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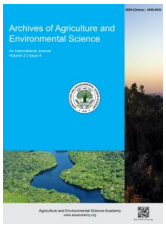

ORIGINAL RESEARCH ARTICLE

Heavy metals toxicity of surface soils near industrial vicinity: A study on soil contamination in Bangladesh

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ABSTRACT

Tangail district is more vulnerable to heavy metals contamination for industrialization in Bangladesh. Present study describe six heavy metals (Cr, Ni, Cu, As, Cd, and Pb) in fifteen several sampling locations in industrial vicinity of Tangail district were determined. The concentration of Cr, Ni, Cu, As, Cd, and Pb in studied areas soils were observed 0.96–14, 0.71–18.39, 1.02–34.44, 1.2–11.21, 0.44–3.31 and 2.01–28.86 mg/kg, respectively. There is representing a potential risk to the environment for presenting of these heavy metals in soils. This metals are generally toxic to soil and environment. They can persist in the environment for many years and have adverse effect to ecology. Certain indices like contamination factor (CF), enrichment factor (EF), geoaccumulation index (Igeo), pollution load index (PLI), source analysis, principle component analysis (PCA), and toxic units were calculated to determine environmental hazard caused by heavy metals in studied soils. Enrichment factors for the studied metals were in the descending order of Cd > As > Pb > Cu >Ni > Cr. The PLI values for studied metals, causes the Cd contamination in soil of Tangail district. Potential ecological risk (PER) showed low to very high risk to studied vicinity.

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INTRODUCTION

Soil, a key element for the survival of human life on the planet, is expected to be the primary recipient of persistent contaminants such as toxic heavy metals (Karim *et al*., 2014). Heavy metal soil contamination is known to be the most adverse environmental issue in the world. In Bangladesh, due to rapid industrialization, heavy metal contamination from industrial waste is now one of the burning problems. Most industries do not have waste treatment plants and the waste is thrown directly into the open environment such as soil, canal and river. These industrial wastes get mixed to soil and pollute soil. Heavy metals have toxicity, persistent, wide sources, accumulative behaviors and non-biodegradable properties which is the result of great concern at present (Islam *et al*., 2014a). The toxicity of heavy metals in surface soil can alter the physical, chemical, and biological characteristics of the soil. Because of these increases in heavy metals in the soil, the soil is toxic (Khan *et al*., 2010; Kumar *et al*., 2015). Soil pollution by heavy metals is universal issues and anthropogenic activities predispose it (Han *et al*., 2002; Vare, 2006). In recent decades, soil pollution has occurred due to several heavy metals for further urbanization, industrialization and is more suitable for developing countries because of the indiscriminate development of these industries

without proper planning (Ahmed *et al*., 2015). Heavy metals may originate in soils around the industrial area from numerous prime cause but industrial activities is the most important one and also generation of power, manufacturing, burning of fossil fuel and disposal of waste (Karim *et al*., 2014; Martín *et al*., 2014). Heavy metals have significant adverse effects on soils because of their potential environmental issues and adverse effects on soil bionetworks (Yuan *et al*., 2014). To determine environmental risks of toxic elements in soils, several methods have been widely used, like contamination factor, enrichment factor, and geoaccumulation index (Liu *et al*., 2014; Rashed, 2010). For determination of multiple risk of heavy metals in soil, pollution load index and potential ecological risk index have been used (Huang *et al*., 2013). Enrichment factor of a vicinity address relative enhancement in any toxic element when pre-industrial soils are compared with studied soils in alike vicinity (Dias *et al*., 2014). Since soil contamination derives from industry, the present area of study has been given more attention to its pollution in the environment facing threats to heavy metal toxicity contamination resulting from exponential growth, industrial activity and congestion (Islam *et al*., 2015a). Heavy metals concentration in the industrial area soils were reported in different studies due to rapid industrial activities in Bangladesh. The main purpose of this study was to determine the degree of pollution of toxic elements in soils using enrichment factors, contamination factors, geoaccumulation index, pollution load index, potential ecological hazard, and to identify potential heavy metal sources and soil pollution determination due to ecological threat in Bangladesh's industrial areas.

MATERIALS AND METHODS

Study areas and sampling

The samples were collected from Tarutia, Tangail Sadar Upzila of Tangail district, Bangladesh (Figure 1). Tangail district area is 334.26 km² and situated at the middle part in Bangladesh. Tangail Sadar Upzila is highly densely area in Bangladesh and population density is 1,100/km² in Tangail district. The study area is situated between Tangail Sadar is located at 24.2500°N to 89.9167°E. Tangail as an industrial vicinity of Bangladesh possess highly vulnerable to environmental pollution now a days. There present different kinds of industries in Tangail district like garments, packaging industry, dyeing, brick kiln, metal work-shops, battery manufacturing industries, tanneries, textile industries, pesticide and fertilizer industries, different food processing industries and other factories produce huge volumes of effluents that contain trace metals. These industries are discharged untreated wastes randomly to river and canals. Then that wastes are mixed with soils and the soil is continuously polluted by toxic elements in the industrial areas of Tangail district in Bangladesh. Soil samples were collected during March - April, 2016. Tarutia was selected for sampling location situated near industrial area of Tangail district, Bangladesh. Fifteen soil sampling sites were selected in the industrial areas of Tangail district. Agricultural field soil samples (samples were collected from surface soil up to 10 cm) were taken and three subsamples collected which were used as composite sample by mixing it thoroughly. Soil was taken with the help of a percussion hammer corer (50–80 cm in length) for metal analysis and this samples were treated as preindustrial sample (Schottler and Engstrom, 2006). To crumble all dried soil samples, a porcelain mortar and pestle were used. Then the samples were sieved with 2 mm nylon sieve. The soil samples were stored in a clean Ziploc bag which was airtight and used for chemical analysis. Several researcher also followed the alike procedure for sampling and storing of soil samples (Oliveira *et al*., 2012).

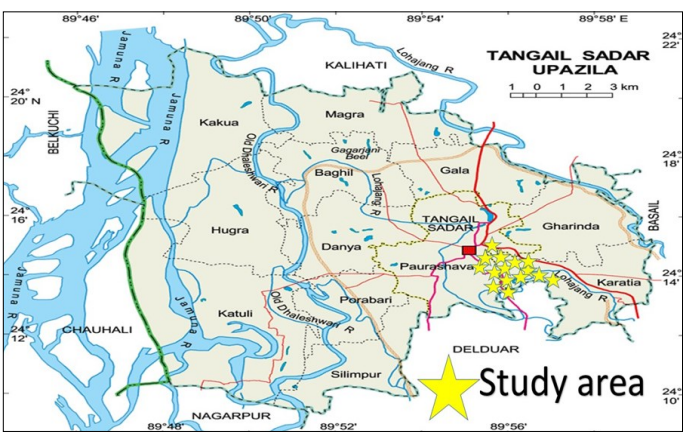

Figure 1. *Map showing the study areas of Tangail district, Bangladesh.*

Physicochemical parameters analysis

Soil pH was determined by using a glass electrode pH meter (WTW pH 522; Germany). 10 g of air-dried soil from each sampling site was taken in 50 mL beakers separately and 25 mL of distilled water was added to each beaker. The suspension was stirred well for 20 minutes and allowed to stand for about 30 minutes. Then each sample was stirred again for 2 minutes before taking the reading. The position of the electrode was immersed into the partly settled soil suspension and pH was measured. For EC determination, 5.0 g of soil was taken in 50 mL polypropylene tubes and 30 mL of Milli-Q water was added to the tube. The lid was closed properly and was shaken for 5 min. After that, EC was measured using an EC meter (WTW LF 521; Germany). For organic carbon, 1.0 g of soil was placed at the bottom of a dry 500mL conical flask (Corning/Pyrex). Then 10 mL of 1N $K_2Cr_2O_7$ was added into the conical flask and swirled a little. The flask was kept on asbestos sheet. Then 20 mL of concentrated H_2SO_4 was added into the conical flask and swirled again 2-3 times. The flask was allowed to stand for 30 minutes and thereafter 200 mL of distilled water was added. After incorporation of 5.0 mL of phosphoric acid and 35 drops of diphenylamine indicator, the contents were titrated against ferrous ammonium sulfate solution till the color flashes blue-violet to green. Simultaneously, a blank titration was run without soil. Particle size was determined using the hydrometer method. The textural classes for different soil samples were then determined by plotting the results on a triangular diagram designed by Marshall followed USDA system. The percentage of sand, silt and clay were calculated as follows.

%(Silt + Clay) = (Corrected hydrometer reading at 40 seconds/ Oven dry weight of sediment) × 100 (1)

%(Clay) = (Corrected hydrometer reading after 2 hours/ Oven dry weight of sediment) × 100 (2)

Sand (%) = 100 - %(Silt + Clay) (3)

Silt (%) = %(Silt + Clay) - % Clay (4)

Heavy metal analysis

All chemicals were analytical grade reagents; Milli-Q water (Elix UV5 and MilliQ, Millipore, Boston, MA, USA) was used for the preparation of solutions. The Teflon vessel and polypropylene containers were cleaned, soaked in 5% HNO_3 for more than 24 h, then rinsed with Milli-Q water and dried. For metal analysis, 0.3–0.5 g of the soil sample was treated with 6 mL 69% HNO_3 (Kanto Chemical Co, Tokyo, Japan) and 2 mL 30% H_2O_2 (Wako Chemical Co, Tokyo, Japan) in a closed Teflon vessel and was digested in a Microwave Digestion System (Berghof speedwave, Eningen, Germany). The digested samples were then transferred into a Teflon beaker, and total volume was made up to 50 mL with Milli-Q water. The digested solution was then filtered by using syringe filter (DISMIC1–25HP PTFE, pore size = 0.45 mm; Toyo Roshi Kaisha, Ltd., Tokyo, Japan) and stored in 50 mL polypropylene tubes (Nalgene, New York, NY, USA). After that, the digestion tubes were then cleaned using blank digestion procedure following the same procedure of samples. For trace metals, samples were analyzed using inductively coupled plasma mass spectrometer (ICP-MS, Agilent 7700 series, Santa Clara, CA, USA). Instrument operating conditions and parameters for metal analysis are done. The detection limits of ICP-MS for the studied metals were 0.7, 0.6, 0.8, 0.4, 0.06 and 0.09 ng/L for Cr, Ni, Cu, As, Cd and Pb, respectively. Multi-element Standard XSTC-13 (Spex CertiPrep®, Metuchen, NJ, USA) solutions were used to prepare calibration curves. Multi-element solution (purchased from Agilent Technologies, Japan) was used as tuning solution covering a wide range of masses of elements. All test batches were evaluated using an internal quality approach and validated if they satisfied the defined Internal Quality Controls (IQCs). Before starting the analysis sequence, relative standard deviation (RSD, <5%) was checked by using the tuning solution purchased from Agilent Technologies. The certified reference materials INCT-CF-3 (corn flour) bought from the National Research Council (Canada), were analyzed to confirm analytical performance and good precision (relative standard deviation below 20%) of the applied method. Metals in soil samples were analyzed using an inductively coupled plasma mass spectrometer (ICP-MS).

Ecological risk assessment for soil pollution

Enrichment factor (EF): Enrichment factor (EF) is considered as an effective tool to evaluate the magnitude of contaminants in the environment (Franco-Uría *et al.*, 2009). The EF for each element was calculated to evaluate anthropogenic influences on heavy metals in sediments using the following formula (Selvaraj *et al.*, 2004).

$$EF = (C_M/C_{Al})_{sample} / (C_M/C_{Al})_{background} \quad (5)$$

Where, $(C_M/C_{Al})_{sample}$ is the ratio of concentration of heavy metal (C_M) to that of aluminum (C_{Al}) in the soil sample, and $(C_M/C_{Al})_{background}$ is the same reference ratio in the background sample. Generally, an EF value of about 1 suggests that a given metal may be entirely from crustal materials or natural weathering processes (Zhang and Liu, 2002). Samples having enrichment factor >1.5 was considered indicative of human influence and (arbitrarily) an EF of 1.5–3, 3–5, 5–10 and >10 is considered the evidence of minor, moderate, severe, and very severe modification (Birch and Olmos, 2008).

Contamination factor (C^i_f): Contamination factor means the proportion of the heavy metal concentration in the soil to that of baseline or background value.

$$C^i_f = C_{heavy\ metal} / C_{background} \quad (6)$$

Contamination factor divided into four classes ranged from 1 to 6 which are: low degree (C^i_f <1), moderate degree ($1 \le C^i_f < 3$), considerable degree ($3 \le C^i_f < 6$), and very high degree ($C^i_f \ge 6$) (Islam *et al.*, 2015a). This approach has been used by other researchers e.g. (Proshad *et al.*, 2017; Kumar and Thakur, 2018).

Geoaccumulation index (I_{geo}): Geoaccumulation index (Igeo) is assumed as an impressive tool to determine contamination degree from toxic metals. At present, geoaccumulation index is used globally to assess soil pollution (Bermejo *et al.*, 2003; Kumar and Thakur, 2017). The most effective objective to determine geoaccumulation index (Igeo) is to identify pollution level in soil. Geoaccumulation index (Igeo) may be assessed by applying equation given here by,

$$Igeo = \log2 (Cn/1.5Bn) \quad (3)$$

Where, Cn is the determined element (n) concentration assessed from soil, Bn is the geochemical baseline value of element n in background sample (Yu *et al.*, 2008).

Pollution load index: To assess the quality of soil in terms of metal contamination, an integrated approach of pollution load index of the six metals is calculated according to Rashed (Rashed, 2010). The PLI is defined as the n^{th} root of the multiplications of the contamination factor (C^i_f) of metals (Bhuiyan *et al.*, 2011).

$$PLI = (C_f{}^i{}_1 \times C^i{}_{f\,2} \times C_f{}^i{}_3 \times \ldots\ldots \times C_f{}^i{}_n)^{1/n} \quad (7)$$

The PLI gave an assessment of the overall toxicity status of the sample and also it is a result of the contribution of the six metals. Therefore, PLI value of zero indicates perfection, a value of one indicates the presence of only baseline level of pollutants and values above one would indicate progressive deterioration of the site and estuarine quality (Thomilson *et al.*, 1980). The PLI gave an

assessment of the overall toxicity status of the sample and also it is a result of the contribution of the six metals.

Potential ecological risk (PER): The degrees of hazardous elements contamination in agricultural soils are determined by PER index. (Guo *et al.*, 2010) and (Yu and Li, 2011) proposed equations which were used to calculate PER and are as follows:

$$C_f^i = \frac{C^i}{C_n^i} \qquad C_d = \sum_{i=1}^{n} C_f^i \tag{8}$$

$$E_r^i = T_r^i \times C_f^i \qquad PER = \sum_{i=1}^{m} E_r^i \tag{9}$$

Where, C_f^i is the single element contamination factor, C^i is the content of the element in samples and C_n^i is the background value of the element. The background value of Cr, Ni, Cu, As, Cd and Pb in soils were 90, 68, 45, 13, 0.3 and 20 mg/kg, respectively (pre-industrial samples of the study area) (Turekian and Wedepohl, 1961). The sum of C_f^i for all metals represent the integrated pollution degree (C_d) of the environment. E_r^i is the potential ecological risk index and T_r^i is the biological toxic factor of an individual element. The toxic-response factors for Cr, Ni, Cu, As, Cd and Pb were 2, 6, 5, 10, 30 and 5, respectively (Amuno, 2013; Hakanson, 1980; Luo *et al.*, 2007; Wu *et al.*, 2010). PER is the comprehensive potential ecological risk index, which is the sum of E_r^i. Sensitivity of the biological community is represented by it to the toxic substance and indicates the potential ecological risk caused by the overall contamination.

Toxic unit analysis: The calculation of toxic units is considered as severe toxicity of toxic metals in agricultural soils. Toxic unit analysis is the proportion of the assessed concentration of heavy metals in soil to possible effect level (Islam *et al.*, 2014b). When the sum of toxic units for all soil samples is more than 4, moderate to serious toxicity of heavy metals remain in soil.

Statistical analysis

SPSS 20.0 (SPSS, USA) was used for statistical analysis for present study. To address the sources of heavy metals in soil, principal component analysis (PCA) were applied. Microsoft Excel 2013 was used for other calculations.

RESULTS AND DISCUSSION

Physiochemical properties of soil

Different physical and chemical properties (Texture, pH, EC and organic carbon) of soil were shown in Table 1. Soils pH values for present study were ranged from 5.48 to 7.15 signifying that the studied soil samples were slightly acidic to neutral except S9 and S13 samples which were alkaline in nature (Table 1). Most of the studied soils were acidic to neutral because of decomposition of organic matter and subsequent formation of carbonic acid (Ahmad *et al.*, 1996). Higher soil acidity favors the availability of cations in soil. Soil pH (acidity) is of particular importance as it controls the behavior of metals and many other soil processes. Heavy metal cations (positively charged metal atoms) are most mobile in acid soils. This means that metal contaminants are more available for uptake by plants, or to move into the water supply (Adeniyi *et al.*, 2008; Oliver, 1997). Electrical conductivity (EC) value of the studied soil was non-saline (0-2 dS/m; SRDI soil salinity class) for all sampling sites which mean the salinity effect is negligible (SRDI, 2009). This condition of soil was due to organic matter decomposition with carbonic acid formation in the studied area soils. The range of organic carbon (% C) was 0.664 to 3.331. High organic carbon content is an indication that metals are more likely to be bound to organic matter to form metal chelate complexes, and this would also result in less availability of metals to plants (Yap *et al.*, 2009). According to the United States soil texture classification system (NRCS, 1993), the textural analysis revealed that the studied soil samples were loam, sandy loam, and silt loam (Table 1) according to the soil texture classes.

Table 1. Physiochemical properties of soils collected from industrial areas of Tangail district, Bangladesh

Sampling sites	pH (1:2.5 H_2O)	EC (dS/m)	Organic carbon (%)	Sand (% in <2 mm)	Silt	Clay	Soil type
S1	6.36	0.23	1.507	49	32.5	18.5	Loam
S2	6.04	0.54	2.661	36	51.6	12.4	Silt loam
S3	5.48	0.32	0.677	46	37.5	16.5	Loam
S4	6.24	0.36	0.660	42.6	44.1	13.3	Loam
S5	6.43	0.43	1.649	47.4	37.5	15.1	Loam
S6	6.87	0.21	0.996	48.5	39.1	12.4	Loam
S7	6.3	0.36	0.644	41.5	39.1	19.4	Loam
S8	6.35	0.3	0.650	60.1	26.6	13.3	Sandy loam
S9	7.11	0.22	1.019	54	30	16	Sandy loam
S10	6.3	0.21	1.062	49	34.1	16.9	Loam
S11	6.7	0.32	3.331	376	46.6	15.8	Loam
S12	6.43	0.25	0.933	51	36.6	12.4	Loam
S13	7.15	0.27	1.945	47.6	39.1	13.3	Loam
S14	6.54	0.47	1.341	53.5	35	11.5	Sandy loam
S15	6.11	0.19	1.402	44	36.6	19.4	Loam

*According to the United states Department of Agriculture soil classification system.

Heavy metals concentrations in soil

The heavy metals concentrations (Cr, Ni, Cu, As, Cd, and Pb) in soil samples were presented in Table 2. The mean concentrations of Cr, Ni, Cu, As, Cd, and Pb in soil were found 4.91, 5.86, 8.06, 4.2, 1.35, and 12.11 mg/kg, respectively (Table 3) around the industrial area of Tangail district, Bangladesh. The highest value of Cr, Ni, Cu, As, Cd and Pb were observed in soil collected from S14, S10, S13, S14, and S11 site. Hazardous element concentrations in present study soil samples were compared with other studies. The mean concentration of Cr was found 4.91 mg/kg in the present study which was lower than The Dutch Soil Quality Standard (VROM, 2000), Canadian Environmental Quality Guidelines (CCME, 2003) and Australian Guideline for Soil Quality (DEP, 2003) indicating lower contamination of Cr in soil (Table 2).

Chromium is a toxic heavy metal is discharged from several industries into the agricultural land around industrial areas and pollutes agricultural soils (Nriagu, 1988). Cr concentration was found in the study areas may be disposed of untreated tannery waste to agricultural fields since chromium salt used in tannery industries (Gowd *et al*., 2010). The concentration of Cr in agricultural soils varies up to values as high as 350 mg/kg (Branca *et al*., 1990). Chromium concentration in the present study was lower than other studies (Ahmad and Goni, 2010; Islam *et al*., 2014a; Luo *et al*., 2007; Proshad *et al*., 2017) conducted different areas in Bangladesh and other countries. The toxicity of Cr has negative impacts on the growth of plants that interfere with some important metabolic processes (Hasnine *et al*., 2017; Shanker *et al*., 2009).

The solubility of nickel in soils increases with its acidity and if the acidity increases it results higher Ni in soils (Barałkiewicz and Siepak, 1999). In the present study Ni concentrations ranged between 0.71-18.39 mg/kg in the study area. The highest amount (18.39 mg/kg) was found in station 10 and the lowest value (0.71 mg/kg) in station 7 (Table 2). The elevated levels of Ni were found in station 10 which results from localized additions or accidental spillages of Ni containing materials (Krishna and Govil, 2007). The mean concentration of Ni was found 5.86 mg/kg in the present study which was lower than The Dutch Soil Quality Standard (VROM, 2000), Canadian Environmental Quality Guidelines (CCME, 2003) and Australian Guideline for Soil Quality (DEP, 2003) indicating lower contamination of Ni in soil (Table 2). Nickel (Ni) concentration in the present study was lower than other studies (Ahmad and Goni, 2010; Islam *et al*., 2014a; Luo *et al*., 2007; Proshad *et al*., 2017) conducted different areas in Bangladesh and other countries.

Table 2. Metal concentration (mg/kg) in soil collected from industrial areas of Tangail district, Bangladesh.

Sampling sites	Cr	Ni	Cu	As	Cd	Pb
S1	0.964	8.058	8.192	2.128	0.447	12.102
S2	2.704	5.423	5.312	2.850	2.608	2.325
S3	4.599	3.237	2.038	1.313	0.487	11.195
S4	1.665	2.085	2.268	3.016	0.190	2.017
S5	0.414	3.349	6.110	2.149	0.692	12.120
S6	5.646	2.114	9.740	1.481	0.312	6.360
S7	5.923	0.712	4.433	1.200	0.788	9.044
S8	2.699	1.955	2.256	1.784	1.586	4.014
S9	4.214	3.656	1.028	1.365	1.309	17.124
S10	4.212	18.394	2.785	5.439	1.134	13.781
S11	5.160	8.607	7.105	3.191	0.543	28.645
S12	4.958	3.247	5.014	10.388	2.238	26.867
S13	10.532	9.036	34.440	8.049	2.416	13.503
S14	5.935	11.033	18.657	11.210	3.311	17.566
S15	14.047	7.103	11.627	7.563	2.228	5.106
Mean	4.91	5.86	8.06	4.20	1.35	12.11
Dutch standard[a]	100	35	36	29	0.80	85
Canadian guidelines[b]	64	50	63	12	1.4	70
Australian guidelines[c]	50	60	60	20	3.0	300
Background value in Tangail district	29	32	27	6.5	0.82	23

[a](VROM, 2000) [b](CCME, 2003) [c](DEP, 2003)

Excessive Cu concentrations are harmful to plants and highly toxic to some microorganisms (Hasnine *et al*., 2017). Soluble soil Cu can be toxic to plants since Cu-enriched liquid dairy waste used in agricultural land as irrigation water (White and Brown, 2010). In the present study, the value of Cu ranged between 1.02 to 34.44 mg/kg (Table 2). The mean concentration of Cu was found 8.06 mg/kg in the present study which was lower than The Dutch Soil Quality Standard (VROM, 2000), Canadian Environmental Quality Guidelines (CCME, 2003) and Australian Guideline for Soil Quality (DEP, 2003) indicating lower contamination of Cu in soil (Table 2). (Alloway, 1990) provided with the regulatory standard for Cu in soil is 20-30 mg/kg. Cu concentration in the present study was compared to other studies conducted in Bangladesh and other countries. Present studied Cu concentrations were lower than other studies (Ahmad and Goni, 2010; Islam *et al*., 2014a; Luo *et al*., 2007; Proshad *et al*., 2017).

In the present study, the concentration of As varied between 1.2 to 11.21 mg/kg (Table 2). A huge amount of groundwater containing As (Hug *et al*., 2011) is being used for tanning in relation to some chemicals especially arsenic sulfide (Bhuiyan *et al*., 2011). Moreover, emission and waste from brick fields and incineration activities might contribute to the high concentration of As (Olawoyin *et al*., 2012). Arsenic in agricultural soils can be derived from both natural and anthropogenic sources, especially use of groundwater for irrigation and uncontrolled application of As enriched fertilizers and pesticides (Neumann *et al*., 2010). All the concentrations of As found to below the recommended value set by Dutch Soil Quality Standard (VROM, 2000),

Canadian Environmental Quality Guidelines (CCME, 2003) and Australian Guideline for Soil Quality (DEP, 2003) (Table 2). As contaminated water and As-enriched fertilizers as well as pesticides were used for irrigation in the agricultural land ((Polizzotto *et al*., 2013). Moreover, emission and waste from brick fields and incineration activities might contribute to the high concentration of As in agricultural soil (Olawoyin *et al*., 2012).

Cadmium concentrations were found between 0.44 to 3.31mg/kg. The mean concentration of Cd was found 1.35 mg/kg in the present study which was higher than The Dutch Soil Quality Standard (VROM, 2000) but higher than Canadian Environmental Quality Guidelines (CCME, 2003) and Australian Guideline for Soil Quality (DEP, 2003). Cadmium (Cd) concentration in the present study was compared to other studies conducted in Bangladesh and other countries. Present studied Cd concentrations were lower than other studies (Ahmad and Goni, 2010; Islam *et al*., 2014a; Proshad *et al*., 2017).

This level of Pb concentration present in soil due to metal processing factories release Pb into the open environment and several anthropogenic factors (Nziguheba and Smolders, 2008). In the present study, station 11 showed the elevated concentrations of Pb which can be due to the emission of Pb contaminated waste from these sites (Gowd *et al*., 2010). The mean concentration of Pb was found 12.11 mg/kg in the present study which was lower than The Dutch Soil Quality Standard (VROM, 2000),

Table 3. Comparison of metal concentration (mg/kg) in soil of present study with other study and guideline values.

Region, Country	Cr	Ni	Cu	As	Cd	Pb	References
Tangail (Bangladesh)	4.91 (0.96-14)	5.86 (0.71-18.39)	8.06 (1.02-34.44)	4.2(1.2-11.21)	1.35 (0.44-3.31)	12.11(2.01-28.86)	Present study
Tangail (Bangladesh)	10.41 (1.57-21.91)	12.69 (4.74-25.71)	15.66 (3.08-38.56)	12.15 (2.69-28.44)	3.1(1.03-8.06)	7.98(2.23-18.32)	(Proshad *et al*., 2017)
Guandong (China)	12.3 (9.66-19)	8.83 (7.04-10.3)	324 (210-450)	NA	0.9 (0.26-1.17)	96 (73-134)	(Luo *et al*., 2007)
Bogra (Bangladesh)	41 (6.6-87)	45 (15-95)	42 (6.4-107)	10 (2.0-36)	4.2 (0.7-10)	44 (13-96)	(Islam *et al*., 2014b)
Dhaka (Bangladesh)	54 (34-68)	58 (36-74)	39 (31-45)	NA	11 (6-16)	50 (44-52)	(Ahmad and Goni, 2010)
Dutch soil quality standard (Target Value)	100	35	36	29	0.8	85	(VROM, 2000)
Dutch soil quality standard (Intervention Value)	380	210	190	55	12	530	(VROM, 2000)
Canadian Environmental Quality Guidelines	64	50	63	12	1.4	70	(CCME, 2003)
Department of Environmental Protection, Australia	50	60	60	20	3	300	(DEP, 2003)

Canadian Environmental Quality Guidelines (CCME, 2003) and Australian Guideline for Soil Quality (DEP, 2003) indicating lower contamination of Pb in soil (Table 2). Lead (Pb) concentration in the present study was lower than other studies (Ahmad and Goni, 2010; Islam *et al.*, 2014a; Luo *et al.*, 2007) conducted different areas in Bangladesh and other countries.

Source analysis of heavy metals in soil

Statistical analyses were performed to elucidate the associations among heavy metals in soils and to identify the important factors involved in controlling the transport and distribution of metal contaminants (Proshad *et al.*, 2019). Pearson's correlation (PC) matrix for analyzed soils parameters was calculated to see if some of the parameters interrelated with each other and the results are presented in Table 4. The value of EC showed significant positive correlation with silt (r=-0.524*). Sand showed significant positive correlation with organic matter (r=-0.675**). There were also showed others positive correlations like silt with organic carbon (r=0.61*) and Pb (r=0.59*), Cr with Cu (r=0.575*), Cu with As (r=0.566*) and As with Cd (r=0.762**). Considering the relationship between the combinations showed positive significant relationship which indicates the parameters were interrelated with each other and may be originated from the same source to the study area. Other relationships among the constituents of soil were not significant.

Table 4. Correlation coefficient matrix for physiochemical properties of soils and heavy metals collected from industrial areas of Tangail district, Bangladesh.

	pH	EC	Sand	Silt	Clay	Organic carbon	Cr	Ni	Cu	As	Cd	Pb
pH	1											
EC	-0.277	1										
Sand	0.204	-0.004	1									
Silt	-0.163	0.524*	0.334	1								
Clay	-0.271	-0.405	0.060	-0.198	1							
Organic carbon	0.216	0.318	0.675**	0.61*	-0.090	1						
Cr	0.160	-0.373	0.013	0.007	0.212	0.074	1					
Ni	0.096	-0.141	0.168	-.053	0.100	0.327	0.196	1				
Cu	0.475	0.002	-0.030	.079	-0.244	0.306	0.575*	0.315	1			
As	0.154	-0.004	-0.071	-.038	-0.326	0.085	0.505	0.462	0.566*	1		
Cd	0.119	0.291	-0.220	-.019	-0.386	0.191	0.450	0.297	0.505	0.762**	1	
Pb	0.349	-0.165	0.590*	-0.059	-0.043	0.336	0.037	0.295	0.107	0.398	0.101	1

* = Correlation is significant at the 0.05 level (two-tailed) ** = Correlation is significant at the 0.01 level (two-tailed)

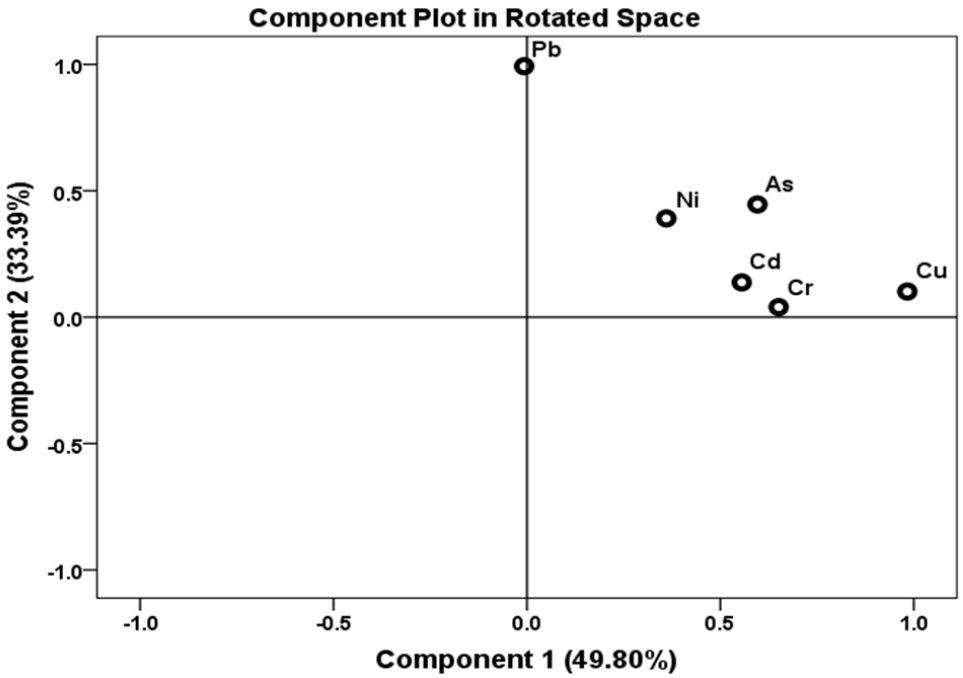

Figure 2. *Principal component analysis (PCA) of heavy metals in soil collected from Tangail district, Bangladesh. Considering the highest component loading, first PC exhibited elevated loadings of Cr, Ni, Cu, As and Cd. Second PC exhibited elevated loadings of Pb.*

Source of toxic elements in soils were assessed in the form of Principal component analysis (PCA) in different soil sampling sites of Tangail district. Principal component analysis is determined for sources identification (Anju and Banerjee, 2012). The principal component analysis was performed on the tabular and standardized forms of data set and is presented in Table 5 and Figure 2. The extraction method was performed to find out the principal components (PC) in PCA analysis that was Eigen values. In this study, two PCs were computed and the variances explained by them were 49.80% and 33.39% for soil samples in the study area (Figure 2). Overall, the PCA revealed two major groups of the metals in soils, where one group consisted of Cr, Ni, Cu, As and Cd which were predominantly contributed by anthropogenic activities (Iqbal and Shah, 2011). Second group consisted of Pb which were contributed by lithogenic sources or by industrial emissions in the sampling sites (Proshad *et al.*, 2019).

In addition, cluster analysis (CA) with dendrogram using Ward's Method was applied to classify the heavy metals into several groups using the overall heavy metals concentration in soil samples (Figure 3). Several cluster shape were found between heavy metals which were in same cluster were of resembling in nature. In respect of metal pollution in soils exhibited strong significant correlations by building primary clusters with each other (Figure 3). The primary clusters such as Cr, As, Cd and Ni was formed and another cluster were formed with Cu and Pb within a distance of five on the scale (Figure 3).

Table 5. Total variance explained and component matrices for the hazardous elements in surface soils collected from industrial areas of Tangail district, Bangladesh.

