slope and intercept to visualize the trend.

2.3.2 Annual Growth Rate

Annual Growth Rate for quantifying the percentage change in pond number, water surface area, production and productivity from previous year was calculated using following formula.

$$Annual\ Growth\ Rate = \frac{Value\ in\ Year\ A - Value\ in\ Year\ (A-1)}{Value\ in\ Year\ (A-1)} \times 100\%$$

2.3.3 Compound Annual Growth Rate

Compound Annual Growth Rate for pond number, water surface area, production and productivity was calculated using following formula assuming linear trend.

$$Compound\ Annual\ Growth\ Rate\ (CAGR) = \left(\frac{Final\ Value^{\frac{1}{Years}}}{Initial\ Value} - 1\right) \times 100\%$$

3. Result and Discussion

3.1 Trend analysis of pond number, water surface area, production and productivity

3.1.1 Pond Number

The pond number has increased from 1169 ponds in 1999/00 to 4290 in 2018/19 with an increase in 266.98% over twenty years. The presence of monotonic trend in pond number from 1999/00 to 2018/19 has been detected ($p<0.0001$) within 95% level of significant. The Kendall's tau value of 0.979 indicate the trend is increasing and there is strong correlation between time and pond number i.e., with time the increase in pond number is significant. This can be explained by the value of the Sen.'s slope in (Table 1) which indicate that the number of ponds had increased at the rate of 179.15 pond per year.

3.1.2 Water surface area

The water surface area has increased from 336ha in 1999/00 to 1488.67ha in 2018/19 with an increase in 343.05% over the period of twenty years. There is the presence of monotonic trend ($p<0.0001$) and the trend is increasing over time (tau=0.989) within 95% of significant level. Also, Kendell's tau value figure out the strong correlation between area and time. The water surface area is increasing at the rate of 57.823 ha per year which can be figure out through the value of Sen's slope (Table 1).

3.1.3 Fish Production

The fish production has increased from 1035000kg in 1999/00 to 7886702 kg in 2018/19 with an increase in 662% over the period of twenty years. The total fish production has slightly decrease in the year 2000/01 this causes the productivity to decrease in 2000/01 but production again increase from the preceding years. The increasing trend of fish production ($p<0.0001$ and tau=0.974) is found significant at 95% of significant level. Kendall's tau value also indicates the strong correlation between time and production. This in turn is supported by the Sen's slope value (Table 1) which indicate production is increasing at the rate of 3606002.94 kg per year.

3.1.4 Productivity

The productivity has increased from 3080kg/ha in 1999/00 to 5298 kg/ha with an increase in 72.01% over the period of eighteen years. The productivity has decrease in the year 2000/01 but increase from 2002/03 to 2008/09. The productivity again decreases in year 2008/09 and increases from 2010/11 to 2012/13 where it again decreases in 2013/14 and increase onwards. The annual average fish productivity over the period was found to be 4286.15 kg/ha. There is strong correlation between productivity and time (tau=0.790). The value of the Sen's slope in Table 1 indicate productivity increased at the rate of 144.667kg/ha per year.

Table 1: Results of Mann-Kendall and Sen's Slope for Fish Production in Bara

Parameters	p-Value	Kendall's Tau	Sen's Slope	Trend	Significant	Alpha
Pond Number	<0.0001	0.979	179.15	Increasing	Significant	0.05
Water Surface Area (ha)	<0.0001	0.989	57.823	Increasing	Significant	0.05
Production (kg)	<0.0001	0.974	360602.94	Increasing	Significant	0.05
Productivity (kg/ha)	<0.0001	0.790	144.67	Increasing	Significant	0.05