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	92.613	49.802	49.802	92.613	49.802	49.802	84.396	45.383	45.383
2	62.099	33.393	83.195	62.099	33.393	83.195	70.316	37.812	83.195
3	17.271	9.287	92.482						
4	8.844	4.756	97.238						
5	4.801	2.582	99.820						
6	0.335	0.180	100.000						

Elements	Component matrix				Rotated Component Matrix			
	Raw component		Rascaled component		Raw component		Rascaled component	
Component matrix	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2
Cr	2.039	-1.073	0.577	-0.304	2.300		0.651	
Ni	2.376		0.511		1.676	1.818	0.360	0.391
Cu	7.695	-3.650	0.893	-0.424	8.472		0.983	
As	2.554		0.741		2.054	1.538	0.596	0.446
Cd	0.539		0.546		0.548		0.555	
Pb	4.097	6.860	0.509	0.853		7.990		0.993

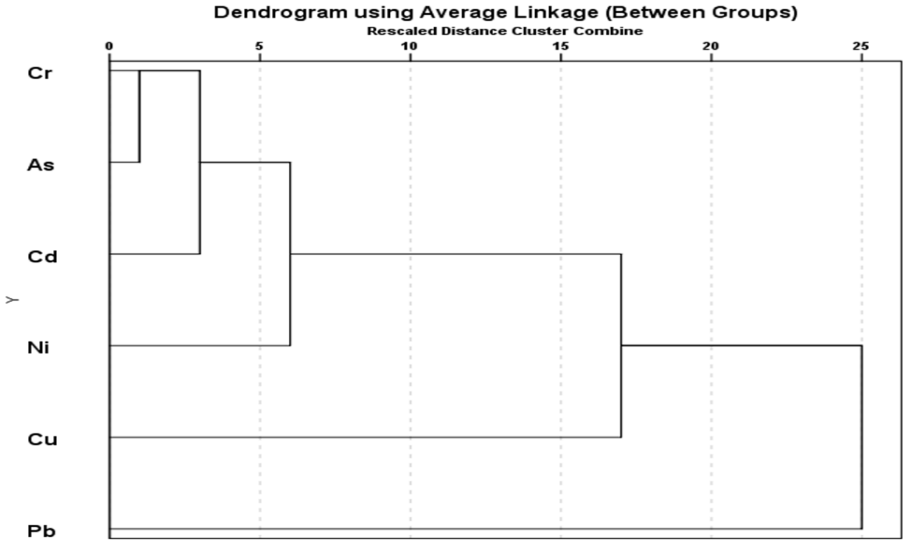

Figure 3. *Cluster analysis of soil samples for heavy metals collected from industrial areas of Tangail district, Bangladesh.*

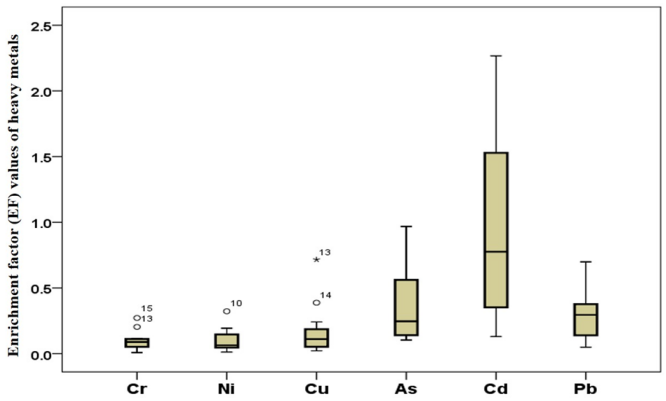

Figure 4. *Enrichment factor (EF) values for heavy metals in soils of sampling sites in Tangail district.*

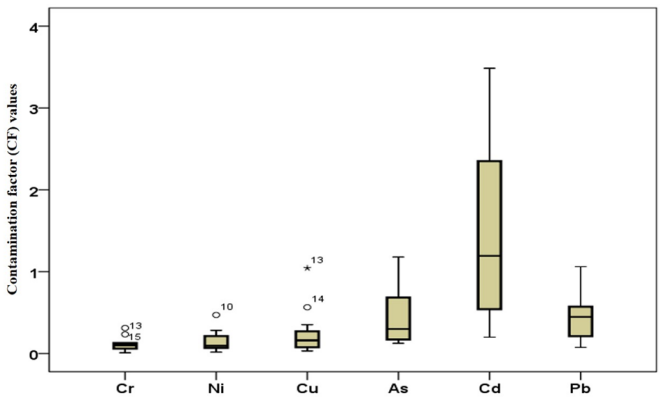

Figure 5. *Contamination Factor (CF) of heavy metals in soils collected from industrial areas of Tangail district, Bangladesh.*

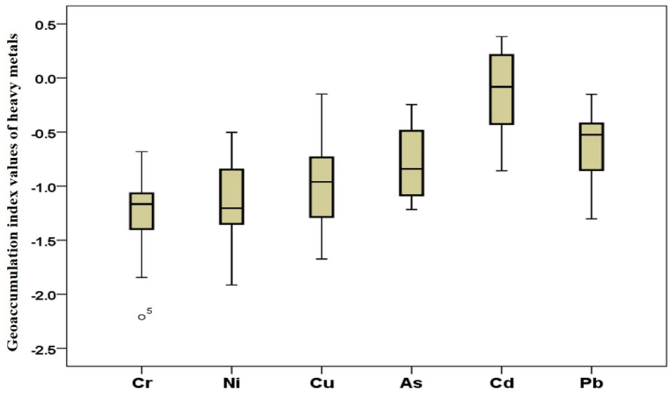

Figure 6. *Geo accumulation index (I_{geo}) value of heavy metals in soils of industrial areas in Tangail district, Bangladesh.*

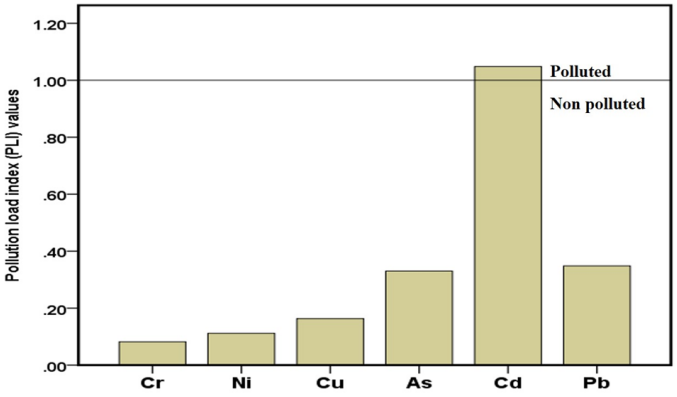

Figure 7. *Pollution load index (PLI) value of heavy metals in soils of Tangail district, Bangladesh.*

Table 6. Potential ecological risk factor, risk index and pollution degree of heavy metals in soils collected from industrial areas of Tangail district, Bangladesh.

Sites	Potential ecological risk factor (E^i_r)						Potential Risk (PER)	Pollution degree
	Cr	Ni	Cu	As	Cd	Pb		
S1	0.171415	4.959013	4.965106	8.961436	56.40616	8.96466	84.42779	Moderate risk
S2	0.480704	3.33746	3.219426	11.99998	329.3994	1.721987	350.1589	Very high risk
S3	0.817569	1.991869	1.235273	5.527944	61.55157	8.292594	79.41682	Moderate risk
S4	0.296072	1.283189	1.374376	12.70005	24.04455	1.493711	41.19196	Low risk
S5	0.07364	2.061149	3.702827	9.046509	87.4643	8.977634	111.3261	Moderate risk
S6	1.003696	1.301099	5.902817	6.234841	39.41723	4.711326	58.57101	Low risk
S7	1.052918	0.438321	2.686423	5.054444	99.56221	6.699138	115.4935	Moderate risk
S8	0.47975	1.203172	1.367192	7.512932	200.3827	2.973274	213.919	Considerable risk
S9	0.749184	2.24997	0.623047	5.748393	165.3143	12.6848	187.3697	Considerable risk
S10	0.748717	11.3191	1.687635	22.89913	143.264	10.20823	190.1268	Considerable risk
S11	0.917281	5.296747	4.305867	13.43615	68.56799	21.21834	113.7424	Moderate risk
S12	0.881346	1.997956	3.038928	43.73748	282.7423	19.90128	352.2993	Very high risk
S13	1.872337	5.560771	20.87269	33.88869	305.2379	10.0019	377.4343	Very high risk
S14	1.055059	6.789283	11.30735	47.19896	418.2094	13.01192	497.5719	Very high risk
S15	2.497315	4.371233	7.046637	31.84236	281.4128	3.782345	330.9527	Very high risk

Table 7. Indices and grades of potential ecological risk of heavy metal pollution (Luo *et al.*, 2007).

Contamination factor (C^i_f)	Contamination degree of individual metal	Degree of contamination (Cd)	Contamination degree of the environment	E^i_r	Grade of ecological risk of individual metal	Risk index (PER)	
$C^i_f<1$	Low	Cd<5	Low contamination	$E^i_r<40$	Low risk	RI<65	Low risk
$1\leq C^i_f<3$	Moderate	5≤Cd<10	Moderate contamination	$40\leq E^i_r<80$	Moderate risk	65≤RI < 130	Moderate risk
$3\leq C^i_f<6$	Considerable	10≤Cd<20	Considerable contamination	$80\leq E^i_r<160$	Considerable risk	130 ≤RI < 260	Considerable risk
$C^i_f\geq6$	High	Cd≥20	High contamination	$160\leq E^i_r<320$	High risk	RI ≥ 260	Very high risk
				$E^i_r\geq320$	Very high risk		

Ecological risk assessment

In present experiment, the enrichment factor, contamination factor, geoaccumulation index, and pollution load index (PLI) were used as ecological risk assessment to determine toxic metal pollution in industrial vicinity soils (Table 6)

The enrichment factor values for the studied soils are presented in Figure 4. Average enrichment factor index of toxic elements assume enrichment of these metals in different sampling locations in the industrial vicinity of Tangail district, Bangladesh. For enrichment factors, cadmium and arsenic have the highest enrichment factor value which indicate soil contamination for total sampling locations. Enrichment factor for studied heavy metals showed a decreasing order of Cd > As > Pb > Cu >Ni > Cr in all sampling locations. Usually, a little enrichment values causes high contribution for crusted source in soils which were identified by several studies where anthropogenic sources have substantial contribution causes high EFs (Islam *et al.*, 2015b; Rashed, 2010).

Four types of contamination Factors (CF), four types of degree of contamination (Cd), five types of Eir and four types of PER were given by Hakanson (Hakanson, 1980) presented in Table 7. The contamination factor (CF) for individual metal were presented in Figure 5. In the studied vicinity, contamination factor was low and was considerable degree only for Cd.

Geoaccumulation index (I_{geo}) values were shown in Figure 6. The I_{geo} values presented the decreasing order of Cd>Pb>As>Cu>Ni>Cr. Average Igeo values for the studied toxic metals for studied locations causing slowly contamination of soil with heavy metals.

Pollution load index (PLI) value is zero means accurate; PLI value is one means there only present baseline level of contaminants where PLI values above 1 means successive contamination by heavy metals in soils (Islam *et al.*, 2015b; Proshad *et al.*, 2017). Present studied soils were polluted by Cd and it was observed for others metals that PLI values was less than one for all sampling sites (Figure 7).

PER index of single metal (E^i_r) with combining potential ecological risk index of the environment (PER) (Table 6) with classifications of PER (Table 7), studied area soil samples indicate the low to very high risk which must possess ecological hazard in the studied vicinity. For individual metal ecological risk assessment, cadmium showed the highest risk and the studied vicinity soils resulted from moderate, considerable and very high potential ecological risk due to combining toxic metal effects. The order of E^i_r for studied soil sample followed decreasing order of Cd> As> Pb> Cu> Ni>Cr. Cd contributes significantly higher than other metals as potential ecological risk index of the environment (PER) which can be due to the effect from anthropogenic activities such as the application of phosphate fertilizers and industrial activities (Martín *et al.*, 2013).

Sum of toxic units (ΣTUs) determine as possible heavy metal toxicity in soils (Figure 8). Toxic units may be calculated as the ratio of heavy metal concentration in soil which is measured to probable effect levels (PELs) (Islam *et al.*, 2015a). Total toxic unit

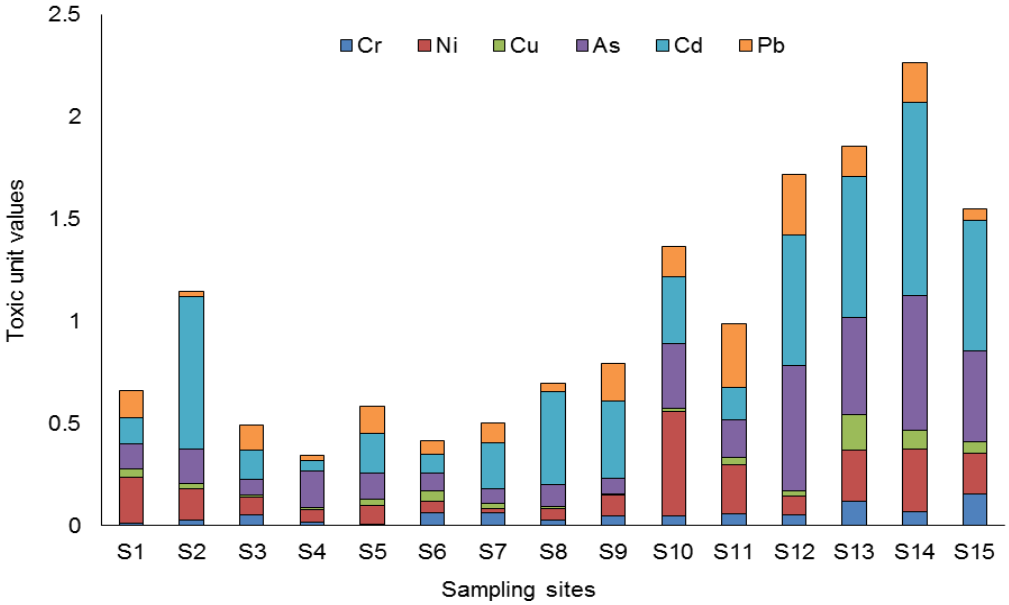

Figure 8. *Estimated sum of the toxic unit (TU) in soils of industrial areas of Tangail district, Bangladesh.*

(ΣTUs) with toxic units (TU) due to heavy metals toxicity in several soil sampling locations in industrial vicinity were presented in Figure 6. Moderate to serious toxicity of hazardous materials were resulted when sum of toxic units of studied soil samples exceed 4 and it causes serious threat to environment. Total toxic units (ΣTUs) for different sampling sites like S12, S13 and S14 were higher than other sites. In the present study, no sample was found which sum of toxic units was higher than 4.

Conclusion

Present study indicated that cadmium have the most hazardous effect to soil samples and soils were polluted by Cd (about 70% soil samples exceed the Dutch soil quality target value). Contamination factors and pollution load index of Cd was higher than other metals in the studied areas. It was also observed from the study that heavy metal concentration in industrial vicinity soils for Bangladesh varied in different locations. Geogenic with anthropogenic elements are the major reasons for enrichment of toxic metals in soils. Around 66% samples were polluted according to potential ecological risk (moderate to very high risk). Maximum sampling sites in the industrial vicinity of Tangail district showed cadmium toxicity with severe ecological risk for single toxic element. So in Tangail district, ecological risk indexes for toxic elements were so much high. There is urgent need to study again in present studied area and to increase public awareness not to throw industrial wastages in the open environment.

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Conflict of interest

No any conflict of interest was declared by the authors.

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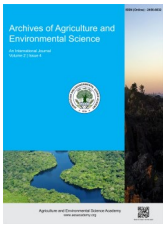

ORIGINAL RESEARCH ARTICLE

Simulating the effects of human urine on phenology and some cultivar coefficients of Cowpea (*Vigna unguicalata* L. Walp) using the DSSAT-CROPGRO model

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ABSTRACT

The DSSAT-CROPGRO model was used to characterize phenology and cultivar coefficients of cowpea treated with diluted human urine (equivalent to 60 kg-N/ha), simulated under ten irrigation schedules for a 5 year production period in Juba County of Central Equatoria State, South Sudan. Two treatments (T_0) without urine and (T_1) with human urine dilution during the growing season of 2016 were used and, 5-years model simulations on the grain number/m², LAI, canopy height (m) and pod number/m² compared. Irrigation schedules were carried out once the volumetric soil moisture content measured using the Theta Soil Moisture Probe was close to 15%. Results showed that cultivar coefficients EM-LF, FL-LF and FL-SH for both T_0 and Y2015 (calibrant) were on average 6-8 days shorter than under T_1. Also, the SIZLF under T_1 was about 8-17% greater than under both T_0 and calibrant Y2015 indicating the significance of diluted human urine on cowpea cultivar coefficients and phenology. The model also gave good agreement between observed and simulated growth parameters with low RMSE of the pod nr/m² at 17 for T_0, and 37.5 for T_1, the RMSE for grain nr/m^2 was 360 kg for T_1, and 347 kg for T_0, whereas the RMSE of LAI showed no significant difference. The *d*-indices in estimating LAI and canopy height were generally low and showed the largest errors than for pod nr/m² and grain nr/m². The results showed that the model satisfactorily simulated and underscored the significance of diluted human urine on both phenology and cultivar coefficients of cowpea.

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INTRODUCTION

Cowpea is one the major food crops in Central Equatoria State of South Sudan and an indispensable source of cheap and easily available plant protein. The young and tender leaves are consumed traditionally as *nete* while the ripened and mature seeds as *pirinda* (Lomeling and Abbass, 2014). In the presence of irrigation water, cowpea can be produced in small farms or household backyards during any time of the year. It is a highly remunerative crop with price increase several times its normal value especially during the annual "*hunger spells*" of mid-July to Mid-August. However, increasing price of potable water and the large influx of Internally Displaced Persons (IDPS) due to current civil war, cowpea production per household has significantly decreased within and around Juba municipality. Similarly, cowpea production, as a cheap source of plant protein, is not only threatened by a reduced availability of irrigation water but also declining soil fertility caused increased and excessive removal of soil nutrients as well as reduction in soil functional properties (Lomeling *et al*., 2016a). As a drought resistant plant, reduced irrigation is not necessarily a limiting factor, since soil moisture requirements during cowpea phenology show temporal variability between 15-30% (Lomeling *et al*., 2016b). However, soil moisture contents <15% at any one developmental stage of growth has adverse effects on the germination rate, flowering, canopy height, pod-setting and maturity (Abayomi

and Abidoye, 2009; Suliman and Ahmed, 2010; Souza *et al*., 2017). Reduction in cowpea yield is not only attributable to insufficient soil moisture during growth, but also to such abiotic stress factors like phosphate (P) deficiency (Goufo *et al*., 2017; Jemo *et al*., 2017; Fatokun *et al*., 2012; Agele *et al*., 2018). Although *Eutric leptosols* are the major soil type around Juba County and can be perceived to be of moderate to good fertility, sustained cultivation over longer period without any concerted soil amendments may ultimately pose serious soil fertility challenges. The use of composted tannery sludge was found to sustain cowpea yield during a six-year period (Araújo *et al*., 2016); increased cowpea yield after application of biochar in loamy sand soil (Pudasainia *et al*., 2016); increased cowpea biomass after addition of nitrogen fertilizers (Hasan *et al*., 2010).

There´s much literature on the use of cow dung organic matter as a soil ameliorant (Adekiya *et al*., 2017; Nweke and Nsoanya, 2015; Nyatuame and Nartey, 2013; Tekwa *et al*., 2010). However, current published data on the application of human urine (Sene *et al*., 2013; Ranasinghe *et al*., 2016; Tampio *et al*., 2016) as a viable fertilizer option are derived from short term studies and are insufficient to adequately assess the agronomic, economic and environmental implications. Human urine in diluted form can successfully be applied as an optional fertilizer for plant growth (Andersson, 2016). However, one critical risk component in the widespread use of human urine across many developing countries of Sub-Sahara Africa would be the local and regional water scarcity. Water scarcity compounded by the erratic spatial and temporal rainfall distribution variabilities would make its use difficult or outright impossible. Thus, it is imperative, that knowledge on the spatial and temporal water availability and accessibility for most smallholder farmers who practice rainfed agriculture, be integrated into the respective country agricultural policies and implementation programs when evaluating the use of human urine. Moreover, farmers' willingness to adopt the use of human urine will depend not only on the available infrastructure in terms of hygienic storage, transportation and dosing, but also on the anticipated increased yields and profitability. Indeed, human urine is a cheap, readily available and considered as a stopgap option for subsistence farmers for whom subsidized industrial fertilizers are often not available, unaffordable and inaccessible. Such an intervention with human urine would not only achieve some annual yield increase to cater for immediate household food needs but also consolidate food security in terms of availing the daily needed cash flow.

To address the sustainable use of human urine as an environmentally and ecologically viable option for most households in Sub Sahara Africa, systematic research and long-term field tests need to be carried out and simulations conducted with dynamic crop models such as the CROPGRO of the DSSAT (Jones *et al*., 2003; Zinyengere *et al*., 2015). Not only can the model be used to assess crop yield and economic returns for a range of different soil and water management strategies, but also to assess environmental impacts in terms of nitrogen loads leached into groundwater as a result of excessive human urine application. Unlike most field trials that describe the causality between fertilizer application amounts and yield, no studies have so far attempted to model crop response to human urine application and dosing.

The application of DSSAT-CROPGRO model for cowpea is therefore an indispensable ex ante analysis tool. The CROPGRO module has been successfully demonstrated across a broad range of soil, management and climatic conditions in tropical environments (Banterng *et al*., 2010; Lomeling *et al*., 2014; Bastos *et al*., 2002; (Nkulumo *et al*., 2015).

It also can be used to assess the type of promising or similar climate smart technologies whose "*low scale*" investments are not only remunerative, but also financially affordable as is the case for most smallholder farmers in South Sudan (Singh *et al*., 2016). Model projections during simulations can be used as basis for long-term actionable trends in terms of assessing food demand and agricultural production based on projected changes in population, income, technology, and climate (Robinson *et al*., 2015). Examples on the use of CROPGRO models have been reported in several studies on bean by Oliviera *et al*., 2012); on safflower by (Singh *et al*., 2016); on faba bean by (Boote *et al*., 2002); on peanut by (Halder *et al*., 2017).

For most smallholder farmers in South Sudan, the erratic rainfall patterns experienced every year prior and during each planting season are inexplicable weather phenomena. However, most farmers do acknowledge a gradual shift in both amounts, patterns and intensity of rainfall over the last 20 to 30 years. Generally, the recent rainfall forecasts reported for example by (FEWSNET, 2018) within the East African region, are mostly limited to short-term one to three months lead time. South Sudan still lacks a good infrastructure, network of weather stations as well as skilled personal to capture and store weather data in real-time. The absence of such important historical weather data therefore makes any long-term predictions on rainfall occurrence, amounts and intensity difficult. The CROPGRO model requires daily, monthly or annual rainfall amounts as an input variable, thus, simulation of crop yield for most parts of South Sudan in the absence of such relevant data may simply be a speculative exercise.

In our study, we sought to simulate the response of cowpea to human urine application under irrigation conditions using DSSAT-CROPGRO model on phenology, yield and some cultivar coefficients. This study is a novelty and the first of its kind in South Sudan and a further step towards scientifically consolidating the application of human urine as a viable organic fertilizer alternative. Furthermore, the paper tries to address the question, whether or, not simulation will expand our understanding of plant-fertilizer interactions and how this could eventually be integrated in cowpea crop production systems.

The simulation reported in this study is one of the first studies in South Sudan applying the CROPGRO-DSSAT model for evaluating the effects of human urine (as an organic fertilizer) application on crop phenology and yield. Furthermore, the paper tries to address the question, whether or, not simulation will expand our understanding of plant-fertilizer interactions and how this could eventually be integrated in cowpea crop production systems.

MATERIALS AND METHODS

Study region

The experimental study was conducted as from May till September 2015 at the Demonstration and Research Plots of the Department of Agricultural Sciences, University of Juba. The study area is located in Juba County, Central Equatoria State at 4°51´33 N latitude, 31° 34´ E longitude and at elevation of about 500 m above sea level. The climate is sub-tropical with mean annual rainfall of 800–1200 mm and a predominantly unimodal distribution. About 80–90% of the rainfall occurs during the rainy months (April–October) with a short dry spell around July. The soil (*Eutric leptosol*) is sandy loam in texture, mild acidic to alkaline in reaction (pH 6.5 - 7.5), low organic carbon by weight (0.55%), CEC in soil (14 cmol/kg) (Table 1, 2).

Experimental design and treatments

The experiment was a Randomized Complete Block Design (RCBD) with two different treatments with five replications each and was conducted from May to September 2015. Each trial was arranged in four randomized complete blocks. Traditional agricultural practices of tillage, seed bed preparation and pest control against aphids, grasshoppers, leaf sucking bugs using ashes from burnt plant leaves were applied. Occasionally, a broad-spectrum pesticide Malathion with application rate of 0.5 l/ha was applied, where the traditional pest control method proved ineffective. Each plot consisted of 5 rows, 2.5 m long, with a spacing of 30 cm between plants and 50 cm between rows. The size of each plot was 5.4 m² with seeds drilled at a sowing depth of 5 cm and density of 30 plants/m^2. The control treatment (irrigation water + No human urine) was designated as T_0 while (irrigation water + human urine: 2 liters per 20 liters water) as T_1. The calculated N-fertilizer amount from T_1 was about 60 kg/ha. Urine from the test person was collected every two days in a 500 ml plastic bottle and mixed with normal water and later kept in a cool dry place until use. Since the overall composition of urine collected was subject to change depending on the nutritional status of the test person, no analytical test on the chemical composition of the urine samples was conducted. Irrigation under both treatments was done once the soil moisture level reached about 15%v/v and was measured using the Theta Soil Moisture Sensor ML3 (Eijkelkamp Agrisearch). The dates of the different phenological stages, i.e. during each trifoliate stage, from seedling emergence to first flower (EM-LF), first flower to end of leaf expansion (R1), pod-setting (FL-SH), maximum leaf size at 8th trifoliate stage (SIZ-LF), plant canopy height (RHIGHT) were all recorded. Leaf Area Index (LAI) was determined directly by measuring the area of the leaves in a plant foliage at any one vegetative stage relative to the surface area covered by the plant. The average LAI was then expressed as a function of the total leaf area for all plants within a given plot. At harvest, the yield per plot was measured by counting the number of pods per plant, seeds per pod (SDPDV), maximum weight per seed (WTPSD) of randomly selected plants. From these figures the grain yield per plot was calculated and projected for entire hectare.

The required weather data for DSSAT WEATHR module, the WGEN subroutine was run to capture the daily rainfall, minimum and maximum air temperature, solar radiation, relative humidity, and wind speed. For Juba County, these data were obtained from the publicly accessible servers of the National Oceanic and Atmospheric Administration (NOAA) of the US Department of Commerce for the years 1980-2014.

Table 1. Some of the physical and chemical properties of sandy loam soil (*Eutric leptosol*) at University of Juba Research and Demonstration Farm.

Soil physical and chemical features	Description
*Soil mapping unit**	*Eutric leptosol*
Texture Classification	Sandy loam
Drainage Class (0-0.5)	Moderately well
Sand (average)	48.9%
Silt (average)	43.7%
Clay (average)	7.4%
pH (LaMotte STH Test Method)	7.0
Nitrate nitrogen	22.68 kg/ha
Phosphorus	170.1 kg/ha
Sulphate	1000ppm (parts per million)
Iron	1.36 kg/ha
Magnesium	Medium
Calcium	396.9 kg/ha
Bulk density (gm/cm^3)	1.34
Humus content	2.95%

*Source: Harmonize World Soil Data viewer version 1.2.

Calculation of cultivar coefficients

The GENCALC program of the Decision Support System for Agrotechnology Transfer (DSSAT Version 4.7) was used to calibrate the cultivar coefficients of the cowpea UCR368 cultivar. GENCALC (Genotype Coefficient Calculator) is a software package that facilitates the calculation of cultivar coefficients for use in existing crop models. Hereby, the coefficients for a genotype are estimated iteratively by running the appropriate crop model with model input data and approximate coefficients, comparing the model output with actual data, and then altering the coefficients until the simulated and measured values match (Hunt *et al*., 1993). In our study, eight morphological traits were selected and calculated by running GENCALC to obtain the best range i.e., the photothermal days from emergence to first flower (EM-FL), from first flower to end of leaf expansion (FL-LF), from flower beginning to pod setting (FL-SH), maximum size of leaf (SIZ-LF), maximum weight per seed (WTPSD), average seed per pod (or pod nr: SDP-DV), photothermal days from seed beginning to physiological maturity (SD-PM) and relative plant/canopy height (R-HIGHT).

Model calibration

The CROPGRO-Cowpea module uses different cultivar coefficients (EM-LF, FL-LF, FL-SH, SIZLF, SDPDV, SD-PM, RHIGHT) amongst others to describe the different phenological stages as a function of time. The CROPGRO-Cowpea model was calibrated for the cowpea cultivar UCR368 with data obtained from May to September 2015 cropping season, to underpin the model´s relevance and application in the region under the current prevailing pedogenic, hydrological and climatic conditions. This was iteratively done through a manual trial and error method, to determine the best possible match between the observed and simulated values to the different default morphological traits obtained from previously grown cowpea cultivar. The values were adjusted to have minimum root mean square error (RMSE) between simulated and observed data. In our study, we used four growth parameters; pod nr/m², canopy height, Leaf Area Index (LAI) and grain nr/m² to evaluate model performance.

Model performance statistics

Model performance for each morphological trait was assessed by comparing the mean simulated with the corresponding measured values based on the Root Mean Square Error (RMSE) and the Index of Agreement or *d*-stat (*d*) (Willmott *et al*., 2012). It was assumed that the best model performance between simulated and measured values was when it gave the lowest RMSE and correspondingly high *d*-value close to 1. The RMSE was computed using the following equation:

$$\mathrm{RMSE} = \sqrt{\sum_{i=1}^{n}(P_i - O_i)^2/n} \qquad (1)$$

and

$$d = 1 - \left[\sum_{i=1}^{n}(P_i - O_i)^2 \Big/ \left(|P_i - \vec{O}_i| - |O_i - \vec{O}_i|\right)^2\right];$$

Where,

$$0 \leq d \leq 1 \qquad (2)$$

Where *n*: number of observations, *P*i: predicted value for the *i*th observation or measurement and *Oi*: observed value for the *i*th measurement, $\vec{O}_i$ is the observed mean of all measurements.

Table 2. Relevant default data used to run the phenology of cowpea in a sandy loam soil under different treatments of moisture content.

Variable	Specification/dimension
Variety /Cultivar	UCR368
Planting date	14/5/ 2015
Emergence date	18/5/2015
Plants/ plot	20
Planting depth	0.03 m
Seeds/hole	2
Planting spacing	0.3 m
Row spacing	0.5 m
Rain fall	depending on rainfall regularity
Plot area	5.4 m^2
Irrigation schedule	Flooding once the soil moisture content was <15% v/v

RESULTS AND DISCUSSION

Cultivar coefficients

Table 3 shows the result of the comparison of observed values during phenology calibrated against those of 2015. The observed times for the genetic coefficient (EM-LF) for T_0 was 4 photothermal days (PD) shorter, but for T_1 was 5 days longer than the calibrated value of 2015. The observed EM-LF for T_1 treatment showed the highest value than either T_0 treatment or calibrated value of 2015 (irrigation schedules without urine addition). The effect of human urine (T_1) appeared to enhance further vegetative growth thus extending the photoperiod to the onset of first flowers. Meanwhile, the observed times for FL-LF was between -6 and +16 PD compared to the calibrated value of 2015 were higher and showed similar effect of human urine (T_1) on R1 and leaf expansion. For FL-SH, these were +4 photothermal days for T_1 than either T_0 or the calibrated 2015 value. The difference between observed maximum leaf area attained at the 8th trifoliate stage (SIZLF) varied between -9 and -14 PD to the 2015 calibrated value. The WTPSD, SDPDV, SD-PM and RHIGHT all showed similar trends of T_1 values higher than either T_0 or the calibrated 2015 value.

Comparisons of the cultivar coefficients between T_0, T_1 and the Y2015 calibrant showed that both T_0 and Y2015 calibrant had about 6-8 days shorter EM-LF than T_1, suggesting that under T_1, the plants required more days for vegetative growth prior to the start of the reproductive phase. A similar tendency was observed for the FL-LF and FL-SH traits that varied between 5-6 days respectively. The SIZLF by T_1 was relatively larger and varied between 8 to 17% more than both T_0 and Y2015 calibrant. There was no significant difference (p<0.05) in the WTPSD under both treatments as well as with the calibrant, but rather in the number of seeds per pod that was slightly higher in T_1 than either T_0 or Y2015. Although both treatments were subjected to equal and timely irrigation schedules, the longer vegetative expansion process resulting into elongated nodes, larger leaf size and subsequently greater canopy height in T_1 than T_0 is attributable to the effects of N-contained in the diluted urine. On the contrary, T_0 had lesser vegetative growth, smaller SIZLF, lower RHIGHT, SDPDV and consequently lesser amount of accumulated dry matter. From an agronomical and plant physiological perspective, T_0 appears to have low determinacy than T_1. Under T_1 with larger SIZLF, there was presumably greater partitioning and accumulation of dry matter to the reproductive organs as shown by the relatively larger WTPSD and SDPDV (Table 3) which subsequently would give higher yield. Although the cowpea UCR368 is considered as a determinate cultivar, the physiological and phenological changes in the morphological traits induced by N-addition give it an indeterminate growth character.

Table 3. Some of the coefficients of cowpea cultivar UCR368 used during calibration and validation. (Irrigation was done, when moisture content was less than 15% v/v).

Cultivar coefficient	Description	Coefficient values		
		2016		2015
		T0	T1	
EM-LF	Time (days) between seedling emergence and first flower	42	48	40
FL-LF	Photothermal days (PD) between first flower (R1) and end of leaf expansion	27	32	20
FL-SH	Photothermal days from beginning flower to pod setting	6	12	7
SIZLF	Maximum size of full leaf in (cm²) at 8th trifoliate stage	38.4	46.5	42.7
WTPSD	Maximum weight (gm) per seed	0.11	0.2	0.13
SDPDV	Average seeds per pod (#nr) under standard growing conditions	14	16	11
SD-PM	Photothermal days from beginning seed to physiological maturity	72-77	76-81	60-66
RHIGHT	Relative plant/canopy height (cm)	62-72	68-79	61-68

Table 4. Growth and yield parameters of cowpea cultivar UCR368 under different treatments during a 5-year simulation period.

Growth and yield parameters	Error and *d*-index values	T_0		T_1	
		Year 1	Year 5	Year 1	Year 5
Pod nr/m²	RMSE	17.3	16.8	38.8**	36.1**
	d	0.46	0.36	0.54**	0.48
LAI	RMSE	0.19	0.18	0.22	0.28
	d	0.36	0.36	0.18**	0.34
Grain nr/m²	RMSE	345	374**	351	343
	d	0.81	0.70	0.52**	0.71
Canopy height (m)	RMSE	0.23	0.23	0.25	0.26
	d	0.18	0.36	0.33	0.36

** significant at p<0.05.

Phenological parameters

Comparisons of phenology parameters between predicted and observed values for Year1 and Year 5 simulations were based on RMSE and *d*-values for both T_0 and T_1 treatments. On average, simulations of the Pod nr/m² for T_1 treatment for Years 1 and 5 showed RMSE values that were between 53-55% higher than T_0 in the respective years (Table 4). The model showed better performance in simulating Pod nr/m² for T_1 than T_0. On the other hand, the Willmott *d*-index for Pod nr/m² for T_1 treatment was significantly different with about 33% difference to T_0 for the simulation period. The RMSE for LAI for both treatments showed no significant differences during the simulation period except for Year 1 under T_0. The model showed poor performance in simulating LAI in Year 1 under T_1 than in T_0 which on average showed relatively low *d*-index at about 0.35. This may be more of an experimental error than a phenological attribute. However, there was significant difference for the RMSE for Grain nr/m² in treatment T_0 for Year 5 simulation, with about 7.7% difference to Year 1 under the same treatment conditions and on average 7.2% more than under T_1 treatment. For the canopy height, both RMSE and *d*-index were more or, less the same under both treatments and simulation period.

Model application

Effect on canopy height: The effect of human urine treatment (T_1) on canopy height during the first 39 DAP showed that although there was some morphological difference to (T_0), this was not significant (p<0.01). The canopy height under both treatments during this vegetative stage was similar to the calibrant Y2015 at about 0.2 m. Canopy height increased thereafter to about 0.6 m for both treatments. On average, the canopy height under T_1 40-60 DAP was 5-12% higher than both under T_0 or that of the calibrant (Figure 1). This gain in canopy height as shown by genetic coefficient (RHIGHT) could be attributed to the continued growth during vegetative stage enhanced by the application of human urine. This was between 68-79 cm under T_1 and 62-72 cm under T_0 (Table 3). On the contrary, findings by (Ndiso *et al*., 2018) while working on cowpea-maize intercrops showed that N-application decreased cowpea canopy height than for maize. The N-application enhanced canopy height in maize giving it a competitive advantage by shading the cowpea plants (Dahmardeh *et al*., 2010). This, therefore reduced photosynthetic activity of the cowpea intercrop. Although not part of our investigation, the combined effects of such macronutrients like phosphorous, potassium as well as other micronutrients contained in the urine (T_1) must have enhanced canopy growth relative to T_0. Such positive effects on biomass increase in okra plants was reported by (Akpan-Idiok *et al*., 2012); and on corn by (Araújo *et al*., 2015).

Effect on pod nr per m²: The CROPGRO cowpea model overpredicted and gave high estimates of the pod nr/m² under both T_0 and T_1 conditions (Figure 2). Rapid pod nr/m² increase for T_0 was between 55 to 61 DAP while this was between 60 to 65 DAP for T_1. Both slightly increased at a decreasing rate till maximum pod nr/m² was reached at 75 and 82 for T_0 and T_1 respectively, at 80 DAP. Results of our study are consistent with those of (Ton and Anlarsal, 2018) who however, used different plant densities and genotypes. The pod nr/m² was affected by application of human urine, but not the time for pod setting that apparently should have been further delayed due to enhanced vegetative growth under T_1. Similar observation in increase in pod nr/m² after N-application was reported by (Elowad and Hall, 1987).

The observed and simulated pod nr/m² clustered slightly above the 1:1 line. The size of RMSE for T_0 and T_1 were 17 and 37 and *d* -indices at 0.54 and 0.55, respectively, indicating that the model did not explain most of the variations in either cases. In Year 5, the observed and simulated pod nr/m² under T_0 clustered more closer to the 1:1 line and gave better prediction. This reduction in pod nr/m² could be due to increased N fixation resulting from accumulation of N in the soil caused by additional application of human urine especially prior to flowering.

Effect on Leaf Area Index (LAI): The development of the observed LAI appeared to be poorly simulated or, was overpredicted in the first 10-35 DAP just between the 2nd and 5th trifoliate stage at the time of intense vegetative growth, but well especially between 40-79 DAP just prior to flowering till physiological maturity. The LAI under T_1 was generally higher than T_0 for most part of the phenology while leveling out after physiological maturity at 82 DAP as in Figure 3. The steep decline in LAI at 60 DAP would suggest a reduction in overall transpiration surface of the plants due to increased senescence with subsequent defoliation. The model overpredicted the LAI. Figure 3 shows, the variability of LAI during different phenological stages. Observed and simulated effect of either treatments on LAI between 20-40 DAP was about 0.31, 0.34 and 0.3 for T_0, T_1 and calibrant respectively. The five-years model simulations and observations of the LAI for both treatments resulted in poor agreements especially during vegetative stages 14-40 DAP, but good agreement when compared to the calibrant 2015. Peak LAI values were reached during reproductive stage 40-60 DAP with gradual decline thereafter until physiological maturity. Model simulations during the five years for T_1 treatment predicted LAI values of between 26-35%, while this was between 28-32.4% for T_0 when compared with calibrant of 2015. The model simulation over predicted LAI values above 0.6 but underpredicted slightly above this value. Under both treatments 55-61 DAP, the maximum LAI ranged between 0.68 for T_0 to 0.88 for T_1. The overall agreement of the measured and simulated data (relative to the 1:1 line) was good with r^2=0.57 and r^2=0.64 for T_0 and T_1, respectively (Figure 3). The RMSE (0.19) with *d*=0.26 during the entire growth period for T_0 was slightly lower than that of T_1 with RMSE (0.25) and *d*=0.36 indicating the slightly better LAI estimation under T_0 than under T_1. The results of this study revealed that application of diluted human urine throughout the vegetative and reproductive stages (27-70 DAP) had significant difference (p< 0.05) on LAI of T_1 than under T_0. Human urine as fertilizer enhanced intense vegetative leaf

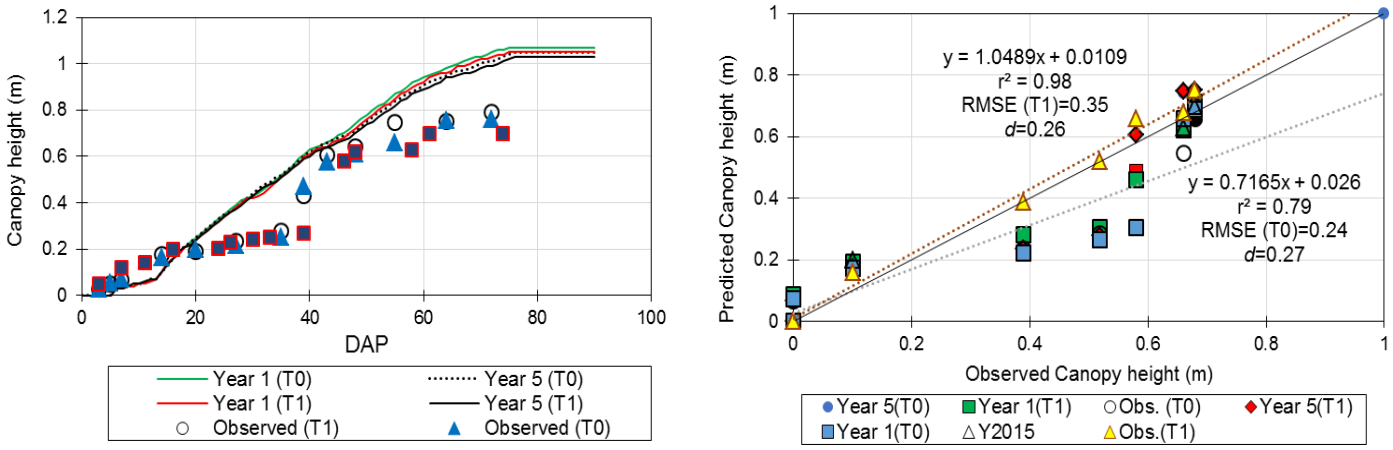

Figure 1. *Comparison between observed and simulated canopy height (m) of cowpea for T_0 and T_1 treatments.*

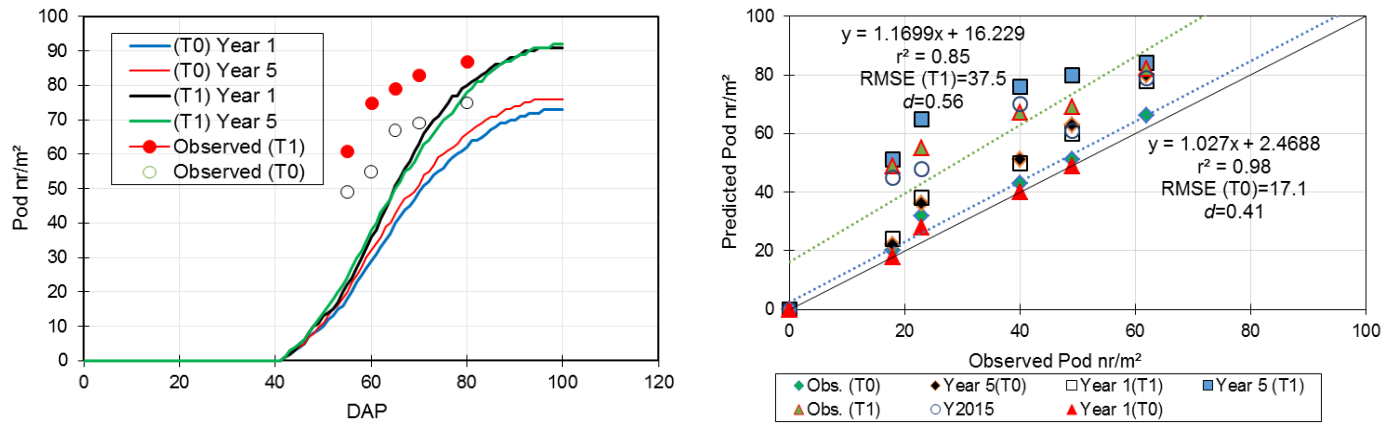

Figure 2. *Comparison between observed and simulated pod nr/m² of cowpea for T_0 and T_1 treatments (a); solid line representing the 1:1 line while dotted blue and red represent regression lines for T_1 and T_0 respectively.*

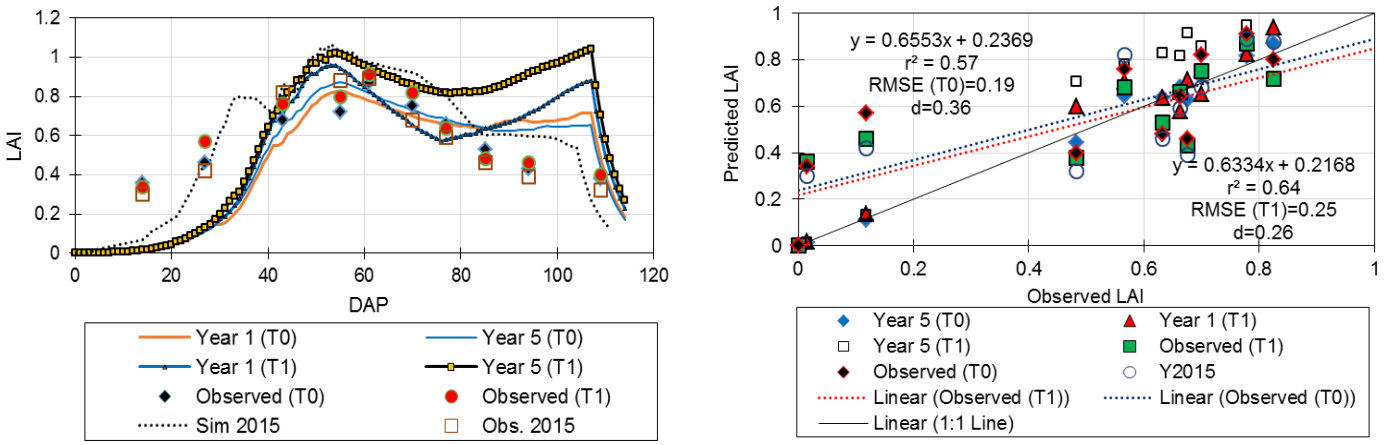

Figure 3. Comparing the observed and simulated LAI of cowpea.

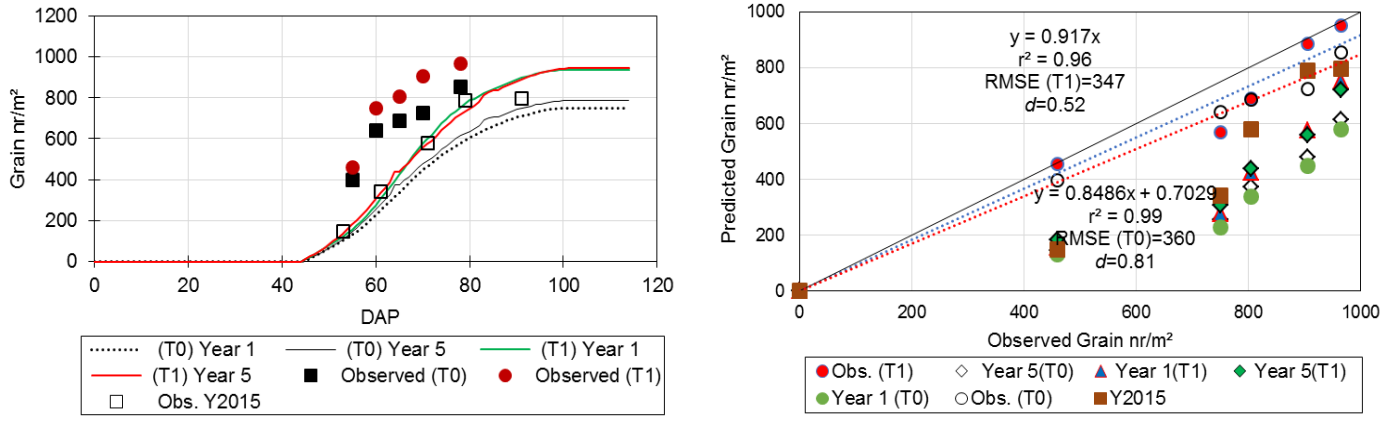

Figure 4. Comparing the observed and predicted grain nr/m² of cowpea under different treatments.

growth, more light interception and hence increased protein photosynthetic activity and nutrient allocation during this period. In general, LAI under either treatment was not a constant variable, but varied at each stage of cowpea phenology. Although the cowpea cultivar UCR368 is a drought tolerant genotype and would withstand water stress periods during phenology, the decline in LAI can be assumed as a natural senescence process. Although, generally the CROPGRO-cowpea model may be used with relative accuracy, more calibration research especially for local dry conditions in South Sudan should be conducted.

Effect on Grain nr per m²: Cowpea grain yield is a product of complex interacting genotypic and environmental factors (GxE). It is strongly and poly-genetically determined by several quantitative trait loci (QTL) that ensure yield output as a function of genetic variability and heritability irrespective of abiotic/biotic stresses the plant is subjected to. Several studies on cowpea have identified some QTL influencing such traits as pod length (Kongjaimun *et al*., 2012a); seed size (Kongjaimun *et al*., 2012b); 1000-seed/grain weight (TGW) and grain number per pod (Pan *et al*., 2017). The cowpea grain yield component is influenced by three main parameters: seeds/pod; pods/plant or grain number/m² and TGW. However, genotypic other than phenotypic expression as influenced by QTL may just be the dominant factor determining the cowpea grain yield. Moreover, finding correlation coefficients between both expressions would give an idea of the mutual interactions and whether, either of them is dominant, recessive or exclusive of the other (Srinivas *et al*., 2017). In this case, both genotypic coefficient of variation (GCV) as well as phenotypic coefficient of variation would indicate which of the expressions have a dominant effect on grain yield.

In our study, the model underpredicted the grain number/m² for both treatments with observed maximum values for T_1 and T_0 at 965 and 855, respectively which were significantly different at $p<0.05$ indicating a differentiated response of the cultivar to human urine application than without. On average, the simulated T_0 value for Years 1 to 5 was about 630 while this was about 767 for T_1. The five-years simulations under T_1 agreed well with calibrated values of 2015 but significantly higher ($p<0.05$) than the simulations under T_0. The RMSE between the simulated and observed grain number per m² under T_0 and T_1 was 360 and 347, respectively, with the relative error margin ranging between 8 and 13% for T_0 and only about 7% for T_1. The RMSE of the observed grain number per m² with the calibrant Y2015 ranged between 5 and 19% for T_0 and T_1, respectively. This wide RMSE range of the calibrant Y2015 to T1 would indicate the significant effect ($p<0.05$) diluted human urine had on grain number per m². Afterall, the cowpea plants under T_0 and T_1 were subjected to similar number of irrigation schedules and therefore, it follows that this wide RMSE range of the grain number/m² to the calibrant Y2015 is solely attributable to the effects of T_1 (Figure 4).

Grain yield and urine fertilizer application

The observed grain number/m² for T_0, T_1 and calibrant Y2015 were 855, 965 and 789, respectively. The difference between each treatment to the calibrant were 56 or 7.1%, 176 or 18.2% for T_0 and T_1, respectively. The results of the five-year simulation with CROPGRO cowpea showed that the grain number/m² under T_1 treatment to the calibrant Y2015 was on average higher at around 944 or 15.8%, while this was at about 785 for T_0, equal to or less than that of the calibrant. Implications are that, both the observed and simulated results under T_1 were comparatively higher than those under T_0. This clearly underpins the long-term effects of human urine as fertilizer on grain number and consequently on cowpea yield. The results of our study confirm the findings of earlier studies on the positive effects on N-application on pods/m², seed weight and yield of cowpea (Elowad and Hall, 1987). However, the presence of other macro- and micro- nutrients contained in the urine should not be underrated especially in influencing the phenology or morphological traits of cowpea.

Conclusion

The five-year (2015-2020) CROPGRO simulation results of cowpea on growth parameters and cultivar coefficients under both treatments found higher correlation coefficients (r^2), with the observed and predicted values when measured in terms of the RMSE and *d*-indices. Whereas the canopy height under both treatments was underpredicted, the pod nr/m² and grain nr/m² were all overpredicted with LAI showing the best prediction results. The DSSAT-CROPGRO model calibration with Y2015 under T_1 was successful especially for both pod and grain number/m², but less satisfactory for LAI and canopy height. Despite these discrepancies, the CROPGRO model can be used in the long-term in predicting phenology, estimating yield and morphological traits of cowpea under the test conditions at the experimental site. This research study showed the positive benefits over 5 years, on the use of diluted human urine as a cheap N-fertilizer. However, there´s still need to conduct further field and simulation tests on the long-term effects of N-fertilizer application on cowpea phenology under the same site conditions that can be calibrated and validated.

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Conflict of interest

No conflict of interest is declared by the authors.

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ORIGINAL RESEARCH ARTICLE

Impact of industrial wastewater disposal on surface water bodies in Kalingarayan canal, Erode district, Tamil Nadu, India

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ABSTRACT

The Kalingarayan canal is crossing the major textile town Erode which is abundantly occupied by textile units. Major streams carrying the untreated / semi treated industrial effluents are mixed into the canal. However, the gradual introduction of a large number of new chemical compounds and the technologies has resulted in a much higher number of contaminants today. The original situation, which local intense pollution from a limited number of well-defined sources has been transferred into a situation with widespread contamination by a large variety of compounds from a multitude of sources. Continuous disposal of industrial effluents on the canal, limited assimilate capacity of the canal and also leads to groundwater pollution. Kalingarayan canal has helped to cultivate more than 6000 hectares. For the past few years, Kalingarayan farmers and cattle are experiencing various problems. The area of cultivation is reduced to 3000 hectares because of the contamination in the canal by the different polluting industries like tanneries, textiles and dyeing units located in Erode and Tirupur areas. Hence yield on their lands has decreased to a certain extent. Thus, this study gives a clear picture of pollution sources, types of effluents added in the canal. The scope of the present study is to assess the impact on the surface water of the Kalingarayan canal, a comprehensive experimental study to identify the pollutant levels in the surface water of the Kalingarayan canal and to suggest a suitable remedial measure to handle this problem.

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INTRODUCTION

The Bhavani is a river of southern India, a tributary of the Kaveri. A small barrage across the river Bhavani was built by Kalingarayan in 1283 AD to feed the 56-mile-long Canal build for irrigation purposes, which is now known by his name Kalingarayan Canal. Bhavani river joins the River Noyyal at Aavudaiaaparai is more or less a perennial river fed mostly by the southwest monsoon. The northeast monsoon also supplements its water resources (Mohanakavitha *et al.*, 2019a). Before the development of industries near the canal, the water in the canal was used for irrigation and drinking water. Because of significant industrial and agricultural development, as well as an increase in the city's population the water quality gradually deteriorated in the canal (Sivakumar *et al.*, 2010). There are 39 leather processing units, more than 10 major textiles processing units, less than 150 Dyeing and Bleaching units present in the Kalingarayan canal command area. There are more than 57 Bleaching units in the command area operating without any approval (Sivakumar *et al.*, 2010; Gayathri *et al.*, 2013). The amount of treated and untreated wastes discharged into the canal by domestic and industrial activities which deteriorated

the water bodies and make them unfit for many useful purposes (Mariraj Mohan and Vanalakshmi, 2013; Samuel Rajkumar and Nagan, 2011; Gayathri *et al.*, 2013; Palanisamy *et al.*, 2007). The Kalingarayan canal near Bhavani town receives wastewaters at different places from industries along with domestic sewage (Mohanakavitha and Meenambal, 2013). To study the impact of the industrial effluents and domestic sewage on the quality of surface water in the Kalingarayan canal, water samples were collected from some areas and the samples were analyzed for various physicochemical parameters.

The quality of groundwater is influenced by natural and anthropogenic activities (Farooq and Ustad, 2015). Chandan *et al.* (2013) made a study to identify the causes, status, impacts and degree of water pollution of Buriganga River. From the assessment, it is revealed that the river water was highly polluted by both natural and anthropogenic activities (industries and agrochemicals). Thoker *et al.* (2012) discussed the impact of dye industrial effluent on the physicochemical characteristics of Kshipra River, Ujjain City, India. They made an assessment of water quality being polluted by the effluents. The parameters selected for the study were pH, temperature, electrical conductivity, total solids (TS), total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), chemical oxygen demand (COD), total alkalinity, total hardness and chloride content.

Tenagne (2009) studied the impact of urban storm water run-off and domestic waste effluent on water quality of Lake Tana and local groundwater near the city of Bahirdar, Ethiopia. From the result found during the study period, major conclusions were drawn. The run-offs collected from areas where hotels and other commercial centers are located have an elevated value of nitrogen and phosphorus which are excessive in the concentration that causes eutrophication of the lake. Spatial variation of groundwater quality depends on the geological formation through which it flows and on anthropogenic activities in the groundwater basin (Aravindan and Shankar, 2011; Shankar *et al.*, 2010; 2011; 2011a; 2011b; Venkateswaran *et al.*, 2012; Kawo and Shankar, 2018; Mohanakavitha *et al.*, 2019b). Water chemistry analysis can be used as a tool for checking groundwater suitability for drinking and irrigation purposes, numerous studies were conducted in south India (Palanisamy *et al.*, 2007; Geetha *et al.*, 2008; Kulandaivel *et al.*, 2009; Sivakumar *et al.*, 2011; Aravindan *et al.*, 2008; 2010; 2011; Zahir Hussain and Rajadurai, 2013; Abdul Bari and Vennila, 2014; Abdul *et al.*, 2015; Mahalakshmi *et al.*, 2018; Balusamy and Indrani, 2018; Mohanakavitha *et al.*, 2019a). Govindarajalu (2003) studied the nature and impact of water pollution in the Noyal river basin in Coimbatore, Erode and Karur districts. The main thrust on the study is on the health status of villagers, agriculture and the livestock population. For this purpose 31 villages and 600 households were selected for the primary survey. To understand the magnitude of the impact of water pollution on the health status of the villagers, three major health camps were conducted. It is evident from the study that almost all the 31 sampled villages are affected by the industrial effluent.

Moreover, Kiran (2010) determined the physicochemical and bacteriological parameters that deteriorate the quality of drinking water at the source of Vadgam taluk in Gujarat, India and evaluated for its parameters of temperature, colour, odor, turbidity, electrical conductivity (EC), pH, total dissolved solids (TDS), total alkalinity, chemical oxygen demand (COD), chloride, fluoride, calcium and magnesium. Quality of the sample was compared with drinking water standards of ICMR (Indian Council of Medical Research, 1975) and EU (European Union 1998). For the statistical analysis, values of mean, standard deviations and correlation co-efficient (r) were also calculated for these water quality characteristics. It is concluded that the quality of water samples is acceptable to the majority of the physicochemical parameters but as TDS values of most of the samples are violating the desirable limit suggested by ICMR, the water should be treated properly before its usage as drinking water to avoid possible adverse effects. From the literature study, it is understood that water pollution cause undesirable changes in the chemical and physical properties of water which are not favorable to domestic purposes. The changes in water quality are due to the physical and chemical characteristics of the effluents received by the canal water. The contamination of water bodies such as lakes, rivers, oceans, aquifers and groundwater causes environmental degradation when pollutants are directly or indirectly discharged into water bodies without adequate treatment to remove harmful compounds (Kumar *et al.*, 2018; Kumar *et al.*, 2019).

The Kalingarayan Canal is one of the historically important sources of water for irrigation in the Erode district. The water in the channel was recently polluted by untreated tannery and textile effluents (Balusamy and Indrani, 2018). It was therefore decided that a study on water quality and its polluting load is felt necessary to the users of the canal water. The water quality is analyzed for physicochemical characteristics. It was felt necessary to evaluate the quality of the water used in irrigation and other purposes in the Canal. This study assesses the quality of canal water and the impacts of industry effluents. This study will be very useful in understanding the impact of effluent dumping in the Canal and the impact on water quality in terms of irrigation and environmental impacts.

MATERIALS AND METHODS

Study area and its location

The Bhavani River, the second largest river in Tamil Nadu, begins in the Western Ghats upper regions of Nilgiris. In the district of Erode, a small amount of water from the Bhavani River is diverted into a canal called the Kalingarayan Canal near Bhavani Town for irrigation purposes. The Kalingarayan Canal is a 56-mile irrigation canal. The Kalingarayan Canal is located on the western bank of the river Cauvery at 77° 40´ E to 77° 48´ E longitude and 11° 16´ N to 11° 26´ N with an area of 7621 Sq.km (Figure 1). The 750 year old Kalingarayan canal travels about 90 km from Kalingarayan anaicut to Avudayaparai. It was built by Kongu chieftain Kalingarayan and finished in the year 1283. The canal has been designed with a meandering route to maximize the benefit of the land. It is 534 feet above sea level where it originates and 412.40 feet above sea level, where it merges with

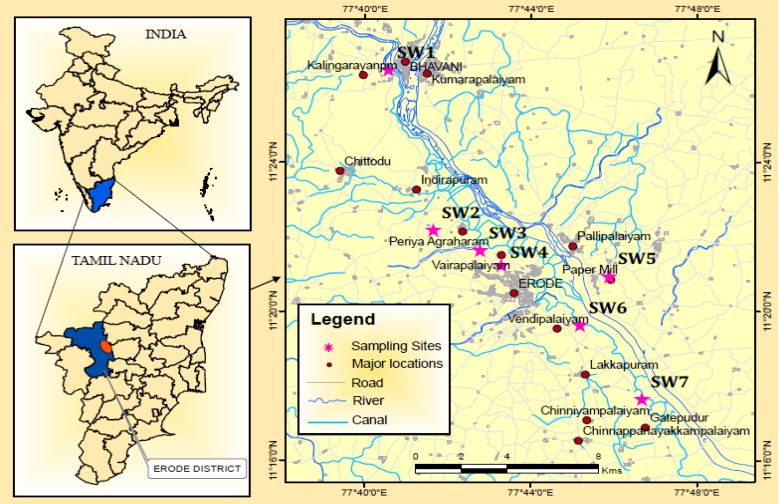

Figure 1. *Location map with sampling sites in the study area.*

Table 1. Locations of surface water samples in the study area.

Sample Code	Latitude	Longitude	Sampling Locations (Polluting factors)
SW1	11°26'26.69"N	77°40'36.27"E	Kalingarayan Anicut (Agricultural Activities)
SW2	11°23'13.92"N	77°41'43.78"E	Chunnambu Oodai (Tanneries)
SW3	11°21'49.29"N	77°42'43.45"E	Convent School (Domestic area)
SW4	11°21'44.96"N	77°43'16.18"E	Vairapalayam (Dyeing units)
SW5	11°21'27.98"N	77°44'12.87"E	Pallipalayam (Paper mills)
SW6	11°19'37.77"N	77°45'9.56"E	Vendipalayam (Domestic area)
SW7	11°17'37.41"N	77°46'39.02"E	Colony Pudur (Domestic area)

Table 2. Parameters and methods for surface water analysis.

S.N.	Parameters of water analysis	Methods	Instrumentation
1	pH in standard units	Potentiometer	pH meter
2	Electrical Conductivity in µs/cm		Conductivity Meter
3	Total dissolved Solids in mg/L		Gravimetric method
4	Total Suspended Solids (TSS)		Oven/ Gravimetric method
5	Dissolved Oxygen, COD in mg/L	Winkler's method	Titration
6	Biochemical Oxygen Demand, BOD in mg/L		
7	Nitrates in mg/L	Brucine method	UV –Vis Spectrophotometer
8	Phosphate in mg/L	Stannous chloride method	

the River Noyyal. The channel goes through a serpentine route. The canal connects the rivers Bhavani and Noyyal, the two main Cauvery tributaries. The land survey showed that the area irrigated is 15,743 acres.

Sample collection and sampling procedure

A study was conducted from 2014 -2015 and seven surface water samples were collected from different sampling locations on the way to the Canal, at a stretch of about 35km from Kalingarayan Anaicut to Colony Pudur. Seven stations were selected as sampling points in the Kalingarayan Canal for the season's *viz*., Pre-monsoon (June, July, and August), Monsoon (September, October, and November), post-monsoon (December, January, February) and summer (March, April, and May). The study area of the canal was the starting place where the discharge of domestic sewage and washing of vehicles, bathing of animals, human activities releasing of municipal wastes as the main sources of pollutants in the Kalingarayan canal (Balusamy and Indrani, 2018). Hence the study has been carried out to analyze the physicochemical parameters of the canal water. Surface water samples from the Kalingarayan canal were collected from different sampling sites in Table 1. Two liters of wastewater prior to mixing with the watercourses from each station were collected in thoroughly rinsed plastic containers, labeled and brought to the approved laboratory on a monthly basis. The samples were analyzed using a standard procedure (APHA, 2012) given in Table 2. The pH of water samples were measured in the field. Samples were subjected to filtration prior to chemical analysis. The samples were preserved in the laboratory at 4°C and various physicochemical parameters were determined (Tripathi *et al*., 1990; 2012). The values obtained for various physicochemical parameters after the analytical study are given in Table 3. All the samples analyzed were not having any objectionable colour, appearance, taste or odour. Summary of the measured physicochemical parameters and the calculation of the maximum, minimum, mean and standard deviations found in different water samples and the final results of the physicochemical concentration are compared by the World Health Organization (WHO, 2011) as shown in Table 3. Statistical analysis was carried out using Statistical Package for Social Sciences (SPSS 10.0). The correlation coefficient values among the parameters for canal ground water are presented in Tables 4a-d.

Table 3. Physicochemical parameters after the analytical study.

Parameters	Seasons	Physicochemical Concentration							Statistical data				WHO (2011)
		SW1	SW2	SW3	SW4	SW5	SW6	SW7	Min	Max	Avg	STD	
pH	Pre-monsoon	7.38	7.58	7.69	7.61	7.7	7.61	7.4	7.38	7.7	7.57	0.13	6.5-8.5
	Monsoon	7.12	7.2	6.9	6.92	7.5	7.31	7.4	6.9	7.5	7.19	0.23	
	Post-monsoon	7.9	8.12	8.6	7.94	7.4	7.2	7.3	7.2	8.6	7.78	0.51	
	Summer	6.88	7.42	7.56	7.4	7.26	7.8	7.78	6.88	7.8	7.44	0.32	
Conductivity (µS/cm)	Pre-monsoon	306	314	521	400	420	417	420	306	521	399.71	72.99	1000
	Monsoon	340	370	396	420	460	530	460	340	530	425.14	64.02	
	Post-monsoon	1600	7850	8280	4600	500	510	480	480	8280	3402.86	3502.03	
	Summer	410	362	380	386	552	440	510	362	552	434.29	71.55	
TDS (mg/L)	Pre-monsoon	230	246	394	310	326	320	324	230	394	307.14	54.84	500
	Monsoon	270	290	308	322	350	390	350	270	390	325.71	40.86	
	Post-monsoon	1010	4042	4190	2510	2400	2300	3000	1010	4190	2778.86	1096.19	
	Summer	308	266	270	278	380	310	356	266	380	309.71	43.93	
TSS (mg/L)	Pre-monsoon	3	2.9	3.26	3.1	4.12	4.2	3.98	2.9	4.2	3.51	0.57	-
	Monsoon	9	8.4	8.1	12	11	12.4	13	8.1	13	10.56	2.03	
	Post-monsoon	32	46	51	49	50	52.3	54.2	32	54.2	47.79	7.42	
	Summer	11	8.6	9.3	14.6	12	11.2	14.6	8.6	14.6	11.61	2.34	
COD (mg/L)	Pre-monsoon	41	90	84	72.6	70.1	84	48	41	90	69.96	18.81	10
	Monsoon	23	93	82	72	72	79	29	23	93	64.29	27.15	
	Post-monsoon	69	174	179	148	84	83.4	82.3	69	179	117.10	47.92	
	Summer	30.6	69	70	71.1	86	89	26	26	89	63.10	25.08	
BOD (mg/L)	Pre-monsoon	8.1	14	13.1	10.4	10.8	11.9	7.9	7.9	14	10.89	2.33	5
	Monsoon	3.8	15	12.6	11.2	11.3	11.9	6	3.8	15	10.26	3.93	
	Post-monsoon	9.1	29	22	16	13.2	12.3	5.3	5.3	29	15.27	8.01	
	Summer	7.4	10.32	11	11.22	13.4	14.1	4.4	4.4	14.1	10.26	3.38	
Nitrogen (mg/L)	Pre-monsoon	2.2	3.8	3.1	3	2.4	2.6	2.1	2.1	3.8	2.74	0.60	50
	Monsoon	1.3	4.1	3.6	3.1	2.9	2.92	1.8	1.3	4.1	2.82	0.97	
	Post-monsoon	2.68	2.4	2.8	2.84	2.4	2.3	1.9	1.9	2.84	2.47	0.33	
	Summer	1.36	3.92	3.42	3.21	3.14	2.8	2.2	1.36	3.92	2.86	0.85	
Phosphate (mg/L)	Pre-monsoon	1.83	4.9	4.6	3.2	3.2	3.6	1.2	1.2	4.9	3.22	1.35	10
	Monsoon	1.63	5.12	4.4	3.9	3.9	4	2.14	1.63	5.12	3.58	1.25	
	Post-monsoon	3.6	3.9	4.1	3.94	3.5	4.1	2.2	2.2	4.1	3.62	0.67	
	Summer	1.7	4.9	4.3	3.84	4.22	3.88	2.3	1.7	4.9	3.59	1.15	

RESULTS AND DISCUSSION

pH and Conductivity

All the samples had their pH values between 6.88 to 8.6 and these were well within the permissible limit of 6.5 to 8.5 prescribed for drinking water by Indian standards. The pH of water in the study area is found to be alkaline in nature. The highest pH value was observed in running water into the canal at the two locations Chunambu Oodai and convent school (Figure 2a) in post-monsoon and a significant difference was noted in the observed pH which may be due to the dilution effect (Mohanakavitha *et al.*, 2019b.) The alkaline nature of groundwater is due to chemicals and water-mixed soap from both industrial and residential environments (Radhakrishnan *et al.*, 2007). The observed values, however, were well within the safe limit for crop production. EC is a good measurement of salinity hazard to crop when using groundwater for irrigation. A Similar trend was also observed in the case of conductivity. The values of conductivity ranged from 306 to 8280 mmhos/cm regarding the highest conductivity at convent school (Figure 2b) maybe due to the mixing of dyeing wastewater. The lowest conductivity may be due to the dilution effect of rain water. The conductivity value was found not with in the permissible limit. If the EC value exists at 3000 mmhos/cm, the production of as in almost all crops would be affected and the yield might be reduced significantly (Srinivas *et al.*, 2000; Sacchidananda and Prakash, 2006).

Total dissolved solids

The total dissolved solids (TDS) of the different sites of canal water samples where the flows of water in the canal were found within the permissible limit (1000 mg/l) of WHO standards. If the TDS value exceeds the permissible limit, the water is not suitable for drinking purposes (Sandeep Arya *et al.*, 2011). Due to the nature of flow runoff water occur during heavy rainy seasons certain variation may occurred but this variation did affect the irrigation system. The values of TDS ranged from 307.14 to 2778.86 mg/l. The high TDS values of water samples collected in no flow of water into the canal, which is in the Chunnambu Oodai and Convent School (Figure 3) in post-monsoon. These two locations have dyeing units. These also confirm the fact that the discharge of effluents from dyeing units into the canal water may also be the reason for the very high TDS values observed for the samples collected from other locations which are having many dyeing units (Balusamy and Indrani, 2018).

Total suspended solids

The values of TSS ranged from 3.51 to 47.79 mg/l. Although all the effluents had a higher concentration of total suspended solids, the sewage effluent at the top had very high values (Balusamy and Indrani, 2018). Spatial-temporal variation shows a high concentration of TSS during the post-monsoon period (Figure 4). The suspended solids determination is particularly useful in the analysis of sewage and other wastewaters and is as significant as BOD determination (Kulandaivel *et al.*, 2009). It is used to evaluate the strength of domestic waste waters and efficiency of treatment units. Suspended solids are objectionable in the canal for many reasons. Suspended solids containing much organic matter may cause putrefaction and may be devoid of dissolved solids. The concentration of TSS at all points was collected in no flow of water into the canal which may be attributed to the direct discharge of domestic and industrial waste.