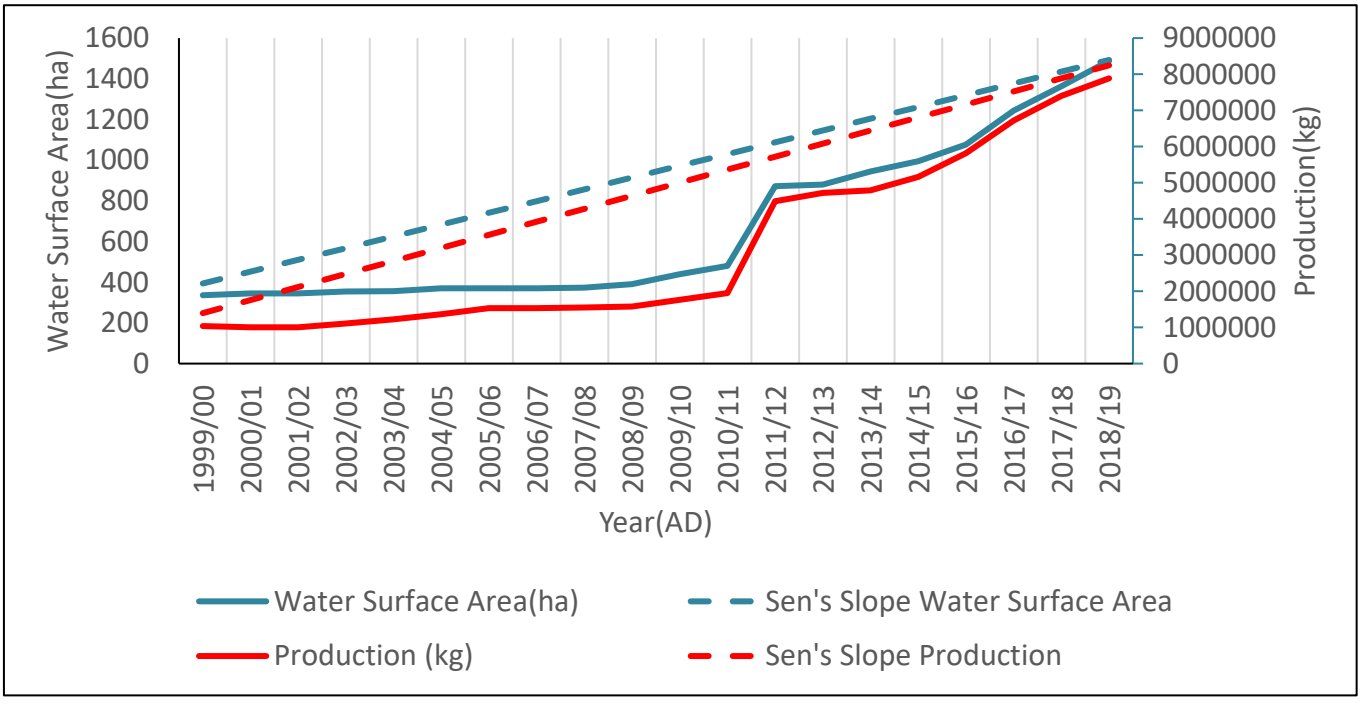

Figure 1: Trend of Water Surface Area and Production of fish in Bara

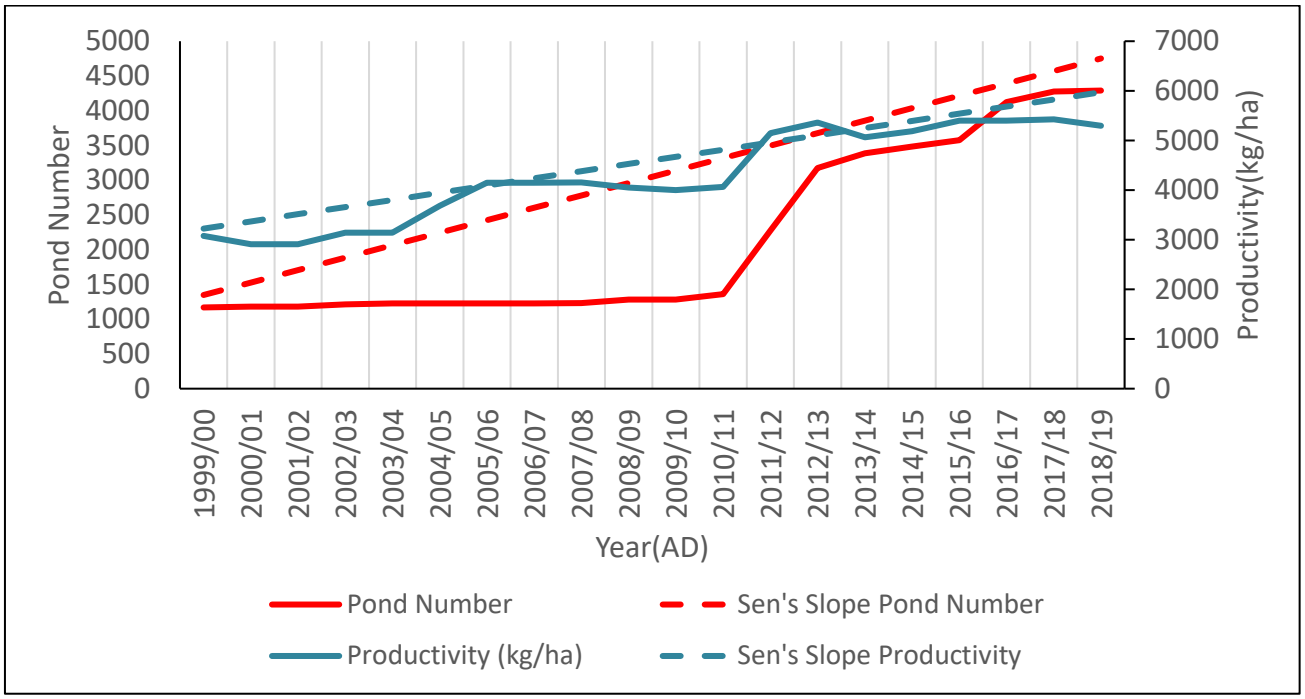

Figure 2: Trend of pond number and productivity of fish in Bara

3.2 Growth rate

3.2.1 Annual growth rate

Table 2: Change from Previous Year Expressed in Percentage

Year (AD)	Pond Number	Annual change in pond number (%)	Water Surface Area (ha)	Annual change in water surface area (%)	Production (kg)	Annual change in production (Kg)	Productivity (kg/ha)	Annual change in productivity (%)
1999/00	1169		336		1035000		3080	
2000/01	1180	0.94	345	2.67	1004000	-2.99	2910	-5.52
2001/02	1180	0	345	0	1004000	0	2910	0
2002/03	1213	2.79	354	2.6	1112000	10.75	3141	7.93
2003/04	1225	0.98	356	0.56	1222000	9.89	3141	0
2004/05	1225	0	370	3.93	1362900	11.53	3684	17.29
2005/06	1225	0	370	0	1534500	12.59	4147	12.57
2006/07	1225	0	370	0	1534500	0	4147	0
2007/08	1230	0.40	373	0.81	1550500	1.04	4157	0.24
2008/09	1280	4.06	390	4.55	1576500	1.67	4052	-2.53
2009/10	1280	0	440	12.82	1760000	11.64	4000	-1.28
2010/11	1360	6.25	480	9.09	1950000	10.79	4063	1.57
2011/12	2276	67.35	872	81.66	4488000	130.15	5147	26.68
2012/13	3176	39.54	880	0.91	4717900	5.12	5361	4.15
2013/14	3385	6.58	945	7.38	4785703	1.43	5064	-5.54
2014/15	3485	2.95	995	5.29	5163560	7.89	5190	2.48
2015/16	3576	2.61	1077.3	8.27	5819314	12.7	5402	4.08
2016/17	4126	15.38	1243	15.37	6717846	15.44	5403	0.020
2017/18	4275	3.61	1363.7	9.70	7399909	10.15	5426	0.42
2018/19	4290	0.35	1488.67	9.16	7886702	6.57	5298	-2.41

From table we can observe some major change. In 2000/01 slow progress can be observe in case of pond number and water surface area and decrease in production and productivity. In 2004/05 there is no change in pond number but increase in area can be observed, this may be due expansion of previously constructed pond or this may be result of failure of some pond but construction of same number of ponds with larger area. In 2005/06 there is significant increase in production and productivity without change in pond and water surface area. Rapid expansion in all of the variable takes place in 2011/12 with 67.32% increase in pond number, 81.66% increase in water surface area, 130.15% increase in production and 26.68% increase in productivity. In 2012/13 pond number have increased by 39.54%. Similarly in 2016/17, there is significant increase in pond number by 15.38% and water surface area by 15.37%.

3.2.2 Compound Annual Growth Rate (CAGR)

This study considered the linear model of growth for Pond Number, Water Surface Area, Production, Productivity and calculated the compound annual growth rate for a period of 19 years from 1999/00 A.D. to 2018/19 A.D. which were found to be 6.71%, 7.73% and 10.69% and 2.74% respectively. The compound growth rates for different periods are presented in Table 2 below.