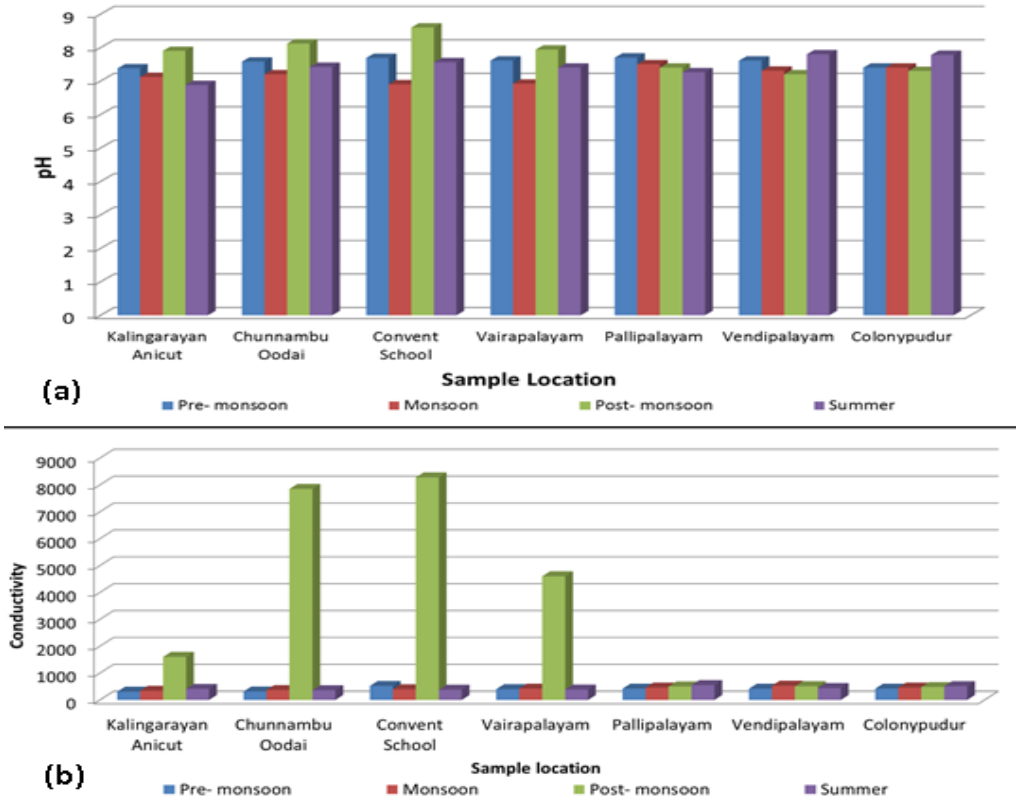

Figure 2. *Spatio-temporal variation of (a) pH, (b) Conductivity (mmhos/cm).*

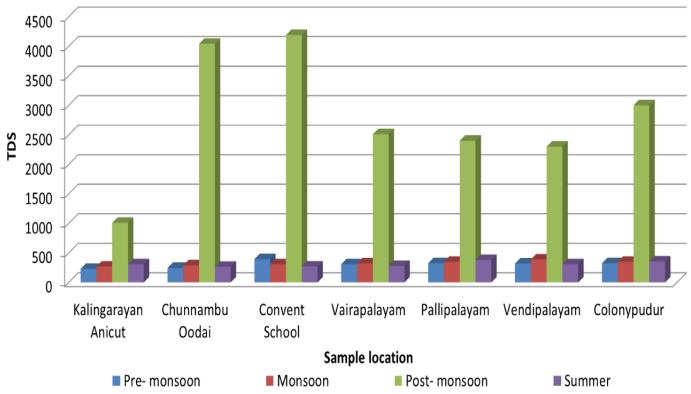

Figure 3. *Spatio-temporal variation of TDS (mg/L).*

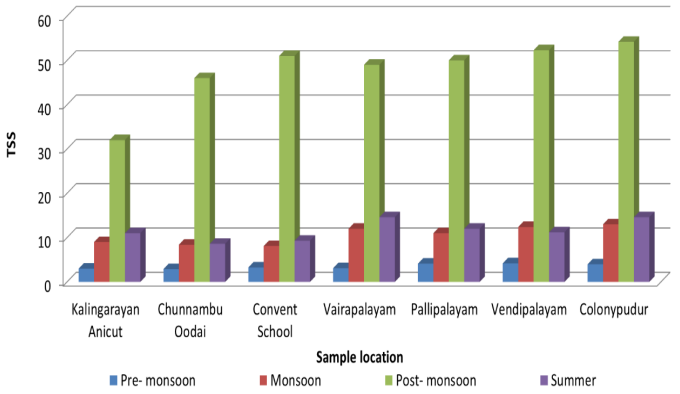

Figure 4. *Spatio-temporal variation of TSS (mg/L).*

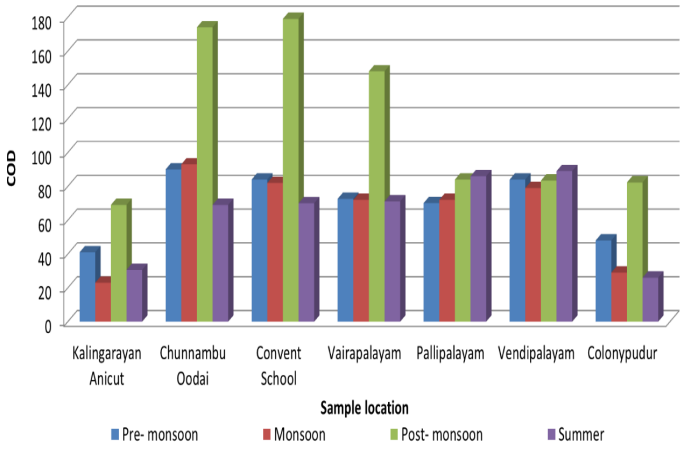

Figure 5. *Spatio-temporal variation of COD (mg/L).*

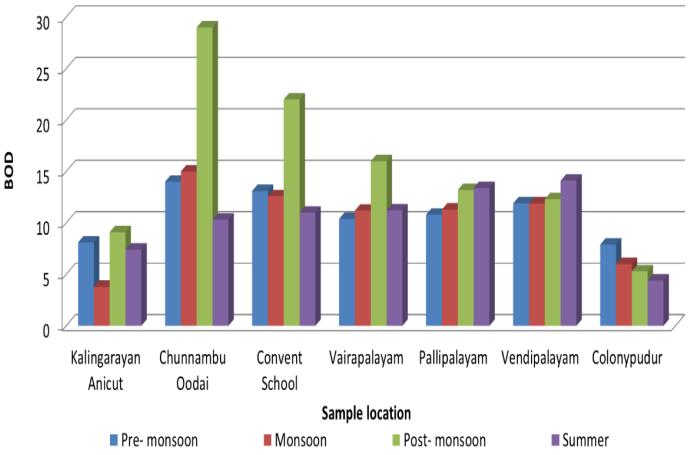

Figure 6. *Spatio-temporal variation of BOD (mg/L).*

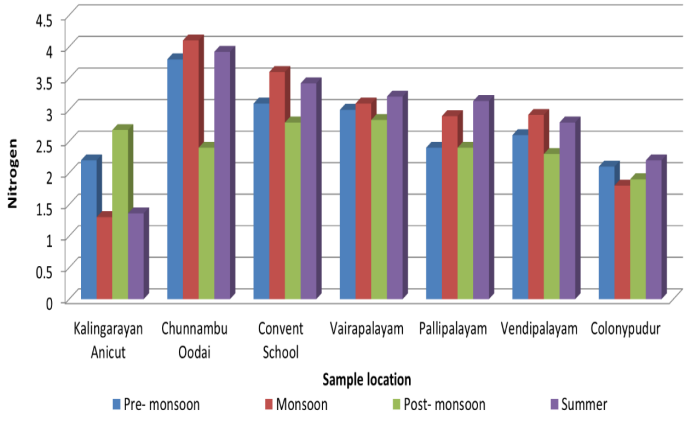

Figure 7. *Spatio-temporal variation of Nitrogen (mg/L).*

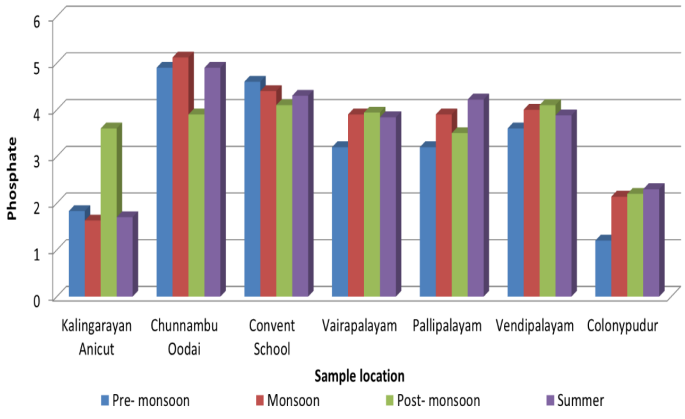

Figure 8. *Spatio-temporal variation of Phosphate (mg/L).*

Chemical oxygen demand

COD test is quite useful in finding the pollution strength of industrial waste and sewage. Chemical oxygen demand is the amount of oxygen required for a sample to oxidize at its organic and inorganic matter (Sivakumar *et al.*, 2010). The COD value of the canal investigated ranged from 23 mg/L to 179 mg/L. The highest value of COD was observed at point Convent School (Figure 5) could link with the inflow of the dyeing unit's effluent which is being discharged into the canal. The higher COD values in the samples indicate the presence of an increased concentration of industrial pollutants containing inorganic and organic substances, thus showing a greater toxicity level (Balusamy and Indrani, 2018).

Biochemical oxygen demand

BOD determination is still the best available single test for assessing organic pollution. BOD concentration found in 3.8 to 29 mg/L in all seasons indicating here water is highly polluted. The observed BOD of water samples value was an indication for the entry of organic waste in the canal (Usharani *et al.*, 2010). The high BOD values suggest more waste product or pollutants are present in Chunnambu Oodai (Figure 6). This may be a result of the escape of organic matter into the canal mostly from fecal deposition by the surrounding populace. During its flow, a significant part of its organic matter, originating from domestic sewage and industrial effluents, is carried by canal water (Kulandaivel *et al.*, 2009).

Nitrogen

The nitrogen content in irrigation water is generally considered beneficial, barring the nitrate form of nitrogen (Grasshoff *et al.*, 1999). It also contained that discharge of ammonium nitrogen and subsequent oxidation that could reduce the DO level in the canal (Khaiwal *et al.*, 2003). The nitrogen concentration of the water sample ranged from 1.3 mg/L to 4.1 mg/L (Figure 7). Both phosphate and nitrate are component of agricultural fertilizer commonly used by farmers within the state. These fertilizers may be leached into the soil and river bodies and this may account for significant concentration observed in this study (Rajaram *et al.*, 2005; Ashok Prabu *et al.*, 2005).

Phosphate

Phosphates are obtained from the rocks converting them into its soluble forms and may also occur in agricultural runoff, industrial wastes, municipal sewage and synthetic detergents. The high concentration of phosphate is always indicative of eutrophic (Fareed and Abid, 2005). The phosphate concentration of the canal ranged from 1.2 mg/L to 5.12 mg/L which was found to be above the permissible limit (0.1mg/L). The spatial-temporal variation shows a high concentration in the post-monsoon period (Figure 8). The maximum level of phosphate was found in the canal water where it receives maximum sewage, domestic wastes and human activities (Saravanaraja *et al.*, 2017). The use of detergent may increase the phosphate concentration to a great extent. The anthropogenic additions of phosphorus to the canal have a considerable effect on the quality of the water. Such phosphorus is derived mainly from domestic sewage and the runoff from agricultural areas (Usharani *et al.*, 2010). The quantity of phosphorus in the domestic sewage and land drainage have increased considerably in recent years due to the increased use of synthetic detergents which contain approximately by weight, the inorganic condensed purposes and the detergents would enhance a load of this element. A higher amount of phosphate represent high pollution loads and causes eutrophication of the aquatic body.

Table 4a. Correlation matrix analysis result for Pre- monsoon.

	pH	Conductivity	TDS	TSS	COD	BOD	Nitrogen	Phosphate
pH	1.000							
Conductivity	0.557	1.000						
TDS	0.582	0.997	1.000					
TSS	0.163	0.416	0.439	1.000				
COD	0.812	0.303	0.331	-0.041	1.000			
BOD	0.747	0.214	0.230	-0.200	0.961	1.000		
Nitrogen	0.487	-0.072	-0.051	-0.574	0.808	0.868	1.000	
Phosphate	0.770	0.201	0.214	-0.295	0.940	0.988	0.881	1.000

Table 4b. Correlation matrix analysis result for Monsoon.

	pH	Conductivity	TDS	TSS	COD	BOD	Nitrogen	Phosphate
pH	1.000							
Conductivity	0.521	1.000						
TDS	0.533	0.999	1.000					
TSS	0.458	0.781	0.784	1.000				
COD	-0.195	0.188	0.182	-0.259	1.000			
BOD	-0.149	0.183	0.180	-0.240	0.991	1.000		
Nitrogen	-0.268	0.033	0.032	-0.352	0.968	0.984	1.000	
Phosphate	-0.190	0.127	0.124	-0.293	0.992	0.998	0.990	1.000

Table 4c. Correlation matrix analysis result for Post-Monsoon.

	pH	Conductivity	TDS	TSS	COD	BOD	Nitrogen	Phosphate
pH	1.000							
Conductivity	0.909	1.000						
TDS	0.494	0.747	1.000					
TSS	-0.275	-0.004	0.580	1.000				
COD	0.811	0.967	0.815	0.209	1.000			
BOD	0.693	0.889	0.713	0.038	0.883	1.000		
Nitrogen	0.728	0.537	-0.052	-0.426	0.481	0.414	1.000	
Phosphate	0.486	0.507	0.110	-0.184	0.488	0.636	0.749	1.000

Table 4d. Correlation matrix analysis result for summer.

	pH	Conductivity	TDS	TSS	COD	BOD	Nitrogen	Phosphate
pH	1.000							
Conductivity	0.125	1.000						
TDS	0.018	0.990	1.000					
TSS	0.180	0.480	0.478	1.000				
COD	0.233	-0.034	-0.126	-0.291	1.000			
BOD	0.074	-0.051	-0.120	-0.318	0.973	1.000		
Nitrogen	0.355	-0.288	-0.393	-0.365	0.712	0.558	1.000	
Phosphate	0.299	-0.245	-0.347	-0.456	0.839	0.721	0.972	1.000

Correlation matrix analysis

The correlation coefficient is the relationship between the variables and the measurement of one variable depends on other variables or not. In order to identify the relationship between the physicochemical parameters of the water samples, correlation coefficients have been established and a large number of significant correlations have been obtained (Helena *et al*., 2000; Usharani *et al*., 2010). A correlation matrix was generated for 8 variables for four different seasons pre-monsoon, monsoon, post-monsoon and summer (Table 4a, b, c, d). The correlation coefficient ranges between-1 and+ 1. The values found above 0.5 have been highlighted and considered for the relationship study. If the correlation coefficient is between 0.5 and 0.8, a moderate relationship was considered and above 0.8, a strong relationship was considered (Vishwakarma *et al*., 2019). It is clear from the results that the TSS was negatively correlated with all variables and was not significantly correlated with any of the parameters in all seasons. During the Pre-monsoon and monsoon (Table 4a, b) strong correlation is exhibited between EC with TDS; COD with BOD, nitrogen, Phosphate; BOD with nitrogen, Phosphate; Nitrogen with Phosphate. Moderate correlation exhibits between pH with EC, TDS, BOD, Phosphate (Pre-monsoon); pH with TDS in monsoon, indicates the discharge of sewage, domestic wastes and human activities. In post -monsoon due to dilution effect strong correlation between pH with EC, COD; EC with COD, BOD; TDS with COD; COD with BOD. Moderate correlation is between pH with BOD and Nitrogen; EC with TDS, nitrogen, Phosphate; TDS with TSS, BOD; BOD and Nitrogen with Phosphate. In summer the strong correlation between EC with TDS; COD with BOD, Phosphate; Nitrogen with Phosphate; a moderate correlation between COD with Nitrogen; BOD with Nitrogen with Phosphate. The correlation analysis is identified that EC, COD, BOD, Nitrogen, find higher- level correlation significance with water quality parameters in all seasons. It provides a means to monitor the quality of water in an area more easily and quickly. Achuthan Nair *et al*., 2005 concluded that a correlation analysis and correlation coefficient values can help to identify treatments to mitigate groundwater pollution.

Impact of industrial wastewater disposal on surface water bodies

Effluents if released prior to treatment, harm the water bodies as well as the paths through which they traverse, as the pollutants in these effluents are still in their complex form and can therefore not be degraded by the micro-flora and fauna The leather processing or the tannery industry has very complex by-products as a result of its activities and hence has among its varied components, a high amount of chrome compounds as well as other miscellaneous heavy metals. The textile industry on the other hand has effluents rich in salts such as sodium chloride and sodium sulphate. In addition to these, effluents are also known for their highly objectionable odour. Kalingarayan Canal, the lifeline of hundreds of farmers in the district, now faces fresh onslaught of pollution.

Conclusion

The analysis showed that the quality of the Kalingarayan canal in the study area is significantly affected by the discharge of toxic effluents and sewage water. It is observed that during non flow times of canal water the effluents discharged by the dyeing units and sewage discharged by the near by residences deposits in the canal itself which is cause of the increase pollution. Due to the discharge of sewage, domestic wastes and human activities the phosphate load in canal water exceeds the permissible limit. Since the sewage mixes with the canal, the canal water cannot be used for irrigation and drinking purposes. Regular monitoring of canal and taking suitable remedial measures like collection of domestic sewage and setting up the common treatment plant before discharge of sewage into canal. Wastewater should be treated. This will control pollution and prevent the depletion of the quality of canal water.

Conflict of interest

The authors declare there are no conflicts of interest.

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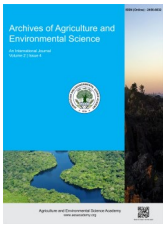

CASE STUDY

Sustainability of smallholder seed enterprises (SSE): A case study of Nagarpur and Shahjadpur Upazila, Bangladesh

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ABSTRACT

Smallholders' seed production, processing, and marketing of major crops such as rice, wheat, and maize have been important issues for seed security worldwide. According to the Food and Agriculture Organization reports, the smallholder's seed enterprise (SSE) is the best way of ensuring the availability of quality non-hybrid seeds. The concept of SSE is built to fulfill the farmer's seed demand by the development of their own seed production system. It is so important for sustainable agriculture. Although, this system does not perform properly due to some limitations. So, the present study aimed to assess the important indicators that directly related to the sustenance of smallholder's seed enterprises. It will be helpful to enhance SSEs effectiveness. Data were collected from 120 smallholders of six villages of Nagarpur and Shahjadpur Upazila under Tangail and Sirajganj districts in Bangladesh, respectively. Results revealed that 92.5% of the smallholder had moderate to highly sustainable seed enterprises. Based on standardized coefficients, institutional functions, price of seed, human capital and marketing facilities considered as highly influential indicators. Finally, the existing institutions play a key role in achieving the sustainability of SSEs by providing necessary supports.

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INTRODUCTION

Seed products are basic agricultural input. Quality seeds of any recommended variety are the basis of improved agricultural productivity since these seeds respond to farmers' needs for both their increasing productivity and crop quality (Pelmer, 2005). Over 90% of the crops with the crops in establishing countries are still rooted in farmers' varieties and farm-saved seeds (Almekinders *et al*., 1994; Almekinders and Louwaars, 1999; Maredia *et al*., 1999; World Bank, 1998). As a result, large international seed companies concentrate on those countries with large commercial seedling sectors, often concentrating on higher-value crops grown by simply larger farmers in even more favorable areas, i.e. targeting those who are best able to pay for their seeds. They are likely to prevent self-pollinating crops (Rice, wheat, etc.) which include most of the crops smallholder farmers grow and on which they depend for their food security because these usually are the crops for which farmers save their own seeds, reducing opportunities regarding commercial seed production associated with these crops.

In the past, public sector universities, governmental organizations, and global organizations were a major source of new varieties and quality seeds of food crops for the smallholder farming sector, especially along with regards to self-pollinating crops.

Nevertheless, in recent yrs., many countries have motivated privatization or commercialization associated with public sector seed activities, while international organizations have faced budget constraints, major to reduced investment in public-sector plant breeding in addition to seed production enterprises. Therefore, public-sector seed activities possess tended to target the narrow range of crops grown by larger maqui berry farmers. This way, reducing supplies associated with the seed of new kinds of subsistence crops to smallholder farmers even further (Bengtsson, 2007). Nevertheless, there are a number regarding examples throughout the globe where seeds of cultivars are supplied by prosperous small to medium-scale seed enterprises or farmer businesses. The Food and Agriculture Organization (FAO) regards typically the Smallholder Seed Enterprises (SSEs) as the best method of ensuring the in addition to quality of non-hybrid seed for food and nourish crops in developing nations around the world as they recognize the particular contribution of smallholder seedling enterprises in addressing international challenges, such as attaining the Millennium Development Targets (MDGs), adaptation to weather change and the attainment associated with food and nutrition safety (FAO, 2010). Sustaining typically the growth of smallholder seed enterprises through the advertising of public and exclusive partnerships and capacity building is a focus area regarding FAO.

The term 'smallholder farmer' varies among nations around the world and ecological zones due to different factors such since crop types, the area developed and produced. People who else participate in the daytime to day activities by providing labor and management of the farm/livestock can be considered as smallholder maqui berry farmers (Babu and Sanyal, 2010). The World Development Report 2008 states that the most significant proportion of farmers in developing countries is smallholders and about 85% of them are farming in less than two hectares of land (World Bank, 2007). According to this statement, in countries such as China, Egypt, Bangladesh and Malawi, smallholder farms with less than two hectares of farmland accounts for 95% of the total. The simplest and conventional meaning of a smallholder is the circumstance when the land available for a farmer is very limited (Hazell *et al*., 2007). However, the meaning goes significantly beyond this conventional description and includes some common characteristics that the so-called small farms or smallholders generally exhibit. Chamberlin has determined four styles based on which smallholders can be differentiated from others. These kinds of themes include landholding size, wealth, market orientation, and amount of vulnerability to risk. Accordingly, the smallholder is one with limited land availability, poor resource endowments, subsistence-oriented and highly prone to risk. Nevertheless, the smallholder may or might not exhibit all these sizes of smallness simultaneously.

Tiny enterprises may be appropriate to smallholder communities because seed selection and seedling use are location-specific, with varieties. Neck (1977) expressed that small corporations are those in which the management lies in the hands of 1 or two and is also in charge of the major decisions. Smallholder seed enterprises (SSEs) is ad advertisement perspective in the informal seed system through which it provides entrepreneurial skills, management expertise, and financial resources to local neighborhoods, farmer cooperatives, NGOs or other groups enthusiastic about producing seed for the local market. Their advantage is based on their ability to serve distant areas, work in near partnership with local maqui berry farmers, produce seeds of diverse varieties including landraces, local varieties, farmer bred varieties and populations, thereby increasing the supply of seeds of a sizable number of locally adapted varieties. Smallholder seed enterprises give attention to countrywide food security, contribution to monetary growth and making sure social and environmental durability of the agricultural sector. Quality seed is one of the main agricultural inputs to ensure food security. Quality seed production and preservation at farmers' degrees following the modern techniques can minimize the seedling shortage as well as storage losses (Islam *et al*., 2010). The use of quality seed only can enhance productivity by 5-20 pct (IRRI, 2013).

Within recent times, the supply of quality seed both from the public and private fields has increased. The volume of seed supply had been 240475 mt. in 2009-10. Seed supply quantity has grown to 267777 mt. in 2012-13, which is twenty-one % of the complete demand. But in the real situation, it is far better, due to the fact rice is our primary crop and in the circumstance of rice, the volume of quality seed provide is almost 60%, in-case of wheat is 56%, maize 75%, Jute 83%, etc. The total average goes down due in order to lessen the flow of spices and oilseed. The top quality is also less in case there is the potato. BADC supplies only 2-3% of quality potato seed, and the rest of the seed comes coming from the farmer's own creation. If the availability of seeds could be increased as much as thirty percent (which is projected in 2015) that will be a fantastic success for the agriculture sector of typically the country.

Although most seeds are still farm-saved, more and more farmers buy commercial seeds of their food crops (Joshi, 2011). Mele *et al.* (2005) reported that poor farmers need better and even more affordable use of quality seeds in order to improve their livelihood. Probert *et al.* (2007) reported that the quality of seed preservation, collection, and hence their value for species reintroduction or restoration, is critically dependent on factors working in the period between the point of series and arrival at environmentally managed processing and safe-keeping facilities. The main issues connected to processing plants in addition to storage capacity in general public sector, low capacity accessible at the private sector for processing/conditioning, a low investment inside seed infrastructure and weak seed processing procedures plus quality measurement. There are also barriers to marketing and advertising of seeds. This consists of a lack of proactive marketing components and poor availability of quality products. The main issues on marketing are usually inadequate seed dealers, programs and networks, insufficient campaign and advertisement campaigns, extreme flow of exotic hybrids and other crop seed (maize, vegetables and affectation crops), absence of improper labeling and inappropriate sizing of seed containers, un-affordable pricing of seed packets, high competition

with imported seeds, and limited seeds quality services. Bangladeshi culture is yet to see modernization and competitiveness regarding attaining national goals regarding food and nutritional protection.

Therefore, it is crucial that identify and analyze the factors that affect the degree of sustainability of smallholder farms as well as seed enterprises. It will be helpful for the policymakers to design appropriate policy instruments, institutions and other interventions for sustainable financial development smallholder farmers.

MATERIALS AND METHODS

Study location and time

The research was conducted in six villages of Nagarpur and Shahjadpur Upazila under Tangail and Shirajganj district respectively. Three villages from each Upazila such as Ghiorkol, Danga Dhalapara, Danga Shalinapara under Nagarpur Upazila and Bathiya Purba study are popular for agricultural seed production. The locales were also selected purposively for the suitability of the researcher to collect data. The data were collected in March and April 2014. The map of Tangail and Shirajganj district have been presented in Figure 1 and the specific study location has also been shown in Figure 2, respectively.

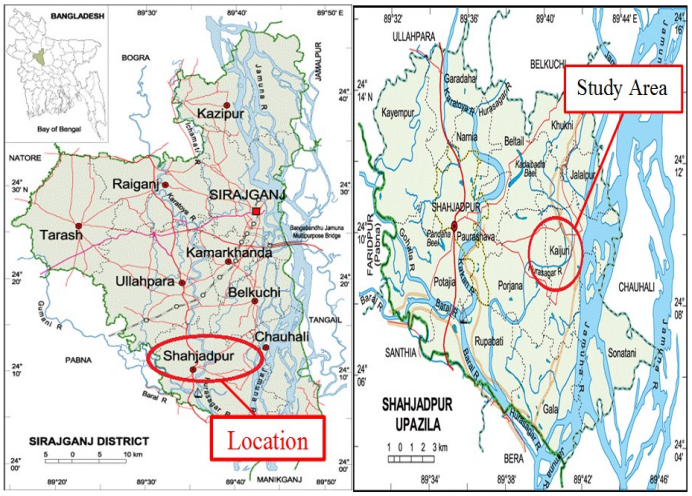

Figure 1. *Map of Tangail District shows study area (Nagarpur upazila).*

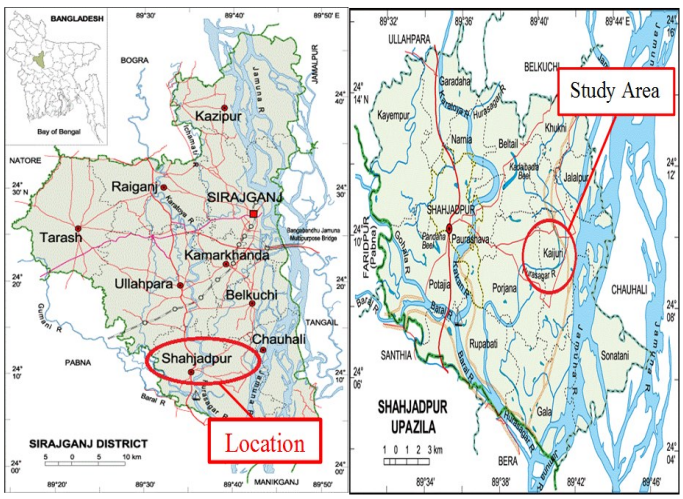

Figure 2. *Map of Shirajganj district shows study area (Shahjadpur upazila).*

Determination of population size

Household heads in the selected villages of Nagarpur and Shahjadpur Upazilas under Tangail and Shirajganj districts constituted the population of this study. Considering the time, financial resources and other constraints, data were collected from a sample rather than the entire population A total of 600 households were listed from 6 villages (Ghiorkol, Danga Dhalapara, Danga Shalinapara, Bathiya Purbapara, Kaijuri, Narina) for household's survey purposively. However, a representative sample from the population was taken for collection of data following the random sampling technique. A random sampling procedure was followed to select one district from the whole of Bangladesh, and the same method was used to select the area of the district as well as the villages as the study group. Six hundred farmers constituted the population of this study which is shown in the following Table 1.

Determination of sample size

There are several methods for determining the sample size; here, the study used Yamane's (1967) formula for the study group:

$$n = \frac{z^2 P(1-P)N}{z^2 P(1-P) + N\,(e)^2}$$

Where, n = Sample size; N, population size = 600; e, The level of precision = 8%; z = the value of the standard normal variable given the chosen confidence level (e.g., z = 1.96 with a confidence level of 95 %) and P, The proportion or degree of variability = 50%; Here, the sample size (n) =120.

Distribution of the population, sample size, and reserve list

According to Yamane's formula, the sample size comprised of 120 farmers. Reserve lists of 12 farmers (10% percent of the sample size) were also prepared so that the farmers of this list could be used for interviews if the farmers included in the original sample were not available at the time of conduction of the interview. The farmers of the villages were measured according to the proportionate of the total sample size (120) which was calculated using Yamane's (1967) formula. The distribution of the population, the number of sample sizes and the number of respondents along with the reserve list are given in the following Table 1.

Sustainability assessment using CI

Sustainability is often described as a vague and heterogeneous concept, but its evaluation by using indicators is well established (Bell and Morse, 2004). CI is the mathematical combination of individual indicators based on an underlying model, taking methodological assumptions and subjective as well as objective judgments. CI is increasingly recognized as a useful tool for assessing the environmental sustainability, policy analysis (Brand *et al.*, 2007), good governance (Rotberg and Gisselquist, 2008), environmental performance, and competitiveness (WEF, 2012). Surveyed a comprehensive review of CI and reported a dramatic growth of CI in diverse fields. In the agricultural sector, CI has been used by many researchers employing different approaches (Rigby *et al.*, 2001).

Table 1. Distribution of the rural farmers involved with different financial services according to population and reserve list.

Name of the selected Upazila	Name of the selected villages	Number of the household	Sample size	Reserve list
Nagarpur	Ghiorkol	97	19	2
	Danga Dhalapara	77	15	2
	Danga Shalinapara	126	25	2
Shahjadpur	Bathiya purbapara	113	23	2
	Kaijuri	89	18	2
	Narina	98	20	2
Total		600	120	12

Table 2. Construction methodology of a composite indicator (CI).

Step	Stage	Tools and methods applied	Output
Step 5	Index construction	Correlation and path analysis	Generating a meaningful and communicative CI
Step 4	Normalization, weighting, and aggregation	Max-min normalization factor analysis for weighting and linear aggregation	Making data comparable, assessing the weight of indicators and combining them
Step 3	Data screening, bivariate and multivariate analysis	Estimating skewness, kurtosis, outlier checking, correlation	Ensuring the quality and structure of the data set for subsequent methodological choices
Step 2	Conducting survey and data collection	Farm household's survey, checking and cross-checking data	Preparing a complete data set
Step 1	Theoretical foundation and indicator development	Literature review, expert opinion, and focus group discussion	Developing a set of indicators

The methodology employed for indicators development and construction of CI

Freebairn and King (2003) have proposed an approach for the generation of indicators, illustrating the significance of key-players in the indicator development process. Many studies (Monroy-Ortiz *et al*., 2009) reported developing an indication by adopting a participatory approach that was fit-for-purpose, integrative, and comprehensive in conditions of the efficiency and effectiveness in creating sustainability-compatible development strategies. Moreover, expert-led indicator development with the active participation of local stakeholders is recognized for consolidative assessment (Roy and Chan, 2012). Table 2 provides an illustration of the methodology utilized for the construction of a composite indicator in the study.

Statistical analysis

The analysis was performed using SPSS (Statistical Package for Social Sciences) computer package. Descriptive analyses such as range, number, percentage, mean, standard deviation were used whenever possible. Throughout the study, at least a five percent ($P<0.05$) level of probability was used as the basis of rejecting a null hypothesis.

RESULTS AND DISCUSSION

Human capital

A human capital score of the respondents ranged from 45 to 60 against possible score 12-60 with a mean and standard deviation of 53.31 and 3.35, respectively. Based on the human capital score, the respondents were classified into three categories (Mean ± Standard Deviation) namely 'low', 'medium' and 'high' human capital. The distribution of the respondents according to their human capital is presented in Table 3.

Table 4 indicates that the highest proportion (74.1 percent) of the respondents had medium human capital compared to 14.2 percent in low human capital and the lowest 11.7 percent in the high human capital category, respectively.

Non-farm income-generating activities

The observed score of non-farm income of the respondents ranged from 2 to 6 score against possible score 0-11 with a mean and standard deviation of 3.03 and 0.87, respectively. Based on non-farm income, the respondents were classified into three categories (Mean ± Standard Deviation) namely 'low', 'medium' and 'high' non-farm income. The distribution of the respondents according to their non-farm income is presented in Table 5. Data revealed that the respondents having medium non -farm income constitute the highest proportion (66.6 percent), while the lowest proportion in high non-farm income (4.2 percent) and low-income category constituted 29.20 percent of respondents. The overwhelming majority of respondents involves in low to medium level non-farm income-generating activities (Table 5).

Access to financial services

The observed score of access to financial services of the respondents ranged from 4 to 10 against a possible range of 0 to 21. The average score of the respondent's needs for financial services was 7.45 with a standard deviation of 1.35 (Table 6). The respondents were classified into three categories based on their access to financial services, they were classified into three categories (Mean ± Standard Deviation) namely 'no access', 'intermittent access' and 'sustained accesses of financial services of the respondents. Data showed that the highest proportion (85.8 %) of the respondents had intermittent access to financial services and no access to financial services was 7.53 percent of them and 6.67 percent fell in sustained access to financial services. From this, it might be concluded that the majority of the respondents had intermittent access to financial services (Table 6).

Utilization of seed of improved cultivars

The utilization of seed of improved cultivars scores of the farmers ranged from 4 to 10 with an average of 5.73 and a standard deviation of 1.29. The possible score of the utilization of the seed of improved cultivars is 0-10. Based on the utilization of seed of improved cultivars score, the respondents were classified into three categories (Mean ± Standard Deviation) namely 'low', 'medium' and 'high' utilization of seed of improved cultivars. Data in (Table 7) reveal that the highest proportion 77.5 percent of the respondents fell into a category and 15 percent had medium utilization category regarding utilization of seed of improved cultivars. 7.5 percent fell into the high utilization category. The mean value (5.73) clearly indicates that respondents tend to low to medium utilization of seed of the improved cultivars.

Market prices of the seeds

Market prices of the seeds of the respondents ranged from 3 to 14 against a possible score of 0 to 24. The average score and standard deviation were 8.23 and 2.84, respectively. Based on the market price scores, the respondents were classified into three categories (Mean ± Standard Deviation) namely low, fluctuating and high market price.

Table 8 reveals that 73.3 percent of the respondents had faced fluctuating market prices of seeds, 14.2 percent had a low market price and 12.5 percent had a high market price. Thus, an overwhelming majority (87.5 percent) of the respondents had faced low to fluctuating market prices of seeds.

Table 3. Salient features of the selected indicators.

Characteristics	Value		Possible score	Skewness	kurtosis
	Min.	Max.			
Human capital	45	60	12-60	-0.122	-0.624
Non-farm income generating activities	2	6	0-11	0.796	0.926
Access to financial services	4	10	0-21	-0.328	0.217
Utilization of seed of improved cultivars	4	10	0-10	1.093	1.632
Market prices of the seeds	3	14	0-24	-0.147	-0.791
Marketing facility	11	24	0-28	0.164	-0.663
Adequacy of extension services	1	9	0-12	0.445	-0.264
Information accessibility	18	24	0-24	0.003	-0.457
Institutional function	12	29	0-36	0.197	-0.565

Table 4. Distribution of the respondents according to their human capital.

Category	Score		Respondent		Mean	SD
	Basis	Observed	Number	Percent		
Low human capital	≤ 49	45-60	17	14.2	53.31	3.35
Medium human capital	50-57		89	74.1		
High human capital	≥ 58		14	11.7		
Total			120	100		

Table 5. Distribution of the respondents according to their non-farm income-generating activities.

Category	Score		Respondent		Mean	SD
	Basis	Observed	Number	Percent		
Low	≤ 2	2-6	35	29.2	3.03	0.87
Medium	3-4		80	66.6		
High	≥ 5		5	4.2		
Total			120	100		

Table 6. Distribution of the respondents according to their access to financial services.

Category	Score		Respondent		Mean	SD
	Basis	Observed	Number	Percent		
No access	≤ 5	4-10	9	7.53	7.45	1.35
Intermittent access	6-9		103	85.8		
Sustained access	≥ 7		8	6.67		
Total			120	100		

Table 7. Distribution of the respondents according to their utilization of seed of improved cultivars.

Category	Score		Respondent		Mean	SD
	Basis	Observed	Number	Percent		
Low	≤ 4	4-10	18	15	5.73	1.29
Medium	5-7		93	77.5		
High	≥ 8		9	7.5		
Total			120	100		

Marketing facility

Marketing facility scores of the respondents ranged from 11 to 24 against a possible score of 0 to 28. The average score and standard deviation were 17.06 and 3.25, respectively. Based on the marketing facility scores, the respondents were classified into three categories (Mean ± Standard Deviation) namely poor, moderate and developed marketing facilities. Table 9 reveals that 68.3 percent of the respondents had a moderate marketing facility, 15 percent had poor marketing facility and 16.7 percent had developed a marketing facility. Thus, an overwhelming majority (85 percent) of the respondents had moderate to developed marketing facilities.

Adequacy of extension services

The observed score of contact with extension agents of the respondents ranged from 1 to 9 against a possible range of 0 to 12. The average score of the respondents' contact with extension agents was 3.69 with a standard deviation of 1.75 (Table 9). The respondents were classified into three categories based on their contact with extension agents scores and distribution of the three categories (Mean ± Standard Deviation) namely 'no visit', 'intermittent visit' and 'frequent visit' of the respondents. Data showed that the highest proportion (85.8 percent) of the respondents had intermittent contact and no contact with the extension agents was 9.2 percent and 5 percent fell in frequent contact with extension agents. From the data of Table 10, it might be said that the majority of the respondents had no contact with intermittent contact with extension agents. It could be stated that the extension agent or media of the study area were available to the respondents. Finding reveals that 9.2 percent of the respondents had no extension organization contact which is indicating the improvement of the communication strategy. No extension contact might be the reason that some respondents may think that they have enough knowledge. This results in a cognitive change of the users with an eventual change in behavior and in skill. They receive information from their neighbors, relatives, and workmates, etc. in the study area.

Information accessibility

Information access scores of the respondents ranged from 18 to 24 against a possible score of 0 to 24. The average score and standard deviation were 21.32 and 1.46, respectively. Based on the Information access scores, the respondents were classified into three categories (Mean ± Standard Deviation) namely low, medium and high Information access. Table 11 reveals that 80.8 percent of the respondents had medium Information accessibility, 10 percent had low Information accessibility and the lowest 9.2 percent had high Information accessibility.

Table 8. Distribution of the respondents according to their market prices of the seeds.

Category	Score		Respondent		Mean	SD
	Basis	Observed	Number	Percent		
Low	≤ 4	3-14	17	14.2	8.23	2.84
Fluctuating	5-11		88	73.3		
High	≥ 12		15	12.5		
Total			120	100		

Table 9. Distribution of the respondents according to their marketing facility.

Category	Score		Respondent		Mean	SD
	Basis	Observed	Number	Percent		
Poor	≤ 13	11-24	18	15	17.06	3.25
Moderate	14-20		82	68.3		
Developed	≥ 21		20	16.7		
Total			120	100		

Table 10. Distribution of the respondents according to their adequacy of extension services.

Category	Score		Respondent		Mean	SD
	Basis	Observed	Number	Percent		
No visit	≤ 1	1-9	11	9.2	3.69	1.75
Intermittent visit	2-6		103	85.8		
Frequent visit	≥ 7		6	5		
Total			120	100		

Table 11. Distribution of the respondents according to their information accessibility.

Category	Score		Respondent		Mean	SD
	Basis	Observed	Number	Percent		
Low access	≤ 19	18-24	12	10	21.32	1.46
Medium access	20-22		97	80.8		
High access	≥ 23		11	9.2		
Total			120	100		

Table 12. Distribution of the respondents according to their institutional function.

Category	Score		Respondent		Mean	SD
	Basis	Observed	Number	Percent		
Less effective	≤ 15		20	16.7		
Medium effective	16-24	12-29	83	69.1		
Highly effective	≥ 25		17	14.2	19.78	4.1
Total			120	100		

Table 13. Distribution of the respondents according to their sustainable smallholder seed enterprises.

Category	Score		Respondent		Mean	SD
	Basis	Observed	Number	Percent		
Not sustainable	≤ 36.27		9	7.5		
Moderately sustainable	36.28-45.54	27.01-64.08	28	23.3		
Reasonably sustainable	45.55-54.81		53	44.2	48.98	8.05
Highly sustainable	≥ 54.82		30	25		
Total			120	100		

Institutional function

The institutional function score of the respondents ranged from 12 to 29 with a mean and standard deviation of 19.78 and 4.1, respectively. The possible against an observed score of institutional function is ranged from 0-36. Based on the institutional function score, the respondents were classified into three categories (Mean ± Standard Deviation) namely a less effective, medium effective and highly effective institutional function score. The distribution of the respondents as per their institutional function score is presented in Table 12. Data reveals that the highest proportion (69.1 percent) of the respondents had medium effective in institutional function, while 16.7 percent had less effective in institutional function and the lowest 14.2 percent had highly effective in institutional function. It might be logical because the respondents of the study area were suppressed by some political barriers.

Sustainability of smallholder seed enterprise

The sustainability of smallholder seed enterprise scores of the respondents ranged from 27.01 to 64.08. The average score and standard deviation were 48.98 and 8.05 respectively. Based on the sustainability of smallholder seed enterprises scores, the respondents were classified into four categories namely not sustainable, moderately sustainable, reasonably sustainable and highly sustainable to rural financial services. This following categorization is based on the Royal London (2017).

Table 13 reveals that 44.2 percent of the respondents had reasonably sustainable to smallholder seed enterprise, 23.3 percent had moderately sustainable to smallholder seed enterprise, 25 percent had highly sustainable to smallholder seed enterprise and the lowest 7.5 percent had not sustainable to smallholder seed enterprise. Thus, an overwhelming majority (92.5 percent) of the respondents had moderately to highly sustainable to smallholder seed enterprises.

Conclusion

From this study, it has been concluded that 92.5% of the smallholder farmers had moderate to highly sustainable seed enterprises in the study area. Although many factors involved in this system but institutional functions, price of seeds, human capital, and marketing facilities considered as highly influential factors among them. Respective institutions may play a key role in achieving the sustainability of SSEs by providing necessary supports to the farmers and the improvement of influential indicators.

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ORIGINAL RESEARCH ARTICLE

Effects of different fertilizers on the growth and yield of okra (*Abelmoschus esculentus* L.) in summer season in Chitwan, Nepal

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Yield

ABSTRACT

An experiment was conducted in the Horticulture Farm of Agriculture and Forestry University to demonstrate the effects of different fertilizers on the yield and yield parameters of okra (var. Arka Anamika). The experiment was laid out in Randomized Complete Block Design (RCBD) consisting of seven treatments and three replications. The various treatments used in the experiment were goat manure, sesame cake, mustard cake, synthetic fertilizer (NPK), poultry manure, vermicompost and untreated control. The required dose of nitrogen was fulfilled by the fertilizer itself whereas insufficient amount of phosphorous and potassium was fulfilled by addition of single super phosphate and muriate of potash respectively. The fertilizers were applied on the basis of recommendation given by the Nepal Agriculture Research Council (NARC). The effect of poultry manure on number of open flowers and number of fruits at 40 DAS was found superior. The effect of poultry manure on plant height, number of leaves, plant diameter was found superior at 50 DAS. Goat manure produced the superior result on number of open flowers at 50 DAS. Poultry manure on the number of leaves and plant height produced the significant result at 60 DAS. Synthetic fertilizer responded well to number of fruits at 60 DAS. Sesame cake produced the superior results at 70 DAS on number of buds. Poultry manure responded well to all the parameters and produced the yield of 200 qt./ha with the BC ratio of 1.77. This experiment suggests the farmers to use the poultry manure to get the highest economic return. Vermicompost and mustard cake producing the superior and significant yield in this research are not recommended as they have low BC ratio unless effective measures are encouraged to reduce the cost of this fertilizers.

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INTRODUCTION

Okra *(Abelmoschus esculentus)* is an important summer vegetable of Nepal which belongs to family *Malvaceae* (Maurya *et al*., 2013). It was originated from Africa and spread to tropics, subtropics and warmer part of temperate region. Okra is the rich source of carbohydrate, amino acids, vitamin which have multipurpose use like fresh or cooked consumption, as fodder to animal, medicinal and industrial use (Farinde *et al*., 2007; Kumar *et al*., 2017). Okra response very well to fertilizer application and an effective fertilizer use is the key to its higher growth and yield (Buob, 2008; Kumar, 2019).

Mineral fertilizers only assure the rapid and short-term growth and yield improvement (Ware and Collum, 1980) but become unable to ensure sustainability of agricultural production (Titiloye *et al*., 1985). The application of organic manure could ameliorate the acidic condition of soil to improve crop production (Akande *et al*., 2003). Poultry manure in comparison to

other supplies more nutrient to plant (Garg and Bahl, 2008). In addition to releasing nutrients, poultry manure is rich in organic matter which improves the physical properties of soil (Ayeni, 2011). Poultry manure increases plant height (Aniefiok, 2013). Earthworm manures is known to restore the destructive effect of chemical fertilizers and improve soil properties and facilitates the growth of the crops (Sinha, 2009). Continuous use of vermicompost reclaims the soil and rejuvenates it. The growth, number of pods and yield of okra increased with increasing amount of goat manure (Awodun, 2007). Various plant originated manures like mustard oil cakes, sesame oil cakes, peanut cakes, castor cakes helps in plant growth and increase yield by reducing the incidence of phytonematodes (Frederick, 2015; Sumbul, 2015). In this investigation, the effect of different organic and inorganic fertilizers on the growth and yield of okra were studied.

MATERIALS AND METHODS

Experimental site

It was carried out in the horticulture farm of Agriculture and Forestry University. The latitude and longitude of the research site is 27°37' and 84°37', respectively. The experiment was conducted from April 7, 2018 to July 2, 2018 and took 85 days from sowing to economic harvesting. It is located at an altitude of 250 meters above sea level. The soil status of the experimental site during field preparation was obtained by soil analysis report from Agriculture Technology Center, Lalitpur, Nepal (Table 1).

Experimental design

This experiment was carried out in Randomized Control Block Design (RCBD). It consists of 7 treatments and is replicated 3 times. The spacing of 50cm × 30cm and wide spacing of 1m around the research plot was used. Spacing of 75cm was used to separate the treatments and replications. The area of the plot is 2.5m × 1.8m and thus covering 4.5m^2. The research filed covers the entire area of 210.1 m^2.

Table 4. Effect of different fertilizers on performance of okra at 10 DAS.

Treatments	10 DAS	
	Plant height (cm)	Number of leaves
Vermicompost	6.733333	3.066667
Sesame cake	6.800000	3.000000
Synthetic fertilizer	6.400000	3.000000
Goat manure	7.300000	2.933333
Mustard cake	6.333333	2.933333
Poultry manure	6.600000	2.933333
Control	6.433333	2.866667
SEM(±)	0.15	0.02
LSD (0.05)	1.05	0.168
CV (%)	8.86	3.18
F-test	NS	NS

Note: Means with the same letter are non-significant at p=0.05 by DMRT, SEM: Standard error of mean, LSD: Least significant difference, CV: Coefficient of variation, NS: Non-significant.

Table 1. Description of soil status of the research field.

Description	Properties
Soil texture	Sandy Loam
Organic matter percentage	3.5
Soil pH	5.54
Electrical conductivity (mmho/cm) at 25©	0.13
Nitrogen percentage	0.17
P_2O_5 (Kg/ha)	55.09
K_2O (Kg/ha)	342.58
Sand percentage	76.4
Silt percentage	18.67
Clay percentage	6.04

Brassica oleracea var. botrytis was grown last season in this research field. Arka Anamika is resistant to yellow vein mosaic virus.

Table 2. NPK content of different fertilizers.

Manures	N%	P%	K%
Goat manure	3	1	2
Sesame cake	6.61	2.1	1.1
Mustard cake	4.52	1.78	1.4
Poultry manure	1.2	0.45	0.8
Vermicompost	2.35	1.6	1.5

Table 3. Amount of different fertilizer added in the research field.

Manures	Applied manures (for N) kg	SSP (g)	MOP (g)
Goat manure	3.000	318.75	-
Sesame cake	1.361	327.56	20.03
Mustard cake	1.991	284.75	-
Poultry manure	7.500	295.31	-
Vermicompost	3.829	123.25	-
Synthetic fertilizer (NPK)	126.74 g Urea	176.08 g DAP	45
Control	-	-	-

Treatment and trial management

There are seven different treatments used in the experiment. They are: T1: Goat manure, T2: Sesame cake, T3: Mustard cake, T4: Synthetic fertilizers (NPK), T5: Poultry manure, T6: Control and T7: Vermicompost. The field was prepared 5 days before sowing and seed was sown after soaking for 24 hrs. Required dose of fertilizer application was given by Nepal Agriculture Research Council (NARC) i.e. 200:180:60 kg NPK/ha which accounts 90:81:27 g NPK/ 4.5 m^2. The NPK content different fertilizer determined by animal science laboratory of AFU is given in Table 2.

The manures were applied to fulfill the required dose of nitrogen. Insufficient dose of phosphorous and potassium were applied through single super phosphate (SSP) and muriate of potash (MOP) respectively. The applied manures per plot are given in the Table 3.

Data collection

There were altogether 30 plants in each plot. There were 18 border plants and 12 inner plants. Out of the 12 inner plants, 5 plants were sampled by using randomizer application and the data were collected on the following parameters.

Estimation of vegetative parameters

Plant height: The plant height was measured in 10DAS, 20DAS, 30DAS, 40DAS, 50DAS and 60 DAS. It was measured using the measuring tape from the base to the tip of the plant.

Plant diameter: The data for the plant diameter was measured in 20DAS, 30DAS, 40DAS, 50DAS and 60DAS. The plant diameter was measured just below the 1st node from the ground.

Number of leaves: The number of fully leaves was measured in 10DAS, 20DAS, 30DAS, 40DAS, 50DAS and 60 DAS.

Reproductive parameters

Number of pods: The total number of pods was counted in 40DAS, 50DAS, 60 DAS and 70 DAS.

Number of fruits: The total number of fruits was counted in 40DAS, 50DAS, 60DAS and 70 DAS.

Number of flowers: The total number of fully opened flowers was counted in 40DAS, 50DAS, 60DAS and 70 DAS.

Yield: Okra fruits were collected in every 3 days by multiple harvesting from 45 DAS and they were picked 20 times up to economic production level.

Statistical analysis

The data were collected and recorded in MS-Excel (Office Package 2007) and subjected to statistical analysis according to one-way ANOVA using R-stat (version: 3.4.2).

Economic analysis

BC ratio of various treatments was calculated. The cost of various materials involved in the research was: Goat manure: NRs 5/kg, Sesame cake: NRs 25/kg, Mustard cake: NRs 30/kg, Poultry manure: NRs 5/kg, Vermicompost: NRs 18/kg, Urea: NRs 20/kg, DAP: NRs 45/kg, SSP: NRs 18/kg, Okra seed: NRs 3500/kg, MOP: NRs 60/kg, Labour: NRs 600/day, NRs 30/kg of the produce. It was calculated by adding all the cost except fertilizers to obtain the common cost (Table 12). The common cost was added to the cost of manures to obtain the total cost (Table 13). The yield was multiplied by the average value of the produce to obtain the benefit (Table 14). Thus BC (Table 14) ratio was calculated.

Meteorological data during the investigation from April 7 to July 2

National Maize Research Program (NMRP) under Nepal Agriculture Research Council (250 m far from the research site) provided required meteorological data of the entire cropping period. The maximum temperature ranges from 27.2 °C to 38.01°C and the minimum temperature ranges from 27.02°C to 29.8°C. The research field received 385mm rainfall during the entire cropping period (Figure 1).

RESULTS AND DISCUSSION

The effect of plant height and number of leaves at 10 DAS was found non-significant (Table 4). Similarly, the effect of plant height, number of leaves and plant diameter at 20 DAS was found non-significant (Table 5). Same result continues with the okra plant at 30 DAS (Table 6).

In 40 DAS, the effect of plant height, number of leaves, plant diameter and number of buds was found non-significant. But, the data for the number of open flowers and number of fruits was found significant at 1% and 5% level of significance respectively (Table 7). Poultry manure and vermicompost was found superior in case of number of buds whereas poultry manure, goat manure, vermicompost and mustard cake were found superior in case of number of fruits. The result corresponds with the findings of (Ajari *et al.*, 2003) in which Poultry manure was found superior in comparisons to other organic manure.

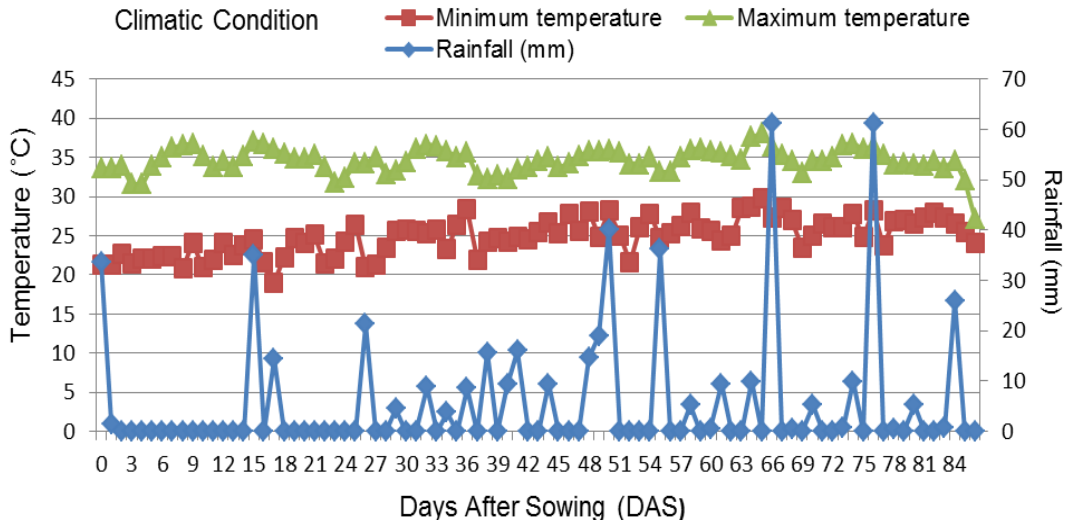

Figure 1. *Meteorological data during the investigation from April 7 to July 2.*

Table 5. Effect of different fertilizers on performance of okra at 20 DAS.

Treatments	20 DAS		
	Plant height (cm)	Number of leaves	Plant diameter (cm)
Goat manure	7.300000	5.466667	0.5400000
Sesame cake	6.800000	5.266667	0.5500000
Vermicompost	6.733333	5.600000	0.5133333
Poultry manure	6.600000	5.866667	0.5666667
Synthetic fertilizers	6.400000	5.600000	0.6133333
Mustard cake	6.333333	5.400000	0.5866667
Control	6.300000	5.633333	0.5466667
SEM(±)	0.15	0.1	0.01
LSD (0.05)	0.801	0.911	0.893
CV (%)	6.78	9.23	8.97
F-test	NS	NS	NS

Note: Means with the same letter are non-significant at p=0.05 by DMRT, SEM: Standard error of mean, LSD: Least significant difference, CV: Coefficient of variation, NS: Non-significant.

Table 6. Effects of different fertilizers on performance of okra at 30 DAS.

Treatments	30 DAS		
	Plant height	Number of leaves	Plant diameter
Mustard cake	26.93333	7.466667	0.7266667
Synthetic fertilizers	26.93333	8.333333	0.7066667
Poultry manure	24.90000	8.666667	0.7000000
Sesame cake	26.13333	7.400000	0.6800000
Goat manure	26.26667	8.466667	0.6133333
Vermicompost	25.13333	8.666667	0.6066667
Control	23.46667	7.600000	0.5933333
SEM(±)	0.44	0.2	0.02
LSD (0.05)	3.26	1.57	0.128
CV (%)	7.15	10.9	10.9
F-test	NS	NS	NS

Note: Means with the same letter are non-significant at p=0.05 by DMRT, SEM: Standard error of mean, LSD: Least significant difference, CV: Coefficient of variation, NS: Non-significant.

Table 7. Effects of different fertilizers on performance of okra at 40 DAS.

Treatments	40 DAS					
	Plant height	Number of leaves	Plant diameter	Number of buds	Number of open flowers	Number of fruits
Vermicompost	53.66667	17.46667	1.19333	5.066667	0.3666667^{a}	0.8666667^{a}
Poultry manure	59.20000	17.13333	1.27333	5.866667	0.6333333^{a}	0.9666667^{a}
Mustard cake	55.33333	15.53333	1.26667	5.066667	0.3666667^{b}	0.9333333^{a}
Synthetic fertilizers	60.86667	15.00000	1.28000	6.466667	0.3000000^{b}	0.6000000^{ab}
Sesame cake	61.40000	14.80000	1.28000	5.133333	0.3666667^{b}	0.6666667^{ab}
Goat manure	60.20000	14.20000	1.24000	4.466667	0.3000000^{b}	0.9333333^{a}
Control	51.76667	14.00000	1.20333	5.033333	0.2666667^{b}	0.4000000^{b}
SEM(±)	1.17	0.72	0.03	0.24	0.03	0.06
LSD (0.05)	8.96	5.47	0.21	2.07	0.154	0.38
CV (%)	8.76	19.9	9.44	21.9	23.4	27.8
F-test	NS	NS	NS	NS	**	*

Note: Means with the same letter are non-significant at p=0.05 by DMRT, SEM: Standard error of mean, LSD: Least significant difference, CV: Coefficient of variation, NS: Non-significant, *: 5% level of significance, 1% level of significance.

In 50 DAS, the vegetative parameters such as plant height, number of leaves and plant diameter was found significant at 5% probability level. The reproductive parameters such as number of buds and number of open flowers were found non-significant. The data for the number of fruits was found significant at 5% probability level (Table 8). In all the cases poultry manure was found superior except in the number of buds, where goat manure was found superior. In 60 DAS, the effect on plant height was found non-significant. Whereas, the data for the number of leaves and plant diameter was found significant at 5% and 1% probability level respectively. In both the cases, poultry manure was found superior. The effect on number of fruits was found significant at 5% probability level (Table 9). Synthetic fertilizer was found superior followed by poultry manure, vermicompost, sesame cake, goat manure, mustard cake and control. The effect on the number of fruits was found non-significant (Table 9). In 70 DAS, the effect on number of buds was found statically significant at 5% probability level. Sesame cake produced the superior number of buds followed by poultry manure, synthetic fertilizers, goat manure, mustard cake, vermicompost and untreated control. The effect on number of open flowers and number of fruits was found non-significant (Table 10).

Table 8. Effects of different fertilizers in performance of okra at 50 DAS.

Treatments	50 DAS					
	Plant height	Number of leaves	Plant diameter	Number of buds	Number of open flowers	Number of fruits
Poultry manure	88.73333^{a}	26.73333^{a}	1.960000^{a}	5.666667	0.6666667^{ab}	2.066667
Vermicompost	87.13333^{a}	24.93333^{a}	1.833333^{ab}	6.800000	0.6666667^{ab}	1.400000
Sesame cake	84.20000^{abc}	19.73333^{bc}	1.746667^{abc}	8.200000	0.3333333^{c}	1.333333
Goat manure	54.66676^{ab}	22.06667^{abc}	1.586667^{abc}	6.933333	0.8000000^{a}	1.466667
Mustard cake	77.46667^{bcd}	18.80000^{c}	1.500000^{bc}	6.600000	0.4666667^{bc}	1.733333
Synthetic fertilizers	75.20000^{cd}	17.93333^{c}	1.343333^{c}	8.666667	0.4666667^{bc}	1.666667
Control	72.36667^{d}	17.00000^{c}	1.336667^{c}	6.466667	0.3333333^{c}	1.466667
SEM(±)	1.65	0.93	0.07	0.33	0.05	0.11
LSD (0.05)	9.11	5.3	0.401	2.16	0.261	0.74
CV (%)	6.29	14.2	14	16.2	27.5	26.2
F-test	*	*	*	NS	*	NS

Note: Means with the same letter are non-significant at p=0.05 by DMRT, SEM: Standard error of mean, LSD: Least significant difference, CV: Coefficient of variation, NS: Non-significant, *: 5% level of significance.

Table 9. Effects of different fertilizers on performances of okra at 60 DAS.

Treatments	60 DAS					
	Plant height	Number of leaves	Plant diameter	Number of buds	Number of open flowers	Number of fruits
Poultry manure	118.6000	44.60000^{a}	2.200000^{a}	10.566667	0.8	3.666667ab
Sesame cake	117.7333	35.66667^{ab}	1.773333^{bc}	9.8000000	0.8	3.100000abc
Vermicompost	111.6667	31.73333^{b}	1.846667^{b}	8.833333	0.9	3.100000abc
Synthetic fertilizers	111.2000	30.73333^{b}	1.676667^{bc}	9.200000	0.6	4.100000a
Goat manure	109.3333	34.86667^{ab}	1.936667^{ab}	10.100000	0.6	2.900000bc
Mustard cake	107.1333	29.60000^{b}	1.740000^{bc}	9.400000	0.5	2.400000c
Control	103.6667	25.06667^{b}	1.436667^{c}	8.933333	0.6	2.333333c
SEM(±)	1.65	1.63	0.06	0.5	0.04	0.2
LSD (0.05)	11.8	10.4	0.325	3.65	0.28	1.1
CV (%)	5.96	17.6	10.2	21.9	22.9	20.1
F-test	NS	*	**	NS	NS	*

Note: Means with the same letter are non-significant at p=0.05 by DMRT, SEM: Standard error of mean, LSD: Least significant difference, CV: Coefficient of variation, NS: Non-significant, *: 5% level of significance, **: 1% level of significance.

Table 10. Effect of different fertilizer on performance of okra at 70 DAS.

Treatments	70 DAS		
	Number of buds	Number of open flowers	Number of fruits
Sesame cake	**15.033333^{a}**	**1.6000000**	**2.333333**
Poultry manure	14.40000^{ab}	1.2000000	2.466667
Synthetic fertilizers	12.200000^{abc}	0.9333333	2.533333
Goat manure	11.266667^{bc}	1.1333333	2.600000
Mustard cake	10.933333^{bc}	1.1333333	2.266667
Vermicompost	10.133333^{c}	1.1333333	2.933333
Control	9.466667^{c}	1.0666667	2.266667
SEM(±)	0.74	0.08	0.12
LSD (0.05)	3.43	0.575	1.1
CV (%)	16.2	27.1	24.8
F-test	*	NS	NS

Note: Means with the same letter are non-significant at p=0.05 by DMRT, SEM: Standard error of mean, LSD: Least significant difference, CV: Coefficient of variation, NS: Non-significant, *: 5% level of significance.

The effect of different fertilizer on the yield was found significant at 1% probability level. Poultry manure producing 20 mt/ha was found superior (Table 11). It was followed by vermicompost, goat manure, sesame cake, mustard cake, synthetic fertilizers and untreated control. The effects of different fertilizers on different growth parameters like plant diameter, height, number of leaves and yield was found highest in Poultry manure which corroborates with the findings of (Fagwalawa and Yahaya, 2016). The increase in yield of Okra was due to the easy Solubilization effect and high nitrogenous contents of Okra and it agrees with the findings of (Sanwal *et al.*, 2007) in turmeric and (Premsekhar and Rajashree, 2009) in Okra in which they respond organic manure improves the physical properties of soil. The BC ratio was highest in poultry manure followed by goat manure, sesame cake, synthetic fertilizers, vermicompost, untreated control and mustard cake (Table 13). Vermicompost produced the comparatively superior yield but due to the high cost of the manure, the BC ratio seems to be quite low. In case of synthetic fertilizers, though they produced the fewer yields but due to the low cost of the fertilizers, they have quite superior BC ratio.

From the above experiment, Poultry manure was found to be superior among all the seven treatments on different growth parameters like plant diameter, height, number of leaves and yield except the number of buds at 70DAS (on significant cases) which corroborates with the findings of Fagwalawa and Yahaya (2016). Benefit Cost ratio was highest in poultry manure followed by goat manure, sesame cake, synthetic fertilizers, vermicompost, untreated control and mustard cake. Hence, it can be concluded that usage of Poultry manure improves the performance of growth parameters and finally increases the yield (200 qt./ha) and have high BC ratio (1.77). It has been estimated that the application of poultry manure releases the nutrient easily and improves the nutrient status of the soil by easy solubilization effect and high-water holding capacity of it. Thus, increases the overall growth parameters of the crop. This result agrees with the findings of Sanwal *et al.* (2007); Premsekhar and Rajashree (2009).

Table 11. Effects of different fertilizers on yield.

Treatments	Average Yield (mt/ha)
Poultry manure	20.00000[a]
Vermicompost	17.386667[ab]
Goat manure	16.728889[ab]
Sesame cake	16.622222[ab]
Mustard cake	14.644444[bc]
Synthetic fertilizers	12.506667[cd]
Control	9.613333[d]
SEM(±)	0.82
LSD (0.05)	3.86
CV (%)	14.1
F-test	**

Note: mt= metric ton (1000kg), Means with the same letter are non-significant at p=0.05 by DMRT, SEM: Standard error of mean, LSD: Least significant difference, CV: Coefficient of variation,**: 1% level of significance.

Table 12. Estimation of common-cost of various components.

Particulars	Amount (NRs/ha)
Rental value of land	105,000
Field preparation	6,000
Seed cost	23,089
Irrigation cost	66,000
Manuring (Labour)	1,800
Weeding	18,000
Harvesting	24,000
Total	243,889

Note: NRs: Nepalese Rupees.

Table 13. Estimation of cost of different components.

Treatments	Common cost (NRs/ha)	Cost of fertilizers (NRs/ha)				Total cost (NRs/ha)
		Respective manures	Single Super Phosphate	Diammonium phosphate	Muriate of potash	
Poultry manure	243,889	83,333	11,812	-	-	339,034
Vermicompost	243,889	153,160	4,390	-	-	401,979
Goat manure	243,889	33,333	12,750	-	-	289,972
Sesame cake	243,889	75,611	13,102	-	2670	335,272
Mustard cake	243,889	132,733	113,90	-	-	388,012
Synthetic fertilizers	243,889	5632	-	17,608	6,000	273,129
Control	243,889	-	-	-	-	243,889

Note: NRs: Nepalese Rupees, ha: hectare.

Table 14. Benefit-Cost (BC) ratio of the cultivation of okra.

Treatments	Benefit (NRs/ha)	Total cost (NRs/ha)	BC ratio
Poultry manure	600,000	339,034	1.77
Vermicompost	521,580	401,979	1.30
Goat manure	501,840	289,972	1.73
Sesame cake	498,660	335,272	1.49
Mustard cake	439,320	388,012	1.13
Synthetic fertilizers	375,180	273,129	1.37
Control	288,390	243,889	1.18

Note: Selling Price estimated at NRs. 30 per kg okra, BC: Benefit-cost, NRS: Nepalese Rupees, ha: hectare.

Conclusion

From this study, it was concluded that, highest benefit cost ratio of 1.77 was found in the case of poultry manure with the productivity of 20 Mt/ha. This study identifies the poultry manure is superior in almost all the vegetative and reproductive parameters of the plant. Hence, use of poultry manure was observed beneficial in terms of economical and production perspectives. Further multi trial and multi-location research should be carried out to suggest the most suitable dose of poultry manure to obtain the maximum profit. Vermicompost, producing the significant superior yield and have less BC ratio, so suitable research should be carried out to prepare cost efficient vermicompost to obtain the better results.

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ORIGINAL RESEARCH ARTICLE

Adoption of certain improved varieties of wheat (*Triticum aestivum* L.) in seven different provinces of Nepal

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ABSTRACT

This study used farm level data to analyze the adoption of improved wheat varieties in Nepal. The seven districts each having the highest wheat area coverage in their respective provinces was selected. Pre-tested interview schedule was used to collect the primary information. The relevant literatures were reviewed for secondary information. The simple random method of sampling was used and 651 samples were taken. Descriptive statistics, probit regression and indexing were applied. This study showed that 94.1% of the area was covered by the improved wheat varieties, while 3.3% by local and 2.6% by the Indian varieties. In addition, of the improved varieties, NL 297 had the highest area coverage (30.88 %) followed by Vijay (23.24%), Gautam (12.95%), NL 971 (8.94%) and Aditya (5.34%) respectively. Probit econometric model revealed that membership of organization (1% level of significance), subsidy by the government (1% level), gender of the household head (5% level) and family member in foreign employment (10%) significantly determined the adoption of improved wheat varieties developed after NARC establishment. The indexing identified and ranked- lack of availability of quality improved seeds (I= 0.75) as the first followed by poor availability of fertilizers (0.65), labour shortage (0.61), lack of proper irrigation (0.55) and lack of agricultural machines (0.45) that were associated wheat production in study site. The concerned government institutions should assure the availability of quality improved seeds and fertilizers to the farmers; the subsidy on irrigation and agricultural machines allied with financial grant could attract the farmers towards wheat cultivation which ultimately contributes to increase wheat productivity.

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is the third most important crop of Nepal which has the area of 706843 hectare (ha) (MoALD, 2019). It is the world's most favored staple food which is nutritious, easy to store and transport and can be processed into various types of food. Moreover, wheat is considered a good source of protein, minerals, B-group of vitamins and dietary fiber (Shewry, 2007; Kandel *et al*., 2018). The national production of wheat in the year 2017/18 is 1949001 metric ton (t) and the productivity 2.75 t/ha (MoALD, 2019). More than 80% of wheat is grown in rice-wheat cropping pattern; in addition, it is a major winter cereal crop in Nepal (Kandel *et al*., 2018). The agriculture sector of Nepal, which shares 27.6% to the Gross Domestic Product (GDP) is greatly influenced by the change in national wheat production.

The area as well production of wheat in Nepal has been distinctly increased after the introduction of semi-dwarf varieties

from Mexico, which has contributed to the food supply (Poudel *et al.*, 2012; Pandey *et al.*, 2019). Of the ecological regions, the Terai region is the major region where more than 60% of wheat is produced. The huge gap existing between the research and extension has limited the wheat productivity in Nepal; availability of improved seed and an improved package of practices could bridge this gap. It has been reported that there is a huge gap between yield potential and average national productivity Timsina *et al.* (2019). The 'yield gap' has been termed as the difference between actual yields in a region and agro-climatically achievable yields in the same region (Shrestha and Subedi, 2019).

More than 40 improved varieties of wheat have been recommended by Nepal Agricultural Research Council (NARC) for different ecological zones of them, 26 are for Terai and 17 for hills. Also, of total improved varieties released, only 30 varieties are under cultivation while 13 have been denotifed (Timsina *et al.*, 2018). The wheat varieties, NL 297, UP262 and RR21 were developed before NARC establishment which are disease susceptible and have been less prioritized for seed production by the government; however, these varieties are yet common among the wheat growers of Nepal. Among these three unprioritized varieties, NL 297, and UP262 have been recommended for Terai whereas RR 21 has been recommended for Terai and mid-hills. The adoption of high yielding improved wheat varieties which are climate suitable and resistant to disease and drought could increase the national production and productivity. Thakur *et al.* (2007) revealed that the adoption of much improved technologies by the farmers have significant effect in rate of change in wheat productivity.

The national commodity research program under NARC has been established in Bhairahawa, Rupandehi district named National Wheat Research Program (NWRP), Bhairahawa, Rupendehi. NWRP has developed improved wheat varieties which are high yielding and disease resistant as well. The improved varieties such as: Gautam, Vijay, Bhrikuti, NL 971, Tilottama, Aditya, WK1204, BL 1473, Dhaulagiri, Danphe etc. which are popular among the Nepalese farmers has been developed by NWRP, NARC. It is very necessary to figure out the status of coverage of these improved varieties. Moreover, the estimation of production and productivity of wheat in Nepal, highlighting the status of different varieties in major wheat growing districts of different provinces is necessary. Also, identification of major five improved wheat varieties grown in Nepal need to be done. Apart from this, identifying the factors affecting the adoption of improved varieties is necessary. There are limited studies on assessment of wheat production in Nepal, identifying the socio-economic and farm characteristics that affect the wheat production. Also, it is necessary to explore the major problems that are associated with the wheat production with their respective rank. In this context, to address these research gaps, this research is designed to investigate the adoption of improved varieties of wheat in seven selected provinces of Nepal.

MATERIALS AND METHODS

Study area, sample size and data collection technique

Altogether, seven districts: Sunsari (Harinagar, Gadi, Ramdhuni), Bara (Simraungadh, Kalaiyamai, Jeetpur Simra), Kavrepalanchok (Mandandeupur, Budhakhani, Ritthe, Khatechaur), Baglung (Baglung municipality, Galkot), Rupandehi (Siyari, Mayadevi, Tilottama, Omsatiya, Suddhodhan) Dailekh (Dhungeshwor, Narayan, Dullu, Guras) and Kailali (Godawari, Fulbari, Dhangadhi) from seven provinces, each having the highest wheat area coverage in their respective provinces were selected (Figure 1). The primary information was collected by using the pre-tested interview questionnares. Also the two Key Informant Surveys were performed. The secondary information was collected by reviewing the literatures that were relevant to this study. The selection of the survey areas in the selected districts were on the basis of the consultation that was performed with Agriculture Knowledge Centre and agricultural officials of the local government. All total, 651 samples were selected for this study after omitting the outliers and incomplete responses.

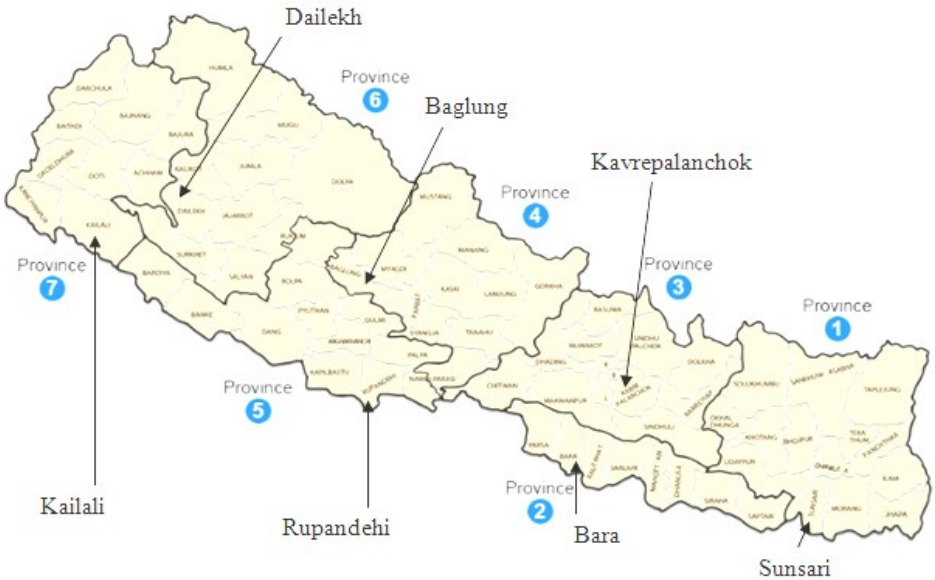

Figure 1. *Map of Nepal showing the selected districts from seven provinces for the study.*

Identifying the determinant factors that affects the decision to adopt improved wheat varieties developed after NARC establishment

To identify the factors that affect the decision to adopt improved wheat varieties developed after NARC establishment, a probit regression model was used. Reviewing the literatures, the probit model has been used to determine the factors affecting the adoption of improved technology (Hattam, 2006). Moreover, Kafle (2010) also used probit model to determine the factors affecting the decision to adopt improved maize varieties. The characteristic feature of the Probit model is that in this model, the effect of independent variables on dependent variables is non-linear. This statistical establishes a relation between probability values and explanatory variables model that ensures the probability value remains between 0 and 1. Probit model is also adopted by Shrestha *et al.* (2018) for assessing determinants of household food insecurity. The social sciences statistical package (STATA) was used for the econometric analysis (STATA version 16 manual; Greene, 2011). The statistical description of the different independent variables used in this model is shown below in the Table 1.