Table 3: Compound Annual Growth Rates (CAGR) of Pond Number, Water Surface Area, Production and Productivity for different Periods				
	Pond Number	**Water Surface Area**	**Production**	**Productivity**
1999/00-2001/02	0.31%	0.88%	-2.99%	-1.87%
2002/03-2006/07	0.19%	0.88%	6.65%	5.71%
2007/08-2009/10	1.33%	5.66%	4.31%	-1.28%
2010/11-2012/13	32.67%	25.99%	34.24%	9.68%
2013/14-2015/16	1.83%	4.46%	6.75%	2.13%
2016/17-2018/19	1.30%	6.19%	5.55%	-0.61%
1999/00-2018/19	6.71%	7.73%	10.69%	2.74%

Further the period of 20 years is break down on the basis of the periodical plan in Nepal as most of development activities are undertaken through these plans. Although the data doesn't cover the whole 8th plan, yet it covers 9th, 10th, 11th, 12th and 14th plan. On observing the compound annual growth rate, the period of 2010/11-2012/13 seems most productive in case of growth of fishery sub-sector with growth of 32.67% in pond number, 25.99% in water surface area, 34.24% in production and 9.68% in productive. This period can be correlated with the 11th three-year plan of Nepal. Further, the growth of fishery sub-sector after the 11th three-year plan shows positive growth.

3.3 Fish among Other Agricultural Commodities

Although fish farming is less labor intensive, more productive and highly profitable then cereal crop production, cereal crop occupies more important place than fisheries in Bara (Table 3). The area for the fish farming is very low compared to other commodity yet Bara is highest fish producing district of Nepal with total production of 6717846kg (MoAD, 2073/74).

Table 4: Area, production and productivity of different agricultural commodity in Bara district			
Commodity	**Area (ha)**	**Production (mt)**	**Productivity (mt/ha)**
Fish	1,363.67	7,399.909	5.426
Cereal Crops	98,720	367,387	3.722
Oilseed	2,079	2,428	1.168
Potato	7,010	133,151	18.995
Sugarcane	2,790	121,525	43.559
Spices	646	4,607	7.13
Pulses	15,651	19,386	1.239
Summer Fruit	2,239	23,320	10.4
Vegetable	10,800	204,472	19

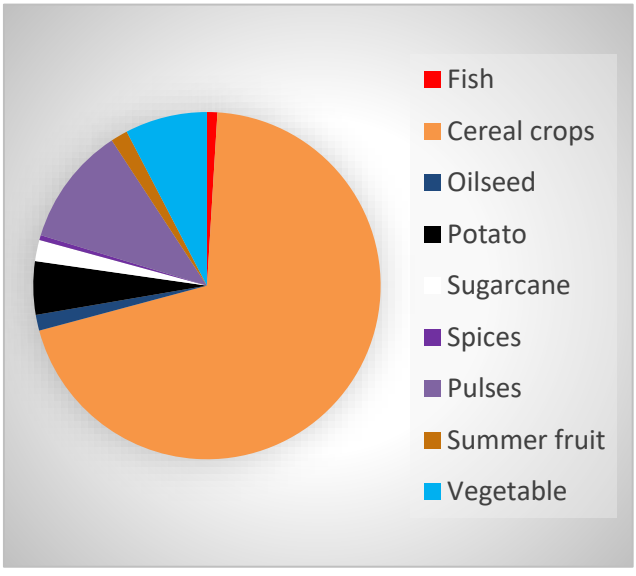

Figure 3: Area occupied by commodities

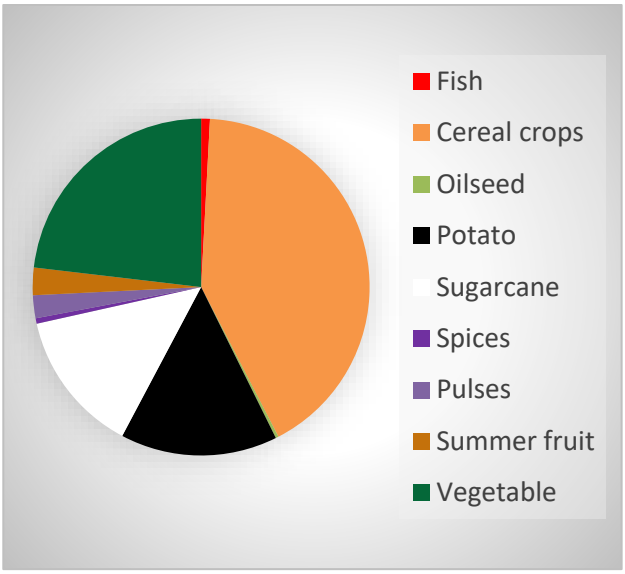

Figure 4: Production of agricultural commodities

3.4 Climatic Suitability for Fish Production

Almost all of the farmer practice semi-intensive Polycarp culture for fish production in Bara District. Carp can adapt to temperature from 4ºC to 35ºC (Amin and Khan, 2016). The optimum temperature for the growth of the most carp is between 28ºC to 32ºC (Bhatnagar and Singh, 2010). Lowland areas of Nepal are most suitable for aquaculture, whereas hill streams have a great attraction for sport fishing (Sharma, 2008). Mean annual temperature of Bara district falls within the suitability range of carp except in some extreme summer and winter days, where management activities should be taken to mitigate the problem.