The identify the factors affecting farmers' decisions to adopt improved wheat varieties developed after NARC establishment; the following probit model has been used.

Pr (adoption of improved wheat varieties developed after NARC establishment =1) = f (b_0+ b_1 X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9)

Where, Pr = Probability score for adoption of varieties developed after NARC establishment.

X_1= subsidy (Dummy)
X_2= membership (Dummy)
X_3= if any family member is in foreign employment (Dummy)
X_4= gender of the household head (decision maker) (Dummy)
X_5= age of the household head
X_6 = number of schooling years of the household head
X_7= number of family members involved in agriculture
X_8= total number of family members
Where, b_1, b_2....b_9 = Probit coefficient, b_0 = Regression coefficient

Problems/constraints associated with wheat production

To explore the major problems associated with the wheat production, indexing/scaling technique was applied and the index was calculated. Subedi *et al.* (2019) also used the scaling technique to identify the constraints associated with the potato production in Terai region of Nepal. The weighted indexes were calculated and the problems were ranked by using five point scales based on their responded frequencies. The formula that was used to determine the index for intensity of various problems was:

$$I_{prob} = \sum \frac{Sifi}{N}$$

where, I_{prob} = index value for severity or intensity of problem
$\sum$= summation
S_i = scale value at i^{th} intensity/severity
f_i= frequency of the i^{th} severity
N= total no. of the respondents = $\sum f_i$
Where, I_{prob} = index, 0 < I < 1

This above formula was also applied by Shrestha and Shrestha (2017) to rank the problems associated with maize seed production (Figure 2).

Table 1. Statistical description of the variables used in the probit regression model.

Variables	Description	Value	Expected sign
Subsidy	Government subsidy in inputs	If subsidy provided = 1, otherwise = 0 (Dummy)	+
Membership	Membership of any organization	If had membership = 1, otherwise = 0 (Dummy)	+
Abroad	If family member is in foreign employment	Abroad yes=1, otherwise =0	+/-
Gender	Gender of the household head	Male=1, otherwise = 0	+/-
Age	Age of the household head	Years (in number)	+/-
Edu	Number of schooling years	Years (in number)	+ /-
ag_inv	Number of family members involved in agriculture	Persons (in number)	+
f_size	Number of family members	Persons (in number)	+/-

+ indicates positive sign; - indicates negative sign.

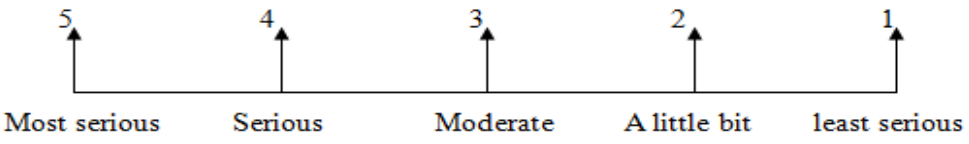

Figure 2. *Scale of rating for the problems associated with wheat production.*

RESULTS AND DISCUSSION

Varietal distribution of wheat in Nepal

This study revealed that 94.1% of the area was covered by the improved wheat varieties, while 3.3% by local and 2.6% by the Indian varieties. The average productivity of wheat in the study area was calculated 2.62 t/ha; improved (2.91), Indian (2.97) and local (1.99). Also, the study showed that of the total improved varieties coverage, 35.67% is occupied by the three varieties (NI 297, UP 262 and RR 21 that were release before NARC establishment, with the average productivity 2.88 t/ha; however, these varieties are not recommended by the government for seed production. The majority area (64.33%) has been covered by the improved varieties developed by NARC. There are Gautam, Vijay, NL 971, BL1473, Aditya, Bhrikuti, WK1204, Danphe, Dhaulagiri, and Annapurna with the average productivity 2.93 t/ha (Field survey, 2019). Cent percent cultivated area is covered by the improved varieties in Sunsari and Baglung while all other districts has good majority of improved varieties. Furthermore, of the improved varieties, NL 297 has the highest area coverage (30.88 %) followed by Vijay (23.24%), Gautam (12.95%), NL 971 (8.94%) and Aditya (5.34%), respectively. It is better illustrated in the Figures 3 and 4.

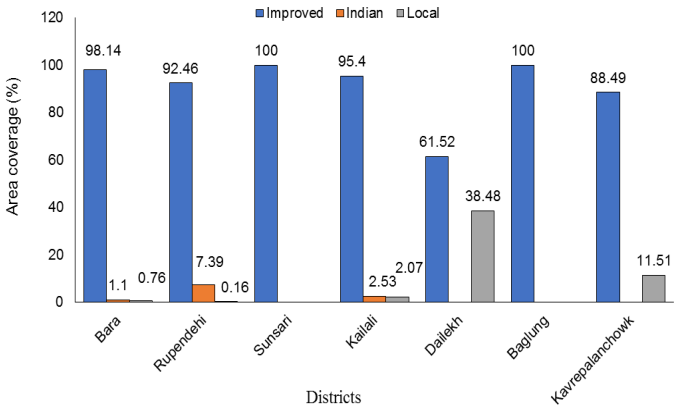

Figure 3. *Area coverage of different wheat varieties in the selected districts.*

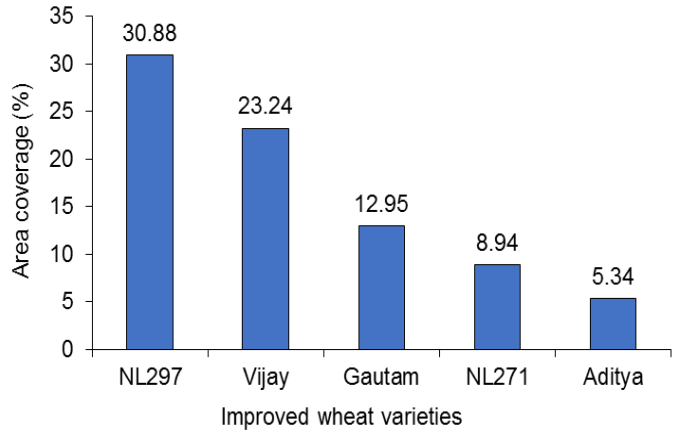

Figure 4. *Area coverage of different improved wheat varieties in the study area.*

Determination of factors affecting the decision to adopt improved wheat varieties

A probit regression model was used to identify the factors affecting the decision to adopt improved wheat varieties developed after NARC establishment where the binary response of the 651respondents was coded as; adopters =1 and 0 otherwise. The Wald test (LR chi^2) revealed that the model has good explanatory power at the 1% level. This means, all the independent or explanatory variables included in the model jointly influence the probability of adoption of improved wheat varieties developed after NARC establishment by the farmers. The probit model estimated the pseudo R^2 0.05 which implies, the variables included in the model explains 5% of the probability of farm household's decisions to adopt or not to adopt wheat varieties developed after NARC establishment. The area under ROC curve for the regression has been estimated 0.66 which revealed that the model presents adequate discrimination. Also, probit regression analysis showed that the four variables: government subsidy in inputs, membership of any organization, family member in foreign employment and gender of the household head significant affects the decision to adopt the improved varieties developed by NARC (Table 2). Furthermore, to interpret the model, the marginal effects were driven from the regression coefficients, calculated from the partial derivatives as a marginal probability which is shown in Table 2.

The farmers who had membership of any organization had 15% more probability for adoption of improved varieties released after NARC establishment as compared to farmers having no membership. This was significant at 1% level of significance (Table 2). In line of this finding, Subedi and Dhakal (2015) also stated that there is positive relationship between the adoption of poultry manure technology in agriculture and membership in any organization or cooperatives. In a like manner, Uaiene *et al.* (2009) stated that individual decisions are affected by social network effects, and that in the context of agricultural Innovations, farmers interact, share and learn from each other. Similarly, the probability of adoption of improved varieties released after NARC establishment is 17% more for the farmers at 1% level of significance, which had got subsidy in inputs for wheat production from the government as compared to farmers who hadn't got (Table 2). The subsidy in inputs supports the cost of production which encourages the farmers for agricultural production. In line of this finding, Mason and Smale (2013) also revealed that the government subsidies could encourage the farmers to adopt the new technology.

Furthermore, the gender of the household head was found to be significant (at 5% level of significance) but negatively related to the adoption of improved wheat varieties developed by NARC. The probability of adoption of improved wheat varieties decreased by 11% for the households having male household head as compared to households having female household head (Table 2). The female who had headed their household might have got opportunity to participate in agricultural training and discussions which could have motivated them in adoption of

new technology. Aregu *et al.* (2011) also reported that women participation and gender inclusion in the workshop and even the training related to seed production, nursery management and fertilizer treatments has been encouraged by the government. In a like manner, Tavya *et al.* (2013) stated that the technological innovation if properly understood from the gender perspective, increment of the agricultural productivity will be encouraged.

Lastly, the probability of adoption of improved varieties released after NARC establishment is 8% more for the households whose family member is in foreign employment as compared to the households having no family in foreign employment. It has been found significant at 10% level of significance (Table 2). The annual household income of the household would be obviously good through remittance if someone from the household is in foreign employment. In addition, if the household have good economic situation, it might be convinced to take risk in adoption of new technology. Gbetibouo (2009) and Deressa *et al.* (2009) also supported the argument that increase in annual household income increases the probability of adoption of new technology as the ability to bear risk increases and comparatively have better economic position to adopt the new technology.

Assessment of problems/constraints associated with the wheat production

When the wheat growing farmers were asked to rank the problems related to wheat production, they ranked- lack of availability of quality improved seeds as the major problem followed by poor availability of fertilizers. Similarly, labour shortage, lack of proper irrigation and lack of agricultural machines were the third, fourth and fifth problems respectively as per farmer's ranking (Table 3). It has been reported that the lack of availability of quality seeds and other inputs such as fertilizers and farm machinery are hindrance to increase the maize production and productivity (Hailu, 1992). Hintze *et al.* (2003) also reported that the increment in production and income are assisted by the availability of technical assistance and adequate irrigation facilities. Furthermore, Paudyal (2001); Shrestha and Timsina (2011) also stated that the seed quality, irrigation facilities and disease pest infestation has significant effect on the yield.

Table 2. Factors that affects the decision to adopt improved wheat varieties developed after NARC establishment.

Variables	Coefficients	P>|z|	Standard error	dy/dx[b]	S.E[b]
Subsidy	.659*	0.010	.257	.171	.050
Membership	.449***	0.000	.109	.146	.035
Abroad	.248*	0.065	.134	.077	.040
Gender	-.376**	0.031	.174	-.111	.046
Age	-.002	0.737	.005	-.001	.002
Edu	-.020	0.155	.014	-.006	.004
ag_inv	-.004	0.908	.033	-.001	.011
f_size	.012	0.492	.018	.004	.006
Constant	.748	0.011	.293		

*** 1% level of significance; ** 5% level of significance; * 10% level of significance. [b]Marginal change in probability evaluated at the sample means.

Summary statistics	
Number of observation (N)	651
Log likelihood	-361.60151
LR chi^2 (8)	40.60*** (Prob> chi^2 =0.0000)
Pseudo R^2	0.05
Predicted probability (adoption)	0.74
Goodness of fit test	Pearson chi^2 (635) = 639.14 .Prob> chi^2 = 0.4465
Area under ROC curve	0.66

Source: Field survey, 2019

Table 3. Problems associated with the wheat production (Source: Field survey, 2019).

S.N.	Problems	Index value	Rank
1	Lack of quality improved seeds	0.75	I
2	Poor availability of fertilizers	0.65	II
3	Labour shortage	0.61	III
4	Lack of proper irrigation	0.55	IV
5	Lack of agricultural machines	0.45	V

Conclusion

This study revealed that around 94% of the area has been covered by the improved wheat varieties. Also, the variety NL 297, government, was found to have the highest area coverage (30.88%). This showed the necessity of proper extension programs to promote the adoption of recently released high yielding and disease resistant varieties developed by NARC. The involvement of farmer in any organization, moreover, the female household heads should be promoted as it has been found to be significant in the adoption of improved varieties developed by NARC. Giving aggressive subsidies, providing the grants to support the annual household income for agricultural investment could promote the adoption of recently released high yielding varieties of NARC. Also, the favorable environment should be created for the remittance earning households in adoption of new technology through technical support and providing membership in farmers' group. Furthermore, this study revealed that lack of proper access to quality seeds and fertilizers, timely unavailability of human labor, inadequate irrigation facilities and having no proper access to agricultural machines has been explored as the major problems associated with the wheat production. The concerned government institutions should assure the availability of quality improved seeds and fertilizers to the farmers; in addition, subsidy on irrigation and agricultural machines allied with financial grant could attract the farmers towards wheat cultivation which ultimately contributes to increase the wheat productivity of the nation.

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Conflict of interest

The authors declare that there is no conflict of interest regarding publication of this manuscript.

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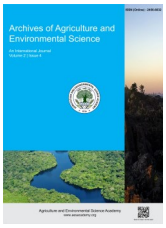

ORIGINAL RESEARCH ARTICLE

Value chain analysis of Allo (*Girardinia diversifolia*) in Solukhumbu district of Nepal

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ABSTRACT

Allo (*Girardinia diversifolia*) is a herbaceous perennial shrub found in subtropical and temperate regions of Nepal. The stem bark of Allo contains fibers with unique strength, smoothness, and silk-like luster. The fiber is used to make clothing since times immemorial. The fiber, thread, and woven clothes are commercially traded in a few districts of Nepal. Residents of hilly areas and ethnic groups have for centuries extracted and spun the fiber to weave durable jackets, porter headbands or straps, fishing nets, ropes, bags, mats, coarse clothing material, and blankets. Therefore, this study was conducted in Solukhombu district using focus group discussion, key informant interview with Allo collectors, and the rapid market survey was conducted with Allo processing enterprises as well as traders at regional to national market hubs in 2018. We found that the exploitation rate of Allo in the study area has been affecting the availability and sustainability of raw material in the natural habitat. This study suggested the need for sustainable management through domestication and proper harvesting technique.

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INTRODUCTION

Allo (*Girardinia diversifolia*) based enterprise is a suitable business to create employment at the local level and reduce poverty in the hilly region of Nepal. There are enough resources in the local forest, many Allo based products are produced at the local level for personal use, and finished goods (at least clothes) are traded overseas. However, there is no authentic government database regarding production and trade. Nepal produces around 1,805 tons of Allo thread per year (MEDEP, 2010). Half of the production is consumed within Nepal whereas the rest is exported. The demand for Allo weaved clothes are high in the international market and it is a prime souvenir product of Nepal. Allo is widely distributed in the southern belt of the Himalayas. It has been recorded in Northern Pakistan, Kashmir, North-west India, Nepal, Sikkim, Bhutan, Southern and Eastern Tibet, Sri Lanka, Northern Myanmar, China, and Malaysia. It is distributed throughout Nepal at altitudes between 1200 to 3000m in moist, forest areas with semi- or no shades, along streams and tributaries, and on the edges of cultivated land (Polunin and Stainton, 1984).

There was no authentic resource inventory of Allo bark in Solukhumbu district. In most of the Rural Municipalities and Municipalities, there is a huge potentiality for harvesting, domestication, and establishment of Allo based enterprises. Mahakulung Rural Municipality-3, Cheskam is popular for doing Allo based enterprises. Annual Allo bark collection trends in Solukhumbu is estimated to be 15 tonnes per year. On the other hand, around 70% of raw materials are harvested from private land. From this scenario, we can assume that through the mobilization of local people, raw materials can be managed more through domestication in community forest and private land. During the field study, it was found that tentative 50% of dried Allo bark was being traded in adjoining district Sankhuwasabha. From the remaining 7500 kg, Allo bark; 3700 kg Allo fiber was produced in Solukhumbu. Around 1500 kg Allo fiber was traded in the Sankhuwasabha district (Paudel and Rosset, 1988). Tentative 2048 kg Allo thread was produced and tentative 1000 kg was utilized for the production of Allo cloth in Solukhumbu district. Through this activity, 63 local people have been getting employment opportunities at the local level and tentative trade value is NPR 6.59 million. If we could support the local communities to

produce cloth from all collected Allo bark; tentative 136 local people will get employment opportunities and trade value will reach NPR 1.44 million per year (Ojha *et al*., 2000). In the present context of Solukhumbu district, consumer products made out of Allo such as bag, hat, cap, shoes, etc. are supplied from Kathmandu (after sending Allo cloth to Kathmandu and return as consumer goods) because of lack of skilled human resource (HR) at local level. There is another possibility to increase employment opportunities through support in technical and other aspects of the production of consumer goods at the local level (Pyakurel and Baniya, 2011).

Allo based enterprises are labor-intensive businesses. This could help to create employment opportunities at the local level and can utilize unused local resources. Through yearly sustainable harvesting, it would not hamper the regeneration of production. In this business, mostly women and DAG have been involved in harvesting, value addition, and trade. In the context of PAF, there are more than 1,136 members directly or indirectly involved in this business from different districts. There is a need for support to prepare a business plan and access to financial services from financial institutions. Likewise, support is required to include it in the operational plan of the CFUG/Buffer zone CFUG for the sustainable management of Allo. Inventory of resources should be taken for assessment of yearly production potential in a sustainable manner. Support is required to make technology and management accessible in order to reduce the cost of production especially for thread making and cloth production. It is necessary to organize skill training and support basic infrastructure at the local level from the cloth industry in coordination with different levels of government and private sectors. To expand business on a commercial scale, it is necessary to encourage and support MEs to produce value-added products and apply new technology to reduce the cost of production. Likewise, research and development are necessary to introduce new technology to reduce the cost of production and improve quality. In the marketing sector, the M4P mechanism should be applied for assurance of the market. There should be regular interaction between market actors including producers to increase market access and produce market demanded products. The following are key objectives to conduct VCA of Allo: To prepare a value chain map and business plan with a special focus on alliance and financing with different actors in the forward and backward linkage. To analyze potentiality of income generation, employment creation, willingness to pay fee/ commission and involvement of private sector in value chains of commodity under study, to identify the current status and gap of the value chain (technology, policy, market, skill/ knowledge, and accessibility) including constraints and opportunities (SWOT) of the commodities under study. To identify the factors affecting the competitiveness of the product produced under PAF pockets, peri-urban and JSDF funded activities, and potentiality for import substitution and/or export promotion. Identify the involved producer groups/CFUGs, areas and potentiality to expand through the mobilization of existing and additional households.

MATERIALS AND METHODS

Methodology and data collection

Both quantitative and qualitative methodologies were used to collect necessary information from value chain actors and enablers at a different stage of the chain of each commodity and were analyzed. A comprehensive value chain analysis of the Allo from Poverty Alleviation Fund (PAF) beneficiaries of the Solukhumbu district of Nepal have been involved directly or indirectly. There are 603 local community organization members who are involved in Allo enterprises. Questionnaires and checklists were developed and used for all value chain actors, enablers including inputs suppliers, producers, collectors, processors, wholesalers and retailers in value chain function. In this context, this study was conducted in Solukhombu district using focus group discussion, key informant interview with Allo collectors, and the rapid market survey was conducted with Allo processing enterprises as well as traders at regional to national market hubs in 2018.

In addition, value chain development (VCD) alliance and financing detail checklist were used to pocket products community organization (CO) members, cooperatives, BFIs, and banks. Two FGDs were conducted in Solukhumbu. Cost-benefit analysis, business potential, gap, and stakeholder analysis, value chain mapping, end market assessment, product, chain, function and process diversifications, potential value chain development alliance and financing models and intervention were assessed in this study. Furthermore, both backward and forward linkage and horizontal and vertical integration of each commodity were judged based on Poverty Alleviation Fund (PAF) Future Strategy, growth and value chain development potential for business promotion in a sustainable manner.

Method of data analysis

Since chain studies were carried out in Nepal in the past by numerous institutions, desk reviews were also conducted to obtain secondary data to ensure validation as well as to avoid the overlap. Desk review, group discussion (with producers using focus group discussion), key informant interview (with input suppliers, key model farmers, collectors, traders, processors, institutions and other VC market chain actors, enablers), rapid market appraisal (with commodity traders and wholesale market) and case studies were used as a VCA study technique using participatory learning and action (PLA) approach. The SWOT analysis, value chain map, backward and forward linkages with a margin of all the actors in the value chain with recommendation mentioning the bottlenecks, opportunities, key leverage points, and intervention strategy were assessed for each commodity. The Statistical Package for Social Sciences (SPSS) was used to analyze data. Descriptive statistics and value chain analysis tools were used to analyze data.

The approach of data collection

The study was conducted in collaboration with Ministry of Agriculture, Land Management and Cooperatives, Ministry of

Industry, Commerce and Supplies, Ministry of Forests and Environment, and MEDEP, other concerned stakeholders/line agencies focusing the core issue in the Agriculture Development Strategy 2015-2035.

RESULTS AND DISCUSSION

Production and marketing context of Allo

The trading of Allo begins with the collection of bark from forests and ends with the export of woven fiber. There are three tiers of actors-micro, meso, and macro-level players-in the value chain. At the micro-level, there are collectors, cloth and thread makers, wholesalers and retailers. At the meso level, there are CFUGs, Buffer Zone CFUG, COs, Cooperatives and district level handicraft associations. At the macro and policy level, there are institutions such as the Cottage and Small Industry Development Board (CSIDB), Department of Forests (DoF), Department of National Park and Wild Life (DNPW) and the Ministry of Industry, commerce and supply, which formulate and implement policies. The structured and predetermined role of these major stakeholders and interactions among them influences the value addition and price mechanism of the enterprise.

All the elements in the supply chain are based on local resources. Allo harvesting is a seasonal business. It is started in October and ends in December (*Kartik-Mangsir*). Allo thread is being traded-in local level and neighboring districts. Likewise, woven clothes are brought to district headquarters, Kathmandu and sold to entrepreneurs or exporters. Entrepreneurs often weave fine clothes in Solukhumbu themselves and sell in the domestic market or export. Likewise, value addition from Allo cloths has been producing mostly in Kathmandu. Therefore, value addition takes place both in urban and rural areas. Income is shared by both rural communities and urban entrepreneurs. The promotion of quality yarn and cloth production has great potential to alleviate rural poverty in the hilly regions of Nepal.

Product forms and respective prices

Each hectare of Allo yields around 600 kg of fiber. Fiber is extracted on a commercial scale in some districts. Allo is traded either raw (dry bark), or semi-processed (coarse fiber), thread or in processed form (cloth). The dried bark is traded anywhere between NRP 90 to 100 per kg; coarse fiber between NRP 200 to 240 per kg; and handmade cloth at NRP 500-600 per meter (Table 1).

Allo-lokta: It means bark of Allo plant or bast extracted from the plant.

Table 1. Product form and price trends.

Product Forms	Grades (NRP/kg)	
	A	B
Allo-lokta	100	90
Fiber	240	200
Dhago	600	500

(**Sources:** FGDs, KII and Field Survey, 2018).

Bhuwa: It means cooked, washed and dried form of Allo-lokta.

Dhago: It's spun or final product of Allo processing i.e. Fiber Further, these products are graded as per the quality of the Allo in these product forms. And the prices differ as per the grade of the product forms. Following is the price list of the different grade

Market actors

Collectors: Collectors here refer to those people who collect the Allo-lokta (Allo-bark) from the forest. Collectors can also be regarded as the Allo bark extractors. Allo bark is collected from the nearby CF, Buffer Zone Forest and private lands by collectors using traditional weapons such as sickles. They cut down the Allo plant and leave it there for some minutes so that the prickles will not hurt them during bark extraction and transportation. Collectors collect only the bark of the Allo plant leaving the solid, rigid stem making the backpack (*Bhari*) light for the extraction from the forest to their home. In the context of CF, extraction time is fixed especially from Mangsir to Poush, the CF allows its member to enter the CF for Allo bark. Collectors cut down the Allo bark as much as they can which can extend to one day long. It is observed that a collector cut down or extract up to 20 kg of Allo bark in one day. The permission is given by CF only after payment of a certain amount by the collectors. Collectors collect the bark to their home and use or sell it as per the market condition. If they have to stock it then they will dry it in the courtyard and store it. However, if they have to produce fiber, they will immediately use it without drying it in sunlight.

Processors/manufacturer/producer: The processors buy the Allo lokta, fiber from the collectors or in some cases collectors themselves form a group and start processing the Allo barks. They process the Allo lokta bought from collectors, produce fiber and they weave out clothes and trade to the local market as well.

Traders: Traders trade clothes prepared by the processors inside as well as the outside district. The most notable matter is that the traders only trade finished Allo products and the processors themselves are traders. The below box shows the different sizes of clothes. The price of Pure Allo cloth was NPR 500 and cost of production was NRP 417 for 26/27 inch*1 meter (30 inch width with 4.5m cloth can make 1 coat; 26-27 inch width with 5m cloth can make 1 coat; 26-27 inch width with 5m can make 1 waistcoat; 30 inch width with 1m cloth can make 1 waistcoat and 30 inch width with 2m cloth can make 1 ZUWARI coat).

Consumers: Most of the consumers are foreigners or tourists. Nowadays domestic consumers are also interested to purchase and use Allo products. Due to a lack of advertisement and knowledge about Allo, the marketing of Allo has not increased the desired level. Most of the Allo products consumers are from Kathmandu and those who visit the district.

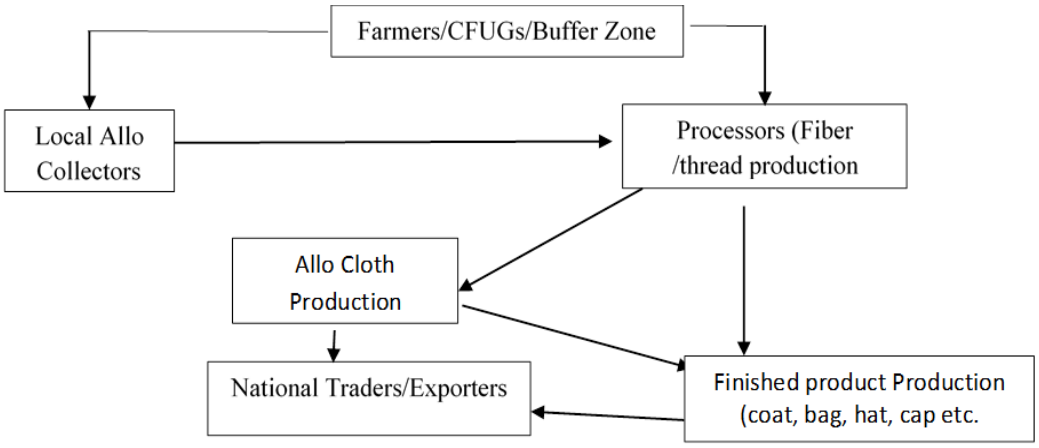

Figure 1. Marketing channels of Allo trade (Source: ECARDS-Nepal/MSFP, 2015).

Distribution of value addition

Allo-lokta extraction: Allo-lokta (Allo Bark) is extracted from the nearby forest i.e. CF, buffer zone, and private lands. People use local equipment such as sickle to cut down and extract Allo bark from the Allo plants. Allo Lokta is extracted at the forest or private land then only carried home (Figure 1).

Drying: Drying is done only if Allo lokta is to be stocked. Otherwise, Allo lokta is directly cooked for further process. Hence, it depends on market demand and the total quantity of Allo-lokta extracted out from the forest.

Cooking: Allo-lokta is cooked with ash, kamero, or caustic soda according to the accessibility, preference and economic condition of the processors. It is usually used for softening the Allo bark into the fiber. Using caustic soda is preferred to ash or kamero because it softens the Allo bark quickly though it is quite expensive with respect to ash and kamero, which is available freely and easily. Cooking usually takes ½ to 1 hour if the appropriate amount of heat is provided but it might take 3 to 4 hrs if the heat is lower than required. However, it totally depends upon the amount of Allo lokta cooked too.

Beating and washing: The cooked bark is cleaned in water by continuously beating it with a wooden mallet. Cleansing requires a lot of water, so it is usually done in streams and tributaries.

Cleansing: The washed bark is mixed with paddy husk or in white clay solution and dried in the sun for 5 to 6 hrs. The process softens the fiber and brings extra whiteness. Coarse fiber is cleansed again by repeating the earlier process. Finally, the fiber is separated manually by using Katuwa, a traditionally designed wooden equipment to separate fiber from softened bark.

Spinning: Spinning is either done with a self-constructed hand spindle made of wood or with a spinning wheel. A hand spindle is lower than the wheel but is preferred because it is light to carry and women find it handy and suitable for spinning during their leisure time or during other activities. It takes one man-day to weave threads for 1.5kg of fiber. Either the threads are sold to entrepreneurs, or collectors themselves weave them to make coarse clothes.

Weaving: Weaving is done with the (taan) loom (weaving machine). The firmness of the yarn depends largely on the skill of the spinner and also on the quality of the fiber. The yarn thus spun is woven on a backstrap loom (ECARDS-Nepal/MSFP, 2015).

Value chain map of Allo sub-sector

This value chain map is the representation of the Solukhumbu district in Nepal. Some adjustments have been made in this value chain map. During mapping, actors involved in this sector with their respective functions are listed and mapped accordingly. Figure 2 presents the definition of each actor, the flow of products within the chain and the relationship between various actors in the value chain map of the Allo sub-sector.

Functions: Major functions involved in this sector are input supply, production, and local processing, threads making and cloth-making at a local level, domestic trading, making different products and trading local and international markets. Allo has been on use in Nepalese society, especially in Himalayan society for rope and their clothes. At present natural fiber products from Allo are used in making various products like a purse, bag, and various types of cloths. These products are also exported to European and American markets.

Actors: The value chain operators and the operational service providers are included as an actor in the value chain (MOAC, 2011). Those functionaries who are directly involved in the transaction or directly support the actors who are involved in the transaction are the VC actors.

Based on activities performed, the actors are classified as below:

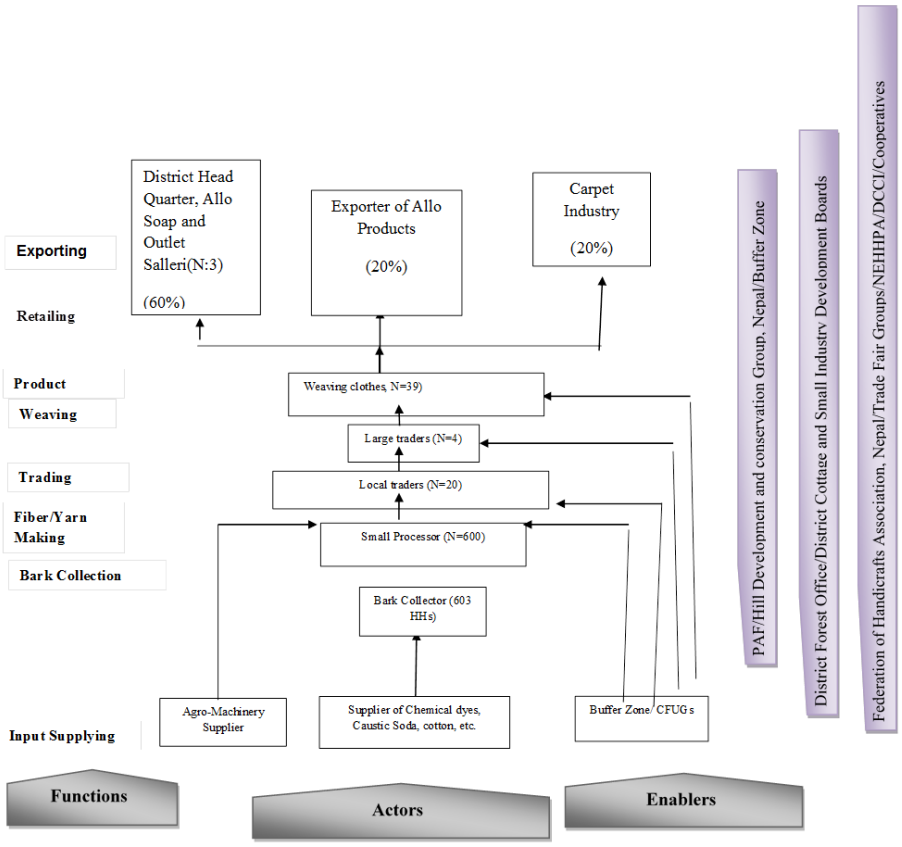

Figure 2. *Value chain map of allo in solukhubu district.*

1. Input suppliers: Input suppliers are those who provide inputs for the production of Allo Lokta, fiber, threads, clothes, and other various product types. Technical inputs, threads, threads making machines, cloths making machines, etc are the major inputs for Allo enterprises. These are unique types of natural-based enterprises that have been expanding on commercial-scale for a decade. At lokta collection stage and making fiber stage, CFUG members manage the required tools and equipment by themselves. Thread making machines, cloth making machines, and other tools and equipment for further processing stage is managed by Agro-machinery suppliers and manufactures of machinery and equipment at Kathmandu and India. Government agencies and non-governmental agencies provide technical knowledge and inputs to some extent; however, the flow of information and inputs is not satisfactory.

2. Buffer Zone Forest Group Member/CFUG Member: The term Buffer Zone/CFUG member refers to a person or his/her family members who have been collecting and selling Allo. The member also protects and manages sustainably in CFUG land. It is observed that 70% of the Allo crop is collected from private land.

3. Local processors: Allo is processed at the local level for making Allo fiber and Allo threads. These processed products are then sold to local entrepreneurs and local traders.

4. Road-head traders: Those traders who are located at road-head and collect the goods from farmers are called road-head traders in the value chain. Road-head traders are usually from the local community and conduct the trading activity of various goods including other NTFPs.

5. National Traders: National Traders are the traders who are actively involved in trading Allo fiber, Allo threads, clothes, and other various products of Allo products. They get goods both from local processors and road-head traders. Besides supplying goods to national markets especially to handicraft industries, they also supply to exporters and national processors/ manufacturers. Sometimes national traders directly provide goods to importers in European and American markets.

6. National processors/manufacturers: They are the firms that are engaged in producing fiber, Allo threads, clothes, and various products from Allo cloth such as Coat, Shawl, Shirt, handbag, etc. These products have been trading in national and international markets.

7. Exporters: Exporters are the firms, which export various final products of the Allo plant. Major products of Allo are exported to Europe and America. Various types of fair trade groups and natural products exporters are involved in exporting these products to Europe, America, and Asian markets.

8. Wholesalers: Wholesalers are defined as those who sell the goods to retailers.

9. Retailers: They are the trader who gets goods from wholesalers and sells to end consumers. Retailing shops of handicrafts and departmental stores are the main retailer of Allo products.

Table 2. Constraints and opportunities of Allo business in different value chain stages.

Value chain stage	Constraints	Opportunities
Input supply	• No supplier for commercial/ cost effective tools and equipment for spinning of Allo threads. • No well certified technology for domestication. • No availability of technology for disease and paste management of Allo plant. • Not enough raw materials for value addition. • No mentioned in operation plan about Buffer Zone forest user group/ CFUG for domestication and sustainable management.	• Allo spinning machine brought form outside district through supporting agencies such as CSIDB, PAF, Hill Development and Conservation Group, Nepal. They are facilitating input supply through coordination of manufacturing companies. • NARC and Agriculture and Forestry University (AFU) can support for research and development of domestication and disease management. • District forest office, wildlife and forest conservation office are willing to support for sustainable commercialization of Allo. These government agencies could support to mention Allo management in new operation plan. • PAF is involved in whole value chain for commercialization of Allo based enterprises.
Production	• Inventory records of raw materials is unavailable. • Allo domestication and sustainable management of Allo is not present in CFUGs' operation plan. • Insufficient financial resource for production and marketing. • High cost of production in comparison to neighbor Allo production district, Sankhuwasabha. • No approved technology for domestication and disease and paste management. • No human resources and infrastructure (sewing machines, over lock machine, etc) for the production of consumer products such as bag, porches, hat, sandals, etc.	• DFO/ National Park and wildlife conservation office can support the members of CFUG for inventory recording during operation plan review and new operation plan development. Through this process, it will be easy to secure permission for business registration. On top of that, MEs will receive training opportunities for technical enhancement.
Marketing	• Limited access to output marketing actors. • No regular interaction mechanism between traders and producer groups. • No transparency mechanism during selling of products. • No sub-contracting model for the assurance of selling products in larger scale.	• Allo based products have increased market demand in national and international market. • Buyer seeks to receive products in large scale. • Could develop sub-contracting model for assurance of buy back guarantee of products.
Processing	• Post harvesting management and local level processing is labor intensive and costly.	• Supporting agencies have been providing training, required tools and equipment to related entrepreneurs. In this regard, entrepreneurs are increasing. • CSIDB has been supporting technology other things declaration of Allo production pocket area.
Financial services	• Financial access with only PAF supported cooperatives, which are very limited in number. • Insufficient credit for doing business.	• Could increase the linkage with other financial institution. • NRB and other financial institutions have the provision of wholesale lending which can increase the financial access to PAF supported cooperatives.
Infrastructure	• No sales outlet of beneficiaries for selling products. • No tools and equipment available for cost efficient and quality threads production. • working places	• Opportunities to link local federal government to construct infrastructure and places. • CSIDB provides cost effective technology and other necessary support.

(**Sources:** FGDs, KII and Field Survey, 2018).

Enablers and facilitators

In a value chain, the enabler is all chain-specific actors providing regular support services or representing the common interest of the value chain actors. Functions at the enabler level include public research and technology development, agreement on professional standards, promotional services, joint marketing or advocacy, and another support service.

Enablers in production and local processing functions

For the producers groups, District Forest Office (DFO), Community Organizations, Cooperatives, Federation of Community Users Nepal (FECOFUN), Buffer Zone Forestry User Coordination Committee, Federation of Handicrafts Association, Nepal and various development organizations provide technical and financial assistance to local producers, cooperatives and private sectors for value addition and marketing.

Enablers in trading and export functions

In traders' level, Business Membership Organizations (BMOs) like Nepal Herbs and Herbal Production Association (NEHHPA), Federation of Handicrafts Association, Nepal District Chamber of Commerce and Industries (DCCI) are involved to make this business successful. Agro Enterprise Centre (AEC) works in the area of market development by providing market information, facilitation for market linkages, etc. Similarly, the Trade and Export Promotion Centre (TEPC) assists in the export of goods, support to organize various trade fair and also maintain the export data. At a higher level, the Ministry of Forest and Soil Conservation (MoFC) and Department of Forest (DoF) Federation of Nepalese Chamber of Commerce and Industries (FNCCI), Ministry of Industry, Commerce and Supplies are involved to enable this value chain.

Table 3. SWOT Analysis of Allo and its processed products business.

Strengths	Weaknesses
• Indigenous skills and culture in Kulung Rai women communities. • Local Communities use their leisure time for doing Allo based business. • More than 60% of raw materials comes from local resources. • Has capacity to produce according to market demand in quality, design and size. • No ban or restriction on collection, trade and export. • Has provision to cultivate to a wider area in CFUG land, private land and buffer zone. • At present more than 70% Allo bark are harvested from private land. Local communities did through cultivation and sustainable management resources.	• No linkage development among producers and buyers. No transparency during product selling to output marketing actors. • Producer has no skills for value addition of products from Allocloths. In addition, there is lack of infrastructure such as industrial sewing machine, over lock machine, working halls, etc. • Lack of knowledge and product diversification. • Fixed season for harvesting of raw materials. • Constraint government policies and taxation process. • Maintaining supply chain and market distribution network is difficult as like Sikki carft (Paras and Varshneya, 2015). • All groups are registered in PAF group. According to CSIDB, there are only 6 registered Allo based enterprises in Solukhumbu district. • Lack of preparation of business plan. • Inadequate raw material for mass scale production. • Producer are still using conventional technology and methods of production, which are highly inefficient. This restricts their production capacity, produce low quality of outputs and require high cost of production.
Opportunities	**Threats**
• PAF and other government agencies are in full support for the commercialization of this business. • Huge opportunity to generate income and employment in the rural areas to indigenous women. • Niche market opportunity due to unique qualities. • Environment friendly production. • District forest office, Makalu National Park and wild conservation office are willing to support for cultivation by supporting CFUG to mention in their operation plan. • Through coordination with NARC and Agriculture and Forestry University (AFU), commercial cultivation technology and disease and paste management technology will identify.	• No approve technology has introduced for commercial cultivation. • Threat to sustainable production of resource. • Most of the productions are done through traditional technology such as spinning of threads. This technology requires high cost of production than other district. i.e. Sankhuwasabha District. • Domestic threats in terms of labor issues. • Misconception about handicraft products being more expensive than conventional products. • Inadequate advocacy and promotions.

(**Sources:** FGDs, KII and Field Survey, 2018; Rai and Chapagain, 2014; Paras and Varshneya, 2015).

Public actors

Ministry of Forest and Soil Conservation (MoFSC) and Department of Forest (DoF): MoFSC facilitates this value chain through the Department of Forest and its districts. It designs a suitable policy for benefiting micro-entrepreneurs and poor CFUG members. Beyond this, it does some regulatory works for the sustainable management of resources and provides a fund to entrepreneurs.

Cottage and Small Industry Development Board: This government agency is under the Ministry of Industry. It supports entrepreneurs especially for registration of enterprises, provides entrepreneurship training, technical training technology access and so on. This government organization also conducts training to Allo entrepreneurs along with training materials.

Trade and Export Promotion Centre (TEPC): TEPC is established under the Ministry of Commerce and Supplies with the objective of promoting foreign trade. This agency supports export promotion through trade fairs, participation in the various program, information dissemination about procedure and others to trading organizations and associations.

Federation of Handicraft Association (FHN), Nepal: This is an association of entrepreneurs involved in handicraft businesses such as Allo, pashmina, bamboo, woolen, artisan, etc. This organization supports entrepreneurs through marketing, connection to the fair trade group, organization of trade fair, advocacy, etc.

Projects/organizations

Poverty Alleviation Fund: PAF supports MEs through a revolving fund, technical training, marketing support, equipment, entrepreneurship development training, domestication, etc.

Hill Development and Conservation Group Nepal: This is the partner organization of PAF in Solukhumbu District. It supports local entrepreneurs for technology, domestication, marketing, entrepreneurship development, etc.

Nepal Herbs and Herbal Production Nepal (NEHPA): This is a trader's association especially of NTFP. This organization supports Allo entrepreneurs through the management of trade fair, buyback guarantee of products, advocacy, etc.

Constraints and Opportunities Analysis

Constraints and opportunities of Allo business in different value chain stages are given in Table 2.

SWOT analysis for production, marketing, and upgrading of sub-sector

SWOT Analysis of Allo and its processed products business are given in Table 3.

Value chain upgrading strategy of Allo processing

The value chain upgrading strategy of Allo processing is given in Table 4.

Potential Intervention Area for Value chain alliance and financing

Potential intervention areas for value chain alliance and financing are given in Table 5.

Internal and external value chain financing

At present, the financing resources to this value chain is mainly RF from PAF and PAF supported cooperative. To increase business to this value chain and create more employment opportunities, it is necessary to make financial services accessible to value chain actors. The main area of the capital requirement is marketing, basic infrastructure (building, industrial sewing machine, overlock machine, iron sets for yarn making, thread making machine, press machine, basic materials for fiber making, harvesting tools), disease and paste management, raw materials management, etc (Table 6).

Environmental analysis

At present more than 70% of raw materials (Allo bark) are coming from private land in Solukhumbu district. Local communities have been cultivating this crop through their own experience especially from the old plant. After two years of cultivation, it will be ready to get harvested. The sustainable harvesting practice eases the collection of the crop every year. But the main problem lies in the production level due to disease and paste management. Research and development are necessary to approve technology for domestication and disease and paste management. On the other hand, in the CFUG/Buffer Forest area, CFUG members have been cultivating and harvesting Allo. However, there is no mention in the operation plan. From a sustainable point of view, it necessary to conduct resource inventory at the district level, need to review and prepare a new operation plan with mentioning the sustainable management plan of Allo.

Market analysis and strategy

In Nepal, around 1805 tonnes of Allo bark is harvestable from 55 districts. At present around 150-200 tonnes of Allo yarn/threads have been producing per year. As it has already mentioned, Allo trading has been generating tentatively NPR 65.94 million trade value per year in Solukhumbu district, if we could support and provide enabling business environment to local communities, the trade value will increase to NPR 1.44 per year. On the other hand, there are a total of 39 micro enterprises (MEs) working for the production of Allo cloths. Their yearly average production is 171 meters. If they are provided with the market assurance, each ME can easily produce 1000 meters per year. As a result, the production will increase as well as employment opportunities at the local level. There are also opportunities to produce consumer-finished products from Allo cloth at the local level. Overall, market penetration is a prerequisite.

Table 4. Value chain upgrading strategy of Allo processing.

Chain level	Context and situation	Key gaps identification	Intervention approaches
Inputs and services	• Labour intensive work in Allo processing is thread making. - MEs have been working through traditional method. • Producers are harvesting more than 70% Allo bark from private land. But there is no well known technology for domestication. They are suffering from disease and paste management. • MEs are getting financial services from revolving fund and PAF cooperative.	• Lack of suppliers for commercial/ cost effective tools and equipment for spinning of Allo threads. • No well approved technology for domestication of Allo. • No technology available for disease and paste management for Allo plant. • Not enough raw materials for value addition. • No mention of Buffer Zone forest user group/CFUGs' operation plan about the domestication and sustainable management.	• Identify and assess tools and equipment for cost effective production. • Conduct R&D and support for commercial domestication and disease and paste management method. • Support to prepare business plan and access financial services from other financial institutions.
Production	• Around 15 tonnes of dried Allo is harvested every year and traded in Solukhumbu district but there is no proper record mechanism by government institution. • No identification about stock and assessment for doing yearly harvesting and trade quantity from sustainable point of view. • High cost of production as compared to neighbor district, Sankhuwasabha district.	• No resource inventory assessment has been done to check the availability of raw materials. • No Mention of Allo domestication and sustainable management of plan in CFUGs' operation plan. • Insufficient financial resource for production and marketing. • High cost of production in comparison to neighboring Allo production district, Sankhuwasabha. • No approved technology for domestication and disease and paste management. • No human resources and infrastructure (Sewing machines, over lock machine, etc)for the production of consumer products such as Bag, Porches, hat, sandals , etc	• Support to include sustainable management of Allo in CFUG/ buffer Zone CFUGs's operation plan. • Inventory of resources should be taken for assessment of yearly production potential in a sustainable manner • Support and assess technology and management to reduce cost of production especially for thread making and cloth production. • Provide technical training and basic infrastructure at local level from cloth industry in coordination with new federal structure, and private sectors.
Collection/ trading	• At present, Allo trading generates tentatively NPR. 65,94,000 trade value per year in Solukhumbu district (through estimated 15 tonnes of Allo bark.) • Around 70% of bark is collected from private land. • Around 50% of raw materials is traded in neighboring district Sankhuwasabha,	• Insufficient raw materials to increase the production level. • Around 50% of raw materials is traded in other district, • From Allo finished products such as hat, cap, bag, shoes are produced in Kathmandu and these finished products are sold back to Solukhombu district. • No sufficient market assurance for selling finished products.	• Encourage and support MEs to produce value addition of products. • Make M4P mechanism for assurance of market.
Processing	• Production of fiber and thread using traditional method. • Tools and equipment are not functional.	• Support technologies are not functional due to low efficiency. • No technical skills with MEs for commercial operation.	• Assess and support commercial viable technology to reduce cost of production. • Train and encourage using new technology to reduce cost of production. • Conduct R&D to introduce new technology to reduce cost of production and improvement of quality.

Table 4. *Continued……..*

End market	• Mostly coat cloth is traded in Solukhumbu district. • Finish products are prepared in Kathmandu and traded in domestic market as well as exported to foreign market.	• Limited access to output marketing actors. • No regular interaction mechanism between traders and producer groups. • No transparency mechanism during selling of products. • No sub-contracting model for the assurance of selling products in large scale.	• Introduce proper mechanism for interaction between producers and market actors to increase market access and produce market demanded products. • Need to conduct advertisement and B2B linkage to increase market sales volume.
Backward linkage	• Limited access and dissemination for input supply such as technology, tools and equipment. • Limited access to financial institution. •	• Producers are not being able to compete in market due to lack of access to technology that reduces the cost of production. • Insufficient capital with different value chain actors to expand their business.	• Access new technology to grow and sustain business. • Make financial resources accessible to different value chain actors to expand their business.
Forward linkage	• Limited B2B linkage. • No transparency in sales and marketing activities. • Unhealthy competition among buyers.	• Producers do not have information about the exact market channel. • No platform to sale their products through open interaction • Producer groups have no end market actors.	• Need to make regular interaction and open market competition mechanism. • Need to introduce MIS system for market dissemination. • Establish outlets in Kathmandu and create opportunities to participants for various trade fairs and workshops.
Vertical integration	• Raw material harvesting, fiber production, thread production and cloth making work are done in single places to some extent. • No value addition from Allo clothes	• Limited financial resources. • Lack of entrepreneurship • No technical skills and infrastructure for value addition in desired scale.	• Financial access and introduce m4p approach for market assurance of products. • Technical training and manage infrastructure through coordination of new federal structure. • Regular business backstopping and entrepreneurship development to increase business and value addition at local level.
Horizontal integration	• Limited relationship among producer group within district through PAF and limited relationship with adjoining district Sankhuwasabha. • No producer association in the district. • Limited relationship between district level traders and other traders.	• No platform for regular interaction mechanism for value chain actors. • No exchange of technology mechanism to reduce cost of production, and marketing	• Build relationship with other actors for experience sharing, technology and marketing. • Form association and their institutional development.

(**Sources:** FGDs, KII and Field Survey, 2018).

Table 5. Potential intervention area for value chain alliance and financing.

VC Functions	Area of interventions	Key partners and alliances	Types of Financing Required	Potential revenue generation for PAF
Raw material Collection & Input supply	• Strengthen awareness among collectors and SMEs about sustainable collection. • Foster collaboration between MoFSC, DFO, Department of National Park and Wildlife Conservation, Buffer Zone Forest User committee, CFUGs and collector /Entrepreneur communities to promote domestication in Buffer Zone/community forest and include it's management in operation plan. • Disease and paste management support services to Allo farmers. • Provide training on appropriate timing and techniques for cultivation and sustainable harvesting • Research and development for domestication, disease and paste management and improve technology for thread making.	• Buffer Zone CFUGs • Collector, CFUGs • Agriculture and Forestry University (AFU) • Department of Agriculture • Tools & Equipment's suppliers • Financial Institutions • DoF • Department of National Park and Wild Life Conservation	• Technical Assistance • Research	• TA service fee, Loan brokerage fee • Support Activities
Raw material Processing	• Facilitate and Improve the supply of quality inputs tools/equipment's to Collector/Allo product producers and SMEs in timely manner • Enhance the capacity of primary processors (fiber production, thread production) with modern tools & equipment to improve processing and production techniques that ensures quality. • Facilitate and support SMEs for enterprise registration in coordination with local federal government structure, CSIDB and increase access to the services for commercialization of their enterprises/ business.	• Collectors • Tools/ Equipment's Manufacturer • FHAN • CSIDB	• Technical Assistance • Co investment (Grants & Loans) for input supply business	• TA service fee for trainings & Enterprises registration , Loan brokerage, Commission on Business linkages for tools & equipment's
Product Design & Development	• Capacitate and co-invest SMEs/producers to produce quality products, value addition, diversified & competitive product following sustainable design trends as per consumer demand (consumer product at local level such as bag, purse, cap, hat, shoes, etc). • Support for technical and advisory services to Allo manufacturers on quality management, cost reduction and business management practices to improve competitiveness. • Encourage artisans /SMEs to participate in cooperatives so that they can better access business development services (BDS) and platform for marketing their product. • Facilitate and enhance capacity of Allo product manufacturer /artisans on financial management and marketing of their products through sales outlet and trade fair /exhibition • Facilitate and support to develop common facility center at specific location • Alliance with primary processors to secure the availability of quality raw materials	• Product manufacturers • Tools/ Equipment's Manufacturer • Service Providers • FHAN • CSIDB	• Technical Assistance for capacity building, Institutional development & Business Management • Co investment(Grants & Loans) for product Manufacturers to adopt new technology / design and to participate in trade fairs • Co-financing storage facilities & Market Centre with product manufactures	• TA service fee, Loan Brokerage fee, Commission fee for brokering business linkages & Service linkages

Table 5. *Continued*.....

End market (national and international)	• Strengthen SMEs for collective marketing and facilitate their business relationships with buyers at local, regional and international markets. • Make regular interaction mechanism between producers and market actors. • Facilitate buy back guarantee and contracts between Allo manufacturers and buyers/ exporters to establish and develop positive relationships. • Conduct Market research of Allo products both at national and international level.	• Product Manufacturers • producers / SMEs • Buyers (institutional as hotels, offices & individual) • Exporters • TEPC • FHAN	• TA, Co investments (Grants & Loan), Research & Studies • Market promotion support activities	• TA, and Commission through brokering business linkages
Service Provision	• Strengthen technical service providers and facilitate their linkages with product manufactures. • Provide technical assistance related to institutional development, market management, market information dissemination, and gender empowerment. • Facilitate Business to Services linkages. • Develop new and appropriate financial products to reach smallholder producers. • Provide financial access to meso level market actor for greater transaction of products.	• FHN • Financial Institutions / commercial Banks • Technical, Business Service Providers • Producers / SMEs	• Technical Assistance • Grants and Loans	• TA service Fee, Loan Brokerage fee, Commission through brokering service business linkages

(**Sources:** FGDs, KII and Field Survey, 2018).

Table 6. Financial Institutions and Government Department to promote value chain alliances and finance in Allo Value Chain.

Financial Institutions	Government Department	Private Sector
Commercial Bank	All department under Ministry of Forest and Soil Conservation and Ministry of Industry, Commerce and Supplies.	FNCCI particularly Agro Enterprise Center
Development Banks	Cooperatives Department, Company registrar Office	Agro-SMEs
Micro-finance Institutions	Municipalities and Rural Municipalities (GaunPalika)	Traders and aggregators
Cooperatives	Agriculture and Forestry University Rampur	Federation Handicraft Association
None-Life Insurance Companies	CTEVT and its affiliated agriculture training center	NEHHPA
	Credit Information Bureau	

Table 7. Cost advantage of the proposed value chain Allo sub-sector.

Aspects of Allo Sub-sector VCD Potentiality	Year 1	Year 2	Year 3	Year 4	Year 5
Income generation (Annual) (NPR in Million)	15.7	31.4	47.1	62.8	78.5
Initial Investment/loan fund required (Annual) (NPR in Million, both FC+OC)	13.1	26.2	39.3	52.4	65.5
Insurance premium cost required (Investment based) (NPR in Million) Not applicable in Allo VC	0.0	0.0	0.0	0.0	0.0
Available capital fund (RF) from COs to be mobilized (NPR in Million)	3.9	7.8	11.7	15.6	19.5
Loan fund required from external financial institutions (NPR in Million)	9.2	18.4	27.6	36.8	46.0
No. of Self Employed/No. of Entrepreneurs	78	156	234	312	390
No. of employment generated (seasonal)	78	156	234	312	390
Allo cloth production (in meter)	31395	62790	94185	125580	156975
No. of potential SMEs to be created for value chain (processing, marketing and product diversification)	6	13	19	25	31
No. of employment to be generated by proposed SMEs	63	126	188	251	314
Total employment generation including enterprises and SMEs from PAF intervention	225	450	675	900	1125
Return to Investment (RoI)%					19.9
Market Share (%) (Only few HHs involved in product making by PAF initiative in Nepal and after three year, out of total production PAF intervention will share 40% at national level)					40
No. of HH members benefited	733	1466	2200	2933	3666
B/C ratio					1.2
Commission to PAF (from loan brokerage and insurance linkage services)	0.2	0.4	0.6	0.7	0.9
Revenue generated by government (CF), Fee, Royalty, Private Sector/Public including tax (NPR in million)	1.0	2.1	3.1	4.2	5.2

Table 8. Assumption notes.

Assumption Notes	No.
Allo enterprises scheme basic features:	
Total Allo small business enterprises in PAF pocket area of Solukhambu (No. HH)	39
Allo bark collection and selling HHs of CO members to enterprise	603
Annual Allo cloths production and sale by each enterprise per year at current situtation (in meter)	161
Potential and proposed Allo cloths production and sale by each enterprise per year (in meter)	403
Average current market price per meter Allo Cloth (NPR/number)	500
Potential Allo based enterprises within 5 years (Numbers) in Solukhumbu, Magdhi, Gorkha, Dailekh, Sankhuwasava) (10 times of existing 39 enterprises)	390
Allo barks require to make Allo thread (kg)	3.2
Annual Allo bark require for each enterprise (kg)	13417
Production of Allo cloths by one kg of thread (in meter)	6
Cost for Allo bark (NPR/kg)	200
Cost for producing Allo thread (NPR/kg)	1140
Price of Allo thread (NPR/kg)	1200
Total thread require for each enterprise annually (kg)	67
Additional Cost of cotton/woolen thread for making 1 meter Allo cloth (NPR)	77
Labor cost and other cost to make 1 meter Allo cloth (NPR)	150
Cost for making 1 meter Allo cloth (NPR)	417
Market price of Allo cloth per meter (NPR)	500
Annual investment/cost require for each enterprise (NPR)	167843
Annual revenue /enterprise (NPR)	201250
No. of employment generated (seasonal)	403
Total annual revenue to be generated from 390 Allo Entrepreneurs (NPR in Million)	78.5
Estimated No. of total annual production in Allo Enterprises in 5th years (Meter)	156,975
Market share %	0
Total annual investment to be required in 5th Year (NPR in Million)	65.5
Available capital fund (RF) from Cost to be mobilized (NPR in Million) [@NPR 50000/CO member]	19.5
Loan fund to be required from external financial institutions (NRs. Million)	46.0
Insurance (Investment based) (NRs. In Million) in Allo product scheme not applicable	0.0
Total annual investment required in 5th year (NRs. In Million)	46.0
No. of potential SMEs to be created for value chain (processing, marketing and product diversification) (@5000 mt cloth = 1 SME=Year flow)	31
No. of employment to be generated by proposed SMEs	314
Total employment generation including enterprises and SMEs from PAF intervention	314
Revenue generated by government (CF), Fee, Royalty, Private Sector/Public including tax (NPR in million)	5.2

(**Sources:** FGDs, KII and Field Survey, 2018).

Gender integration in value chain development

Allo cultivation is a labor-intensive and women-friendly business. There are more than 80% of women involved in the raw material collection, fiber production, thread production, and cloth production. And men are mostly involved in the transportation of raw materials and marketing finished products. It has become one of the major sources of income to that 80 % of women utilizing their leisure time to this business. In order to attract more women to this business, the value addition of Allo clothes could be done which creates more opportunities. In addition, technical training, management of basic infrastructures such as industrial sewing machines, overlock machines, more financial access and regular business backstopping could also create a positive atmosphere to integrate more women and DAG. Thus, while promoting alliances Table 5 provides the actors or enablers that help to promote value chain alliances and finance in Allo Value Chain.

Conclusions and recommendations

The exploitation rate of Allo in the study area has been affecting the availability and sustainability of raw material in the natural habitat. The situation indicates the need for sustainable management through domestication and proper harvesting technique. There is a need for improved processing techniques for cost-effective and environmental points of view. Exploring marketing channels of overseas markets for fashionable products is necessary to sustain the enterprise and enhance income generation. Research and development works should focus on domestication, cultivation, regeneration, disease and paste management and sustainable harvesting along with appropriate processing and spinning techniques for better utilization of Allo. As *Allo* cultivation may be combined with community forestry programs as an under-story crop, following research would help to promote it.

- Identify different types/ varieties of Allo plant and fiber yields.
- Need to know the effects of various growing conditions and harvesting practices on fiber quality and quantity, so that optimum conditions can be employed.
- Need to investigate ways in which Allo might usefully find a place within existing farming and forestry system.

Following areas of intervention are recommended for sustainable Allo value chain development in Nepal:

- Allo cultivation: Support Allo cultivation in CF buffer zone and private land. There is a need to develop and establish technology for commercial cultivation
- Technical support: Training, workshops, demonstration tour package, weaving, and fiber production technique can help to upgrade their (local people) skills for the Allo profession.
- Disease and paste management: Farmers are suffering from disease during cultivation and production. It is necessary to develop technology for disease and paste management.
- Policy: In spite of the large volume of harvesting and trade, there is no inventory of resources. On the other hand, there is no mention of sustainable management of resources in CFs' operation plans. For this purpose, it is necessary to do inventory and revision of the operation plan of CFUG/ Buffer zone CFUG.
- Advertisement: Advertisement could be the medium to increase the familiarity or popularity of Allo products among local and national customers. It could increase trade in all over Nepal and abroad.
- Accessible Extra Entities: Extra entity's supplies can help those manufacturers who are not getting extra profit from the business as these materials increase product value.
- Financial Access: Financial access is a prerequisite for sustainable expansion of the business. It is necessary to increase financial access to value chain actors through the management of wholesale lending to MFI and linkage to development and commercial banks.

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Abbreviations and Acronyms

AEC: Agro Enterprise Center; AFU: Agriculture and Forestry University; ANSAB: Asia Network for Sustainable Agriculture and Bioresources; B2B:Business to business; CFUG: Community Forestry User Group; CF: Community Forest; CO: Community Organization; DAG: Disadvantage Group; DCCI: District Chamber of Commerce and Industry; DCC: District Coordination Committee; DFO: District Forest Office; DI: Department of Industry; DNPW: Department of Department of National Park and Wild Life; FECOFUN: Federation of Community Forestry Users, Nepal; FGD: Focus Group Discussion; FNCCI: Federation of Nepalese Chambers of Commerce and Industry; HR: Human Resource; MEDEP: Micro-Enterprise Development Programme; MFI: Micro Financial Institution; ME: Micro Entrepreneur; MIS: Marketing Information System; MOFSC: Ministry of Forest and Soil Conservation; M4P : Making Markets Work for the Poor; MSFP: Multi Stakeholder Forestry Programme; NARC: Nepal Agricultural Research Council; NEHHPA: Nepal Herbs and Herbal Production Association; NRB: Nepal Rastra Bank; NTFP: Non-Timber Forest Products; PAF: Poverty Alleviation Fund; R&D: Research and Development; RM: Rural municipality; VCA: Value Chain Approach; VCD: Value Chain Development; WWF: Worldwide Fund for Nature.

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ORIGINAL RESEARCH ARTICLE

Production economics of Ginger (*Zingiber officinale* Rose.) in Salyan district of Nepal

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ABSTRACT

This study investigates the economics of ginger (*Zingiber officinale* Rose.) production in the Salyan district of Nepal. The production economics was assessed by the household survey in purposively selected Sharada municipality and Siddhakumakh Rural Municipalities. The semi-structured interview schedule was administered to interview randomly selected forty-three producers from Sharada Municipality and thirty-one producers from Siddhakumakh Rural Municipality. The results indicated that the ginger production was found to be a profitable enterprise in the study area with an average B:C ratio of 1.55. The overall productivity of ginger in the study area was found to be 16.28 MT/ha. The Cobb-Douglas production function indicates that ginger production exhibited increasing returns to scale at a decreasing rate. The regression function of 0.784 implies that if all the inputs specified in the production function are increased by 100%, the gross return will increase by about 78.4%.

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INTRODUCTION

Ginger (*Zingiber officinale* Rose.) is a widely grown spice crop of mid-hills of Nepal with a huge export value (ITC, 2007). Ginger as a high-value spice crop can contribute more to improve the socioeconomic status of rural people by raising their income (NSCDP, 2007). It is one of the nineteen commodities of Nepal that has significant export potential (NTIS, 2017). Globally, Nepal is fourth in ginger production after India, China, and Nigeria with about 9.2% of the world's share (FAO, 2017). About 99% of Nepal's ginger export is to India, about three fourth of which is fresh ginger rhizome while remaining is in dried form locally known as '*sutho*' (TEPC, 2017). The total area under cultivation of ginger in Nepal was 22649 hector (ha) with the production of 279504 Metric Ton (MT) in fiscal year 2016/17 (MoAD, 2018). Salyan is the second most important district of Nepal after the Ilam district in ginger production. The total area under ginger production in Salyan district in 2016/2017 was 2000 ha with a total production of 25006 MT (DADO, 2018). Salyan district shares 8.95% of total national ginger production and shares 8.83% of total cultivated land area (MoAD, 2018). Agricultural development is the key factor of poverty reduction in Nepal and commercialization of the Nepalese agriculture sector can be brought about through increased market research and product development (ADS, 2015). Despite this humongous potential of ginger to alleviate rural poverty, the studies that investigate the profitability of ginger production are lacking. Ginger production is basically a family farm enterprise of small-holder farmers who are facing multi-faceted challenges like increased cost of production, lack of production, sub-optimal level of resource use, lack of market information and inefficient marketing channels (Khanal, 2018). However, studies on economic aspects of ginger production are limited. To fill this gap, this study was conducted to investigate the economics of ginger production in the major ginger-producing pocket of the country. It also explores the level of resource used by the ginger

producers and identifies the scale of production.

MATERIALS AND METHODS

Selection of study area

Among all the districts of Nepal, Salyan district ranks second, after the Ilam district, both in terms of area under ginger farming and total production (MoAD, 2018). Salyan district, famous for its fibreless ginger, has a promising scope of improving the ginger sub-sector which can lead to employment generation and poverty alleviation if problems of marketing could be solved (FNCCI, 2012). *Malneta* of Sharada Municipality and *Chande* of Siddhakumakh Rural Municipality were selected purposively as they were major ginger producing areas in Salyan District (PMAMP, 2018).

Sources of data

Primary data was collected by conducting a household survey using a semi-structured, pre-tested interview schedule while the secondary sources of data were reports of government authorities, NGOs and INGOs along with research articles on national and international journals and proceedings. The collected information was further verified through a focus group discussion conducted within the study area.

Sample size and sampling techniques

For the samples of producers, an inventory of farmers of the research study areas was prepared to consult farmers groups/ cooperatives, Project Implementation Unit of Prime Minister Agriculture Modernization Project (PMAMP) and District Agriculture Development Office (DADO). Random sampling technique was used to select 43 producers from Sharada Municipality and 31 from Siddhakumakh Rural municipality.

Data analysis

The collected data was analyzed using the statistical packages like Microsoft Excel and Statistical Package for Social Science (SPSS version 16). Cobb-Douglas production function was used for the assessment of production economics.

Economic analysis

Cost of production: Only variable cost items were considered and the total variable cost of production was calculated by adding all the expenditure on variable inputs.

Total variable cost = Rhizome cost + labor cost (land preparation, planting, manure application, weeding, mulching, harvesting, and other post-harvest activities) + Farm Yard Manure (FYM) cost + fertilizer cost + insect-pest management cost

Benefit-cost analysis: The benefit-cost analysis was carried out after calculating the total variable cost and gross returns from ginger production (Poudel *et al.*, 2016). The benefit-cost analysis was carried out by using the formula:

$$\text{B: C Ratio} = \frac{\text{Gross returns}}{\text{Total variable cost}}$$

Where,

Gross return (in NRs) = total quantity of ginger marketed (kg) × price (per kg) of ginger + total quantity of *sutho* (kg) × price (per kg) of *sutho* + total quantity of seed rhizome (kg) × price (per kg) of seed rhizome

Empirical model

The extended Cobb-Douglas production function which was used as the empirical model in the study is given below:

$$Y = AX_1^{b1}X_2^{b2}X_3^{b3}X_4^{b4}X_5^{b5}e$$

Where,

Y = Gross returns, A = Intercept, X_1 = rhizome cost, X_2= labor cost, X_3= farmyard manure cost, X_4= fertilizer cost, X_5= insect pest management cost, b_1 to b_5 = elasticity coefficients, e = Error term.

When Cobb-Douglas production function was transferred into linear form, it was expressed as:

$$\ln Y = \ln A + b_1\ln X_1 + b_2\ln X_2 + b_3\ln X_3 + b_4\ln X_4 + b_5\ln X_5 + e$$

Returns to scale in Cobb-Douglas function is determined by the sum of the power coefficients i.e. b1 + b2 + ... + bn

If b1 + ... + bn = 1, we have constant return to scale.

If b1 + ... + bn < 1, we have decreasing return to scale.

If b1 + ... + bn > 1, we have increasing return to scale. The values of the input coefficient imply their contribution to the production of ginger. Similarly, the Cobb-Douglas production frontier has been used to investigate the resource use analysis by Islam *et al.* (2012) and Poudel *et al.* (2016).

RESULTS AND DISCUSSION

Productivity and production of ginger

The overall productivity of ginger in the study site was found to be 16.28 MT/ha. It was recorded higher than the average productivity of the district (12.50 MT/ha) and the national average (12.34 MT/ha) (MoAD, 2018). The study area is identified as one of the most productive areas in the country for ginger and has huge climatic suitability for ginger production. *Malneta* (17.09 MT/ha) was found to be significantly superior to *Chande* (15.15MT/ha) in terms of ginger productivity. The overall average production of ginger by each farm was found to be 2080.40 kg which statistically similar in both the villages (Table 1)

Quantity of ginger traded (rhizome, *sutho* and seed)

In the study area, ginger was found to be traded in three different forms. They were: mature rhizome, the dried form of rhizome (locally known as '*sutho*') and seed rhizome. One kilogram of *sutho* can be obtained by drying about 6 kg of the

Table 1. Productivity and production of ginger in the study site.

Variable	*Malneta* (N=43)	*Chande* (N=31)	Overall	Mean difference	t value	p value
Productivity (MT/ha)	17.09	15.15	16.28	1.931***	3.936	0.000
Production of ginger(kg)	2176.75	1946.75	2080.40	229.969	0.656	0.514

Note: *** indicate level of significance at 1% level.

Table 2. Quantity of ginger sold (fresh mature rhizome, *Sutho* and Seed).

Quantity (kg/ha)	Malneta (N=43)	Chande (N=31)	Overall	Mean difference	t value	p value
Fresh rhizome	11534.88	11881.72	11680.18	346.836	-0.501	0.618
Dried form	923.25	614.73	794.00	308.52**	2.066	0.042
Seed rhizome	975.19	109.67	116.90	612.61**	3.208	0.002

** indicate level of significance at 5%.

Table 3. Cost of production per hectare, revenue and B:C ratio of ginger.

Cost (NRs)	*Malneta* (N=43)	*Chande* (N=31)	Overall	Mean difference	t value	p value
Rhizome cost	71534.88	72946.23	72126.126	-1411.352	-0.462	0.645
Labor cost	100279.06	77338.70	90668.918	22940.360	4.734***	0.000
FYM cost	22325.58	21045.69	21789.414	1279.882	0.586	0.560
Fertilizer cost	372.09	0.00	216.216	372.093	1.992*	0.050
Insect-pest management cost	5174.80	7339.90	3349.774	4356.526	3.227**	0.002
Total cost of production/ha	199686.43	172148.92	188150.450	27537.509	4.705***	0.000
Return	330000.00	238899.99	291836.48	91100.00	6.111***	0.001
B:C ratio	1.67	1.39	1.557	0.280	3.317***	0.001

Note: ***, **, * indicate level of significance at and 1%, 5% and 10% respectively.

Table 4. Cobb-Douglas production function of ginger production.

Variables	Coefficient	Standard error	t-value	p-value
Constant	6.760***	2.038	3.320	0.001
Rhizome cost	0.125	0.148	0.845	0.401
Total labor cost	0.220**	0.085	2.596	0.012
FYM cost	0.167	0.133	1.255	0.214
Fertilizer cost	0.012	0.013	0.989	0.326
Insect pest management cost	0.260***	0.007	3.818	0.000
F-value	12.920			
R square	0.487			
Adjusted R-square	0.449			
Return to scale	0.784			

Note: ***, ** indicate level of significance at and 1% and 5%, respectively.

fresh mature rhizome. The overall average quantity of fresh ginger marketed on the per hectare basis was reported to be 11680.18 kg. The quantity of fresh mature rhizome sold was found to be more in *Malneta* (11534.88 kg) than *Chande* (11881.72 kg). The quantity of marketed *sutho* was significantly higher in *Malneta* (923.25 kg) compared to *Chande* (614.73 kg). Similarly, the quantity of seed rhizome marketed was found to be significantly more in *Malneta* (975.19 kg) than that in *Chande* (109.67 kg) (Table 2).

Estimation of cost of production, revenue, and B: C ratio of ginger

The average cost of ginger production was estimated to be NRS. 188150.45 (USD 1636.09) per hectare. The cost of production in *Malneta* (NRs 199686.43 = USD 1736.40) was found significantly more than that of *Chande* (NRs 172148.92 = USD 1496.95). The average returns from ginger in the study area were estimated to be NRS. 291836.48 (USD 2537.71) per hectare. The farmers of *Malneta* (NRs 330000 = USD 2869.56 per hectare) were recognized to be generating significantly higher returns than that of the ginger producers of *Chande* (NRs 238899.99 = USD 2077.39 per hectare). The overall B:C ratio of producers was calculated to be 1.55 which indicates that ginger production is a profitable business in the study area. B:C ratio was found to be significantly higher in *Malneta* (1.67) as compared to *Chande* (1.39). Similar findings of profitability in ginger production were also reported by Poudel *et al.* (2016), Timsina (2010) (Table 3).

Cobb-Douglas regression analysis of ginger production

The estimated values of the coefficients and related statistics of Cobb-Douglas production functions are shown in Table 4. Out of five independent variables included in regression analysis, the costs on insect-pest management and labor were found significant while rhizome, farmyard manure, and fertilizer costs were not found significant in the study area. Poudel *et al.* (2016) also reported labor costs to be significant in ginger production. The regression coefficient of insect-pest management cost was 0.26 which indicates that increasing 100% cost in insect-pest management, the gross returns could be increased by 0.26. Similarly, a 100% increase in labor costs could increase the gross returns by 22%. The sum of all the regression coefficients of all the inputs considered in the regression function was estimated to be 0.784 which indicates that the production function exhibited an increasing return to scale at a decreasing rate. This implies that if all the inputs specified in the production function are increased by unity, the gross return will increase by about 0.784. The adjusted R-square value was estimated to be 0.449 which implies that the specified variables affect gross return by 44.9 %.