3.5 Major Fish Species Cultivated in Bara

Indigenous and exotic fish species are cultured in Bara. Among the carp the three main Indian carp rohu (*Labeo rohita*), naini (*Cirrhinus mrigala*), bhakur (*Catla catla*) and Chinese carp viz. Common carp (*Cyprinus carpio*), Silver carp (*Hypophthalmichthys molitrix*), Bighead carp (*Hypophthalmichthys nobilis*), Grass carp (*Ctenopharyngodon idella*) comprise the fundamental fish species for the pond fish culture in Bara District. Yet some farmers have recently started production of tilapia and pangas fish in ponds.

3.6 Water Resource Availability

Terai region of Nepal has readily available ground water source (Sanstha, 2018). Underground source of water is the major source of water for the pond fish culture in Bara (Gupta et al., 2019). Bara district is rich in river and rivulets. Major rivers in Bara district comprise of Aruwa, Bagari, Dudhana, Pasaha, Lalbakiya, Sakti, Mohar, Dudhasa, Bagari, Dhalhi, Sirsiya and Tiyar (CFPCC, 2075). The district is further enriched with 12 rivulets and 29 gholes (CFPCC, 2075).

3.7 Fish Farming Systems

Fish production is mostly semi-intensive polycarp culture with total water surface area 1488.67 ha which is nearly 1% of total area of Bara district (CFPCC, 2018/19). The average pond size is 0.32 ha. Fish farming business is dominated by male's community in Bara district. Lease farming system with underground water source as irrigation is common practice. Private hatcheries were the main source of seed and average stocking density is

210000 fry/ha and stocking size is less than 3 cm (Gupta et al., 2019). Cost of fish production for one hectare of pond in Bara is NRs. 971927 per year with benefit cost ratio of 1.67 (Adhikari et al., 2019).

Chhadi fish production is one of the popular practice of fish farming in Bara (Yadav, 2018). Most of the chhadi fish production comprise of Malekhu size chhadi (31gm-50gm) though demand of Kathmandu size chhadi (50gm-100gm) is highest of all chhadi in market (Gupta et al., 2019). The Total Variable Cost, Total Fixed Cost, Total Revenue and Benefit cost Ratio for chhadi fish production in Bara district are NRs 827390, NRs 286600, NRs 1470000, 1.77 respectively (Gupta et al., 2019).

3.8 Infrastructures

The district has tremendous potential for fish farming. Regarding the comparative advantage of fishery sub sector, Prime Minister Agriculture Modernization Project was launched on Bara district as fish super zone for horizontal and vertical expansion of fishery subsector. There are 4290 fishpond, 15 private hatchery with potential to produce one billion hatchlings, 10 private fish nursery and 1 veterinary hospital in Bara district (CFPCC, 2075).

4. Conclusion

The pond number, water surface area, total fish production and productivity showed significantly increasing trend over the past 20 years from 1999/00 to 2018/19. The mean pond number, water surface area, production, and productivity through the study period were 2057 ponds, 626.579 ha, 2933585.8 kg and 4232.9 kg/ha respectively. The pond number, water surface area, production and productivity had jumped by 266.98%, 343.05%, 662%, and 72.01% respectively during the study period. From the study, the number of ponds had increased at the rate of 179 pounds per year, area increased at 57.823 ha per year, production increased at 360602.94 kg per year and productivity increased at 144.67 kg/ha per year. Overall, the fish sector have significantly increasing trend. However, the increase in production corresponds to the expansion in water surface area. The increase in fish productivity is not still satisfactory with Compound Annual Growth Rate of 2.74%. The production efficiency can be increased through training farmers, overcoming technologies associated constraints, quality and efficient input use and adoption of improved pond management practices.

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Conflict of Interest

All of the author agreed there is no conflicts of interest in relation to the publication of this manuscript.

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