Conclusion

Higher productivity indicates better suitability of ginger farming in the study area. Similarly, the benefit-cost ratio of 1.55 demonstrates the higher profitability of the ginger production enterprise. The Cobb-Douglas regression model revealed that ginger production exhibited an increasing return to scale at a decreasing rate. The regression coefficient of 0.784 implies that if the specified cost variables in the production function are increased by unity, the gross return will increase by 0.784 units. The costs on insect pest management and labor costs were identified to be significant for increasing the revenue. This implies that increasing labor and insect pest management costs will significantly increase the returns from ginger production.

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Conflict of interest

The authors hereby declare that they possess no conflict of interest in this research project.

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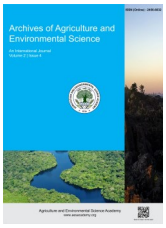

ORIGINAL RESEARCH ARTICLE

Irrigation water quality assessment of Betagi Upazila under Barguna district in Bangladesh

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ABSTRACT

Irrigation water quality is important for the successful crop production. The present study aimed to assess the quality of both ground and surface water for use of irrigation purposes at Betagi Upazila under Barguna district in Bangladesh. Forty two water samples were collected from different locations and their important chemical properties including pH, EC, the concentration of PO_4^{3-}, SO_4^{2-}, K^+, and Na^+ were analyzed. Results revealed that the pH of the ground and surface water were ranged from 7.23 to 8. 49 and 6.98 to 7.96, respectively. Electrical conductivity (EC) of the water samples were 590 to 1950 µ Scm^{-1} and 110 to 380 µ Scm^{-1} respectively. The PO_4^{3-} concentration in groundwater was 0.10 to 0.74 mgL^{-1} and surface water was 0.05 to 0.20 mgL^{-1}. The SO_4^{2-} concentration of groundwater ranged from 1.29 to 3.10 mgL^{-1} and surfacewater was 2.11 to 7.28 mgL^{-1}. The K^+ ion concentration was 4.55 to 11.38 mgL^{-1} in groundwater and 6.12 to 22.44 mgL^{-1} in surface water. The PO_4^{3-} and SO_4^{2-} concentration in most of the ground and surface water samples within the "safe" limit for irrigation, whereas the pH, EC, and K^+ concentration in both ground and surface water were not in the safe limit. Besides this, Na^+ concentration was higher in groundwater than surface water. Based on chemical properties, surface water is more suitable as irrigation water compared to groundwater in the study area.

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INTRODUCTION

Water, the vital element in all aspects of life in the world, plays a significant role regarding a person, socio-economic development and the existence of ecosystems (Goswami and Bisht, 2017). It is a fundamental part of humans, plants, animals, and other living organisms. The quality and quantity of any water supply organizing are highly important, especially when considering purposes. Irrigation water influences soil and crops, and their management. It is possible to be able to produce high-quality crops only by using high-quality irrigation water sources when other inputs are optimal (Sarker *et al*., 2000). Normal water quality for irrigation will be a significant criterion for the prosperous crop production as this contains different toxic ions in varying concentrations. Irrigated agriculture is dependent on the water of useable quality. If inferior of normal water is employed for irrigation, poisonous aspects may accumulate in the soil thus showing signs of damage soil properties. In Bangladesh, a major part of cultivable land is under rainfed ecosystem (Goel *et al*., 2019). But the rainfall is not enough for the dry season. Therefore, farmers face an acute shortage of irrigation and drinking water during the dry season and use water from the two surface and underground sources. Besides agricultural point of view, the water of desirable quality is necessary for the drinking, domestic and industrial purposes. Thus, water quality assessment is most considerable for irrigation.

The substance constituents of irrigation water can affect plant growth directly through toxicity or even deficiency, or indirectly by simply altering plant availability regarding nutrients (Kumar *et al*., 2019). The substance constituents of water determine its quality as well as its utilization about irrigation, industrial and domestic usages. All water includes a varying amount of different species of cations and anions. Among them, the primary soluble constituents are Ca^{2}+ Mg^{2+}, Na^{+} and K^{+} as cations and Cl^{-}, SO_4^{2-} and HCO^{3-}, PO_4^{3-} as anions. From the soluble constituents, Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, SO_4^{2-}, HCO^{3-} and B^{+} are regarding prime importance in judging the water quality regarding irrigation. Water contains specific potentially toxic ions such as B^{+}, Na^{+}, Cl^{-} etc. (Kumar *et al*., 2018). The concentrations regarding these toxic ions in the irrigation water are extremely important because many crops are susceptible to even extremely low concentrations of these types of aspects (Hira *et al*., 2018). Irrigation water top quality is normally judged by the total salt concentration, comparative proportions of ions or even sodium adsorption ratio and the contents of HCO_3^{-} and CO_3^{2-}. For this specific reason, some important active agents of water are vital to evaluate its suitability for irrigations, drinking, livestock and business usages.

Within the southern area of Bangladesh, there are mainly three resources of irrigation water - surface water, rainwater, and groundwater. Owing to the effect of climate change, rainfall anomaly leads to the uncertainty of rainwater as a source of irrigation water. Moreover, monsoon rains usually are available for only several months (May to August). Surface water in the southern area of the region is exposed to seawater intrusion due to the continuous influence of high and low tides and the salinity is increasing daily due to the effect of climate change. During the monsoon, the salinity of surface drinking water decreases but in additional season's salinity remains largely determined by the geology regarding the area. This can make surface water unsuitable to be able to use as irrigation normal water all year round, especially in the dry season (November to April). At that moment, groundwater is the only source to irrigate crops field.

Some organized investigations on the water quality in some selected sites regarding Bangladesh have been conducted; all chemical analyses of these investigations confined within Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, SO_4^{2-}, HCO^{3-}, Fe^{2+}, B^{+} and Na^{+}. But attention has not yet done on the water quality regarding Betagi Upazila, for this area was selected for the study. The total land area of Betagi Upazila under the district of Barguna is 64.77 square kilometers. There are usually seven (7) unions of the Betagi Upazila, which are the Bibichini, Betagi, Mokamia, Hosnabad, Buramazumdar, Kazirabad, Sarishamuri. The analysis area under the AEZ 18 (Young Meghna Estuarine Floodplain). In the study area surface water source (pond) is used for irrigation and groundwater (deep tube-well especially hand tube-well) can be used for drinking without judging chemical quality. Consequently, the objective of the present investigation was to evaluate the quality of surface and groundwater as well as their suitability for irrigation and drinking purposes.

MATERIALS AND METHODS

Water selections for quality assessment were analyzed for chemical matters. An effort has been obtained to analyze ground and surface water samples collected from the Betagi Upazila under the district regarding Barguna and the substance analyses are the determination of pH, electrical conductivity (EC) and major ionic matters like PO_4^{3}-, SO_4^{2}-, K^{+}, and Na^{+}.

Site selection

Groundwater and surface water samples were collected from selected sites regarding Betagi Upazila. Forty-two (42) groundwater and surface water samples were collected from 7 unions. Twenty-one (21) groundwater samples and Twenty-one (21) surface water samples were collected in the course of the dry season from January 25 to December 28, 2016.

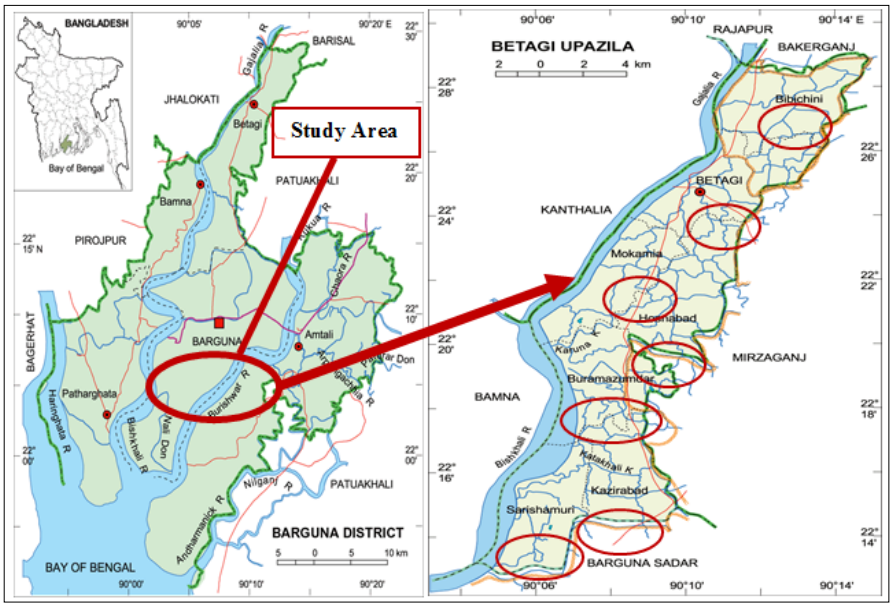

Figure 1. *Map showing location of the experimental area.*

Methodology of sample collection and analysis

All analyses were done following the procedures mentioned by Hunt and Wilson (1986) and APHA (2012). The water samples were collected from both surface and underground sources (Figure 1). Water samples were collected in 500 ml plastic bottles. These bottles were cleaned with dilute hydrochloric acid and then washed with tap water followed by distilled water. Before sampling, bottles were again rinsed 3 to 4 times with water to be sampled. The collected samples were tightly sealed immediately to avoid publicity to air. Samples were collected at the running condition of the hand tube well after the discharge of enough quantity of water. All water was colorless, air, tasteless and free from turbidity at the time of sampling. The water samples after proper marking and labeling were carried to the Central Laboratory, at Patuakhali Science and Technology University, for chemical substance analyses and were retained in a clean, cool and dry place. Samples were filtered through Whatman number I filter document to eliminate undesirable solid and suspended materials. The analyses were conducted within a few days'. The pH and EC are immediately taken while carried to the samples at the central lab of Patuakhali Science and Technological University. Water samples were protected against bacterial invasion either by adding two to three drops of pure toluene.

Statistical analysis

Statistical analysis of the data generated out of the chemical analysis of water samples was done with the help of a scientific calculator (Casio Super FX-100D) following the standard procedure as described by Gomez and Gomez (1984). Correlation studies also performed following the standard method of a computer program (SPSS).

RESULTS AND DISCUSSION

The pH, EC and the ionic constituents such as PO_4^{3-}, SO_4^{2-}, K^+, Na^+ in the water samples have been presented in the Tables 2 and 3. The salient features of the analyses have been discussed in the light of relevant research findings wherever applicable. The results have been discussed under the following headings.

Ground and surface water rating for irrigation purposes

pH: The pH of groundwater in the dry period ranged from 7.23 to 8.49 indicating the particular slightly alkaline in characteristics with the mean value of 8.00 (Table 2). The pH regarding 8 samples was below the mean value and the rest 13 samples were higher than the suggested value. The standard deviation of groundwater samples was 0.264. The pH of surface water samples ranged from 6.98 to 7.96 in dry season indicating neutral to alkaline in characteristics with the mean value 7. 32 (Table 3). The pH of 13 samples was less than the mean value. The pH level of 8 samples was higher than the suggested value in the dry time of year. The standard deviation had been 0.260 in the dry season (Table 3). Amongst all the samples the highest pH value 8.49 was obtained in the sample no. MG 2 was hand tube well water, collected from Mokamia union, Mokamia bazar and the lowest value 6.98 had been obtained in the sample no. BS 3 it had been pond water, collected from Bibichini Union, adjacent pond. (Fipps, 2003) reported of which the suitable pH range for irrigation water 6.0 to 8.5. Based on this limit, both the groundwater and surface water of the study area were suitable for irrigation.

Electrical conductivity (EC): The electrical conductivity regarding groundwater samples in dry season ranged from 590 to 1950 μScm^{-1} with the mean value of 1068. 57 μScm^{-1} (Table 2). The EC value of 13 samples was below the mean value, and the rest 8 samples were higher than the mean value. The standard deviation of groundwater samples was 429.17 (Table 2). The EC value of surface water samples ranged from 110 to be able to 380 μScm^{-1} with all the mean value 210.95 μScm^{-1} (Table 3). The EC value of 10 samples was higher than the mean value, in addition to the rest of the 11 samples have been lower than the mean value. The standard deviation was 75.13 in the dry season (Table 3). The groundwater regarding the study area showed higher EC value as compared to surface water. Among all the water samples the highest EC value 1950 μScm^{-1} was obtained in typically the sample no. BeG 1 had been Hand tube well water sample, collected from a hand tube well adjacent Betagi college regarding Betagi union and the lowest value 110 μScm^{-1} was obtained in the sample no. BS 1 had been Pond water collected from Bibichini union, Khashpukur par, sample no. BeS 2 was pond water collected from Betagi Bus Stand, sample no. KS 1 was pond water collected from Kazirabad union, Kaonia. According to (Islam and Shamsad, 2009) the groundwater in the research area was found "permissible" class and surface water was of "good" class.

Ionic constituents

The ionic constituents like PO_4^{3-}, SO_4^{2-}, K^+, Na^+ of the water samples were analyzed. The ion present in all samples in relation to irrigation water quality have been discussed as follows:

Phosphate (PO_4^{3-}): The phosphate concentration of groundwater samples in dry season ranged from 0.10 to 0.74 mgL^{-1} with mean value with 0.32 mgL^{-1} (Table 2). The PO_4^{3-} concentration of 11 samples were lower than the mean value, the rest 10 samples were higher than the mean value. The standard deviation was 0.169 (Table 2). The PO_4^{3-} concentration of surface water samples ranged from 0.05 to 0.20 mgL^{-1} in dry period with the mean value of 0.08 mgL^{-1} (Table 3). The PO_4^{3-} concentration of 4 samples was higher than the mean value, the rest 16 samples were lower than the mean value and one sample has been equal to the mean value. The standard deviation was 0.0362 (Table 3).

Sulphate (SO_4^{2-}): The concentration of sulphate of groundwater samples in dry season ranged from 1.29 to 3.10 mgL^{-1} with the mean value of 1.99 mgL^{-1} (Table 2). The SO_4^{2-} concentration of 12 samples were lower than the mean value, and the rest 9

Table 1. Detail information regarding surface and groundwater sources of Betagi Upazila under Barguna District in Bangladesh.

Sample number	Sampling location		Sources	Depth (ft.)	Season
	Union	Village			
BS 1		Khashpukur par	PW	-	
BS 2	Bibichini	Bibichini Bazar	PW	-	Dry season
BS 3		Fultola	PW	-	
BG 1		Bibichini Bazar	HTW	550	
BG 2	Bibichini	Fultola	HTW	760	Dry season
BG 3		Bibichini Bazar	HTW	850	
BeS 1		Betagi Bazar	PW	-	
BeS 2	Betagi	Betagi Bus Stand	PW	-	Dry season
BeS 3		Betagi College	PW	-	
BeG 1		Betagi College	HTW	1250	
BeG 2	Betagi	Betagi Bazar	HTW	1200	Dry season
BeG 3		Betagi Bus Stand	HTW	1000	
MS 1		Mokamia Madrasha	PW	-	
MS 2	Mokamia	Karuna	PW	-	Dry season
MS 3		Mokamia Bazar	PW	-	
MG 1		Karuna	HTW	1200	
MG 2	Mokamia	Mokamia Bazar	HTW	1000	Dry season
MG 3		Mokamia Madrasha	HTW	1000	
HS 1		Hosnabad Bazar	PW	-	
HS 2	Hosnabad	Jailsha	PW	-	Dry season
HS 3		Jailsha	PW	-	
HG 1		Jailsha	HTW	1250	
HG 2	Hosnabad	Hosnabad Bazar	HTW	1000	Dry season
HG 3		Jailsha	HTW	1000	
BUS 1		Kajirhat Bazar	PW	-	
BUS 2	Buramazumdar	Kajirhat School	PW	-	Dry season
BUS 3		Kajirhat	PW	-	
BUG 1		Kajirhat	HTW	800	
BUG 2	Buramazumdar	Kajirhat School	HTW	850	Dry season
BUG 3		Kajirhat Bazar	HTW	1000	
KS 1		Kaonia	PW	-	
KS 2	Kazirabad	Kaonia School	PW	-	Dry season
KS 3		Kaonia Mosjid	PW	-	
KG 1		Kaonia Mosjid	HTW	1000	
KG 2	Kazirabad	Kaonia School	HTW	850	Dry season
KG 3		Kaonia	HTW	750	
SS 1		Sarishamuri Bazar	PW	-	
SS 2	Sarishamuri	Sarishamuri Bazar	PW	-	Dry season
SS 3		Talukder Bari	PW	-	
SG 1		Molla Bari	HTW	1250	
SG 2	Sarishamuri	Talukder Bari	HTW	950	Dry season
SG 3		Sarishamuri Bazar	HTW	850	

HTW= Hand tube well water; BG= Bibichini ground water; HG= Hosnabad ground water; BeG= Betagi ground water; MG= Mokamia ground water; BuG= Buramazumder ground water; KG= Kazirabad ground Water; SG= Sarishamuri ground water.

samples were higher than the mean value. The standard deviation was 0.525 (Table 2). The SO_4^{2-} concentration of surface water samples ranged from 2.11 to 7.28 mgL^{-1} in the dry season with the mean value regarding 3.96 mgL^{-1} (Table 3). The SO_4^{2-} concentration of 12 samples have been lower than the mean value, and rest samples were higher than the mean value. The standard deviation was 1.55 (Table 3).

Potassium (K^+): The potassium concentration of groundwater in dry season ranged from 4.55 to 11.38 mgL^{-1} with the mean value of 7.45 mgL^{-1} (Table 2). The K^+ concentration of (10) ten samples was higher than the mean value and rest 10 samples were lower than the mean value and one sample have been equal the standard deviation was 2.18 (Table 2). The K^+ concentration of surface water samples ranged from 6.12 in order to 22.44 mgL^{-1} in the dry season with the mean value of 9.68 mgL^{-1} (Table 3). The K^+ concentration of seven (7) samples was higher than the mean value and the rest 14 samples were lower than the mean value. The standard deviation was 3.87 (Table 3). The surface water contained a larger quantity of K^+ than the groundwater. Among all the water samples the lowest value of K^+ 4.55 mgL^{-1}, was seen in the sample no. SG 2 was Hand tube well water, collected from Sarishamuri union, Talukder bari adjacent hand tube well and the highest value of K^+ 22.44 mgL^{-1} was observed in the sample no. HS 3 it was Pond water, collected from Hosnabad union, Jailsha. The presence of better quantity

Table 2. pH, EC, and concentration of PO_4^{3-}, SO_4^{2-}, K^+, and Na^+ in groundwater collected in the dry season.

Sample number	Sources of water	pH	EC (µScm^{-1})	PO_4^{3-} (mg L^{-1})	SO_4^{2-} (mg L^{-1})	K^+ (mg L^{-1})	Na^+ (mg L^{-1})
BG 1	HTW	7.48	1020	0.42	2.34	8.13	52.71
BG 2		8.01	1050	0.35	1.73	6.80	50.57
BG 3		8.07	910	025	1.81	5.82	54.68
BeG 1		7.72	1950	0.13	1.58	11.38	57.96
BeG 2		7.91	1590	0.17	1.61	9.08	64.37
BeG 3		7.94	1720	0.16	1.61	10.09	60.43
MG 1		8.10	1540	0.17	1.29	8.40	66.34
MG 2		7.91	1630	0.18	1.40	11.09	54.52
MG 3		7.96	1390	0.21	1.58	8.43	65.02
HG 1		8.08	960	0.15	1.58	5.65	56.49
HG 2		8.05	1250	0.23	1.35	7.51	61.74
HG 3		7.23	1310	0.10	1.67	7.84	63.22
BuG 1		7.98	610	0.55	2.54	5.41	48.11
BuG 2		8.03	690	0.53	1.78	5.38	51.56
BuG 3	HTW	8.07	630	0.44	2.28	11.32	51.23
KG 1		8.20	730	0.36	2.25	5.06	52.87
KG 2		8.49	610	0.40	2.51	5.68	47.29
KG 3		8.13	910	0.28	2.84	5.03	58.62
SG 1		8.31	720	0.51	2.31	7.45	42.86
SG 2		8.19	630	0.42	2.54	4.55	52.05
SG 3		8.17	590	0.74	3.10	6.24	48.60
Range		7.23-8.49	590-1950	0.10-0.74	1.29-3.10	4.55-11.38	42.86-66.34
Mean (n=24)		8.00	1068.57	0.32	1.99	7.45	55.30
Sd (±)		0.264	429.17	0.17	0.525	2.18	6.49

HTW= Hand tube well water; BG= Bibichini ground water; HG= Hosnabad ground water; BeG= Betagi ground water; MG= Mokamia ground water; BuG= Buramazumder Ground water; KG= Kazirabad ground water; SG= Sarishamuri ground water.

Table 3. pH, EC, and concentration of PO_4^{3-}, SO_4^{2-}, K^+, and Na^+ of surface water collected in the dry season.

Sample number	Sources of water	pH	EC (µScm^{-1})	PO_4^{3-} (mg L^{-1})	SO_4^{2-} (mg L^{-1})	K^+ (mg L^{-1})	Na^+ (mg L^{-1})
BS 1	PW	7.37	110	0.07	2.13	6.39	9.03
BS 2		7.57	240	0.07	4.97	6.12	10.02
BS 3		6.98	120	0.05	2.11	6.71	6.73
BeS 1		7.06	220	0.05	4.36	6.59	11.17
BeS 2		7.20	110	0.06	3.92	8.28	10.18
BeS 3		7.96	270	0.06	5.26	8.81	15.93
MS 1		7.06	240	0.10	2.16	11.03	12.48
MS 2		7.51	290	0.05	2.81	11.21	12.97
MS 3		7.64	380	0.08	7.28	11.32	17.57
HS 1		7.24	200	0.07	6.58	8.66	11.33
HS 2		7.22	220	0.06	5.00	6.15	14.12
HS 3		7.64	380	0.20	2.75	22.44	11.33
BuS 1		7.29	220	0.06	2.75	9.52	14.12
BuS 2		7.03	220	0.09	6.20	8.93	11.66
BuS 3		7.23	180	0.08	5.47	7.75	12.48
KS 1		7.71	110	0.06	2.51	7.63	8.21
KS 2	CW	7.13	170	0.05	3.19	7.24	14.61
SS 1	PW	7.06	190	0.07	3.13	10.47	11.66
SS 2	CW	7.34	170	0.08	3.10	15.61	12.15
SS 3	PW	7.23	190	0.16	3.48	14.10	8.54
Range		6.98 -7.96	110-380	0.05 -0.20	2.11-7.28	6.12-22.44	6.73 -17.57
Mean (n=26)		7.32	210.95	0.08	3.96	9.68	11.67
Sd (±)		0.260	75.13	0.0362	1.55	3.87	2.68

HTW= Hand tube well water; BG= Bibichini ground water; HG= Hosnabad ground water; BeG= Betagi ground water; MG= Mokamia ground water; BuG= Buramazumder ground water; KG= Kazirabad ground water; SG= Sarishamuri ground water.

of K^+ in some groundwater samples could be as a result of some potash bearing minerals just like sylvite (KCl) and niter (KNO_3) in aquifers (El-Gohary, 2011) reported that seas containing less than 2 mgL^{-1} K^+ are well suited for irrigation. In accordance with this limit, both the ground and surface waters from the study area were unsuitable for irrigation.

Sodium (Na^+): The sodium concentration of groundwater samples in dry season ranged from 42.86 to 66.34 mgL^{-1} with the mean value 55.30 (Table 2). The Na^+ concentration of 9 samples was higher than the mean value and the rest 12 samples were lower than the mean value. The standard deviation was 6.49 (Table 2). The sodium concentration regarding the surface water samples ranged from 6.73 to 17.57 mgL^{-1} with the mean value of 11.67 mgL^{-1} (Table 3). The sodium concentration of 9 samples was higher than the mean value and rest twelve (12) samples were lower than the mean value. The standard deviation was 2.68 (Table 3). The groundwater study was higher Na^+ content than the surface water. Among all the samples, the highest value of Na^+ 66.344 mg L^{-1} was observed in the sample no. MG 1 was Hand tube well-drinking water, collected from Mokamia union, Karuna adjacent road and the lowest value of Na^+ 6.73 mgL^{-1} had been noticed in the sample no. BS 3 it was pond water collected through Bibichini union, Shikder bari adjacent pond. Tester and Davenport (2003) proposed that water containing less than to 40 mgL^{-1} Na^+ had been well suited for irrigation of crop plants. Based on Na^+ content, all the collected surface water of the study area can safely be used for irrigation of crops but groundwater was unsuitable for irrigation goals.

Conclusion

From the above results, it has been concluded that PO_4^{3-} and SO_4^{2-} in both ground and surface water in the study area were within the "safe" limit for irrigation. The pH, EC and K^+ concentration in both ground and surface water were not in the safe limit. Besides these, Na^+ concentration was higher in groundwater than surface water. Based on the chemical properties, surface water is more suitable as irrigation water compared to groundwater in the study area.

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ORIGINAL RESEARCH ARTICLE

Communication exposure of sub-assistant agriculture officers (SAAOs) towards e-agriculture in Khulna district of Bangladesh

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ABSTRACT

The purpose of this study was to determine the extent of communication exposure of the Sub-Assistant Agriculture Officers towards e-agriculture in Khulna district of Bangladesh. Study was conducted in the five selected upazilas of Khulna city *viz.*, Rupsa, Dighalia, Phultala, Dumuria and Batiaghata which consist of 108 agricultural blocks. A sample of 100 Sub-Assistant Agriculture Officers (SAAOs) was selected from these blocks. Data were collected following a structured pretested interview schedule. Findings revealed that most 60% of the SAAOs had low communication exposures to e-agriculture. Correlation analysis indicates that age, income and service experience had negative significant relationship with communication exposures of SAAOs to e-Agriculture. T raining exposure and knowledge on e-agriculture had positive significant relationship with their communication exposures towards e-agriculture. The enter method of regression analysis revealed that knowledge on e-agriculture, training exposure and monthly income described 77.5 percent variation in the communication exposure of SAAOs. The estimates indicated that knowledge on e-Agriculture had strongest (β=0.479) contribution to the variance of communication exposure to e-Agriculture. On the other hand, monthly income had contributed to the variance of communication exposure of SAAOs towards e-Agriculture in negative direction (β=-0.156). Mobile phone was the highest preferred device in using e-Agricultural media by the SAAOs. "Unfamiliarity of extension workers with e-agriculture application" was the main personal constraint and "lack of training on e-agriculture" was the main organizational constraint which might have led to low communication exposure of SAAOs towards e-agriculture.

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INTRODUCTION

Bangladesh is an agrarian country and agriculture is the backbone of its economy where more than 60% land is used for cultivation (Ahmed, 2007). The national economy of Bangladesh is primarily based on agriculture and more than 80% of the total populations are directly or indirectly engaged in a wide range of agricultural activities. Agriculture sector contributes about 15.89% of GDP for her national economy (BBS, 2014). As now-a-days decreasing availability of natural resources but the agricultural sector is confronted with the major challenge of increasing production to feed a huge population (Bhalekar *et al.*, 2015). However, the growing demand, including for higher quality products, also offers opportunities for improving the livelihoods of rural communities (Bhalekar *et al.*, 2015). But to enhance the livelihoods of the rural population, new approaches and technical innovations are required to cope with these challenges. In this regard information and communication

technology (ICT) plays a vital role in agricultural development by providing fast and relevant information to the end users (Reddy, 2012) and different government and non-government organizations that have been working in this field (Jensen, 2007) by practicing e-agriculture. E-Agriculture has been defined as an emerging field for enhancing sustainable agriculture and food security through technology dissemination and delivering information by using Internet and related technologies (Ghogare and Monga, 2015). More specifically, it involves the conceptualization, design, development, evaluation and application of new (innovative) ways to use existing or emerging information and communication technologies (ICTs) (Singh *et al*., 2015; Ghogare and Monga, 2015). ICTs can speed up agricultural technology transfer from research and development institutions to farmers (Joyous and Paul, 2016). ICTs improve adoption of agricultural technology by supporting farmer learning, problem solving and accessibility to profitable markets for their crops (World Bank, 2011). Asfaw *et al*. (2012) argue that development of agriculture can only be possible through the dissemination of improved agricultural technologies and information to the farmers in the rural area. In Bangladesh all agricultural information and recommended technologies are being disseminated to grass-root level by Department of Agricultural Extension (DAE) especially by the extension workers who are designated as Sub-Assistant Agriculture Officer (SAAO). The information needs of farmers will increase in the changing context of agriculture as they must make more and more complex decisions that impact the livelihoods of their families and society (FAO, 2015). Agricultural extension is a service or system which increases the knowledge of farmers through educational procedures, it helps to improve farming methods and techniques, increase farmer's income and raise the living standards of rural life. Agricultural extension could be considered as a connector between the information of scientists and Governmental bodies and agricultural practice or farming (Timmer, 1982). The farmer's desired agricultural information is required on urgent basis; the Sub-Assistant Agriculture Officer (SAAO) can access e-agriculture to obtain the necessary agricultural information from the concerned person or the authentic source in a short time. In past the extension agents face difficulties in facilitating direct contact with farmer clients and with researchers due to the physical distances involved and lack of transportation needed for their mobility, but now the use of Information and Communication Technologies offers excellent possibilities, for strengthening research extension systems. Agricultural extension is one of the most important sectors in which ICT have particularly significant impact because it is solely depending on information dissemination and technology transfer (Ballantyne and Bokre, 2003). The frontline extension workers have direct communication between farmers and other actors in the extension of agricultural knowledge and information systems; they have great scope to make use of ICT to access expert knowledge or other types of information that could facilitate the accomplishment of the farmer's routine activities (Fawole and Olajide, 2012). Making frequent access of e-agriculture by the agricultural extension workers, they will able to gather much needed agricultural information (i.e., pre-harvest and post-harvest information, pricing, weather conditions among others) that can boost agricultural productivity (Awuor *et al*., 2013). With limited SAAOs disseminating quality information to the farmers we need to adopt e-agriculture as an effective tool. As the Sub-Assistant Agriculture Officers (SAAOs) are the prime outlet of agricultural information for the farmers, so it is necessary to know to what extent the extension workers are using e-agriculture now.

The objectives of this study are: a) to determine and describe the extent of communication exposure of Sub-Assistant Agriculture Officers (SAAOs) towards e-Agriculture. b) to identify the factors contributing the extent of communication exposure of Sub-Assistant Agriculture Officers (SAAOs) towards e-agriculture. c) to identify some constraints of communication exposure towards e- agriculture. d) to identify the device preference in using e-agriculture by the SAAOs.

MATERIALS AND METHODS

The study was conducted in Khulna district which consist of nine upazilas such as Phultala, Terokhada, Dumuria, Rupsa, Dighalia, Paikgaccha, Batiaghata, Dacope and Koyra upazilas. From nine upazilas, five upazilas (Phultala, Dumuria, Rupsa, Dighalia, Batiaghata) were purposively selected as the locale of the study as these are close to city and may have greater access to e-agriculture.

Population and sample of the study

Total number of SAAOs in Dumuria, Rupsa, Dighalia, Batiaghata and Phultala upazilas of Khulna district were 108 which constitute the population of the study. Out of this population, several 100 (93%) respondents were selected as the sample of the study. With the consideration of population size=108, confidence interval=99, margin of error=5 the required number of sample size was 94. Selected sample size can exceed the required sample size. Distribution of population and sample are shown in Table 1.

Collection of data

In order to amass pertinent information, an interview schedule was prepared that contained both close and open type questions. Appropriate technique and measurement were applied to ensure correct responses of the variable concern. Data were collected from the respondents through personal contact by the researcher himself. The researcher made all possible efforts to establish rapport with the respondents so that they could feel easy to respond to the questions contained in the schedule. Data collected from the respondents were coded, compiled, tabulated, and analyzed in accordance with the objectives of the study. Qualitative data were converted into quantitative form by assigning suitable score whenever needed. The biasness of usage or uniformity of interview was prohibited.

Statistical tests

Descriptive statistical methods like range, mean, percentage distribution and standard deviation were used in describing the dependent and independent variables. For clarity of understanding, tables were used in presenting data. For exploring the relationship between the selected characteristics of the SAAOs with their communication exposure towards e-agriculture Pearson's Product Moment Coefficients of correlation (r) and regression analysis were used. Throughout the study $P<0.05$ as 95% of probability was used as a basis for rejecting or accepting the null hypothesis. The SPSS v16.0 (statistical package for social sciences) was used to perform data analysis.

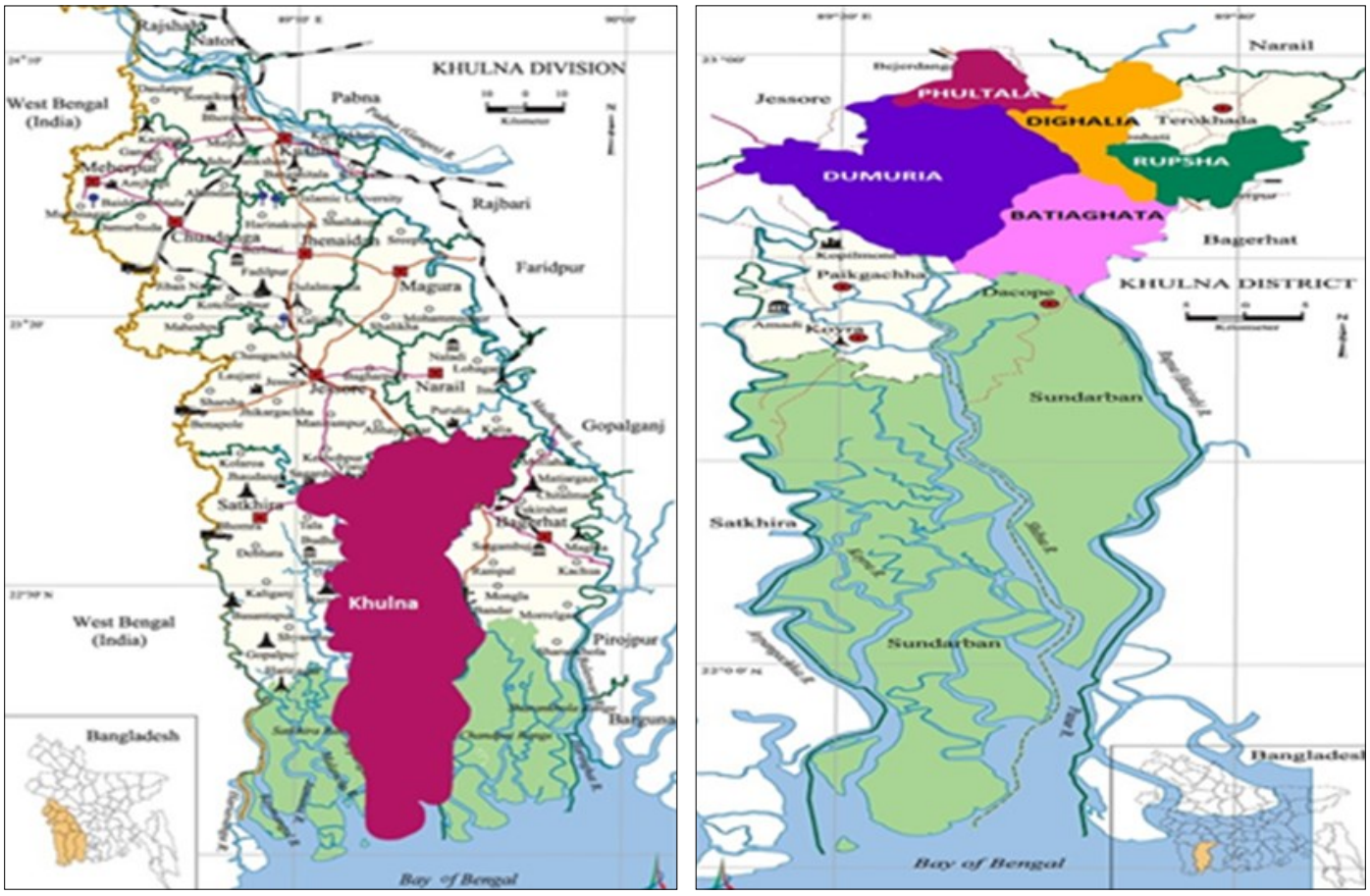

Figure 1. *The first map 1 (a) showing the location of Khulna division in Bangladesh (inset) and Khulna district in the division. Figure 1 (b) shows the five selected study areas (upazilas) in Khulna district (Source: Banglapedia, National Encyclopedia of Bangladesh, 2011).*

Table 1. Distribution of population and sample from Dumuria, Rupsa, Dighalia, Batiaghata and Phultala upazilas of Khulna district.

District	Upazilas	Population	Sample
Khulna	Dumuria,	42	38
	Rupsa,	15	14
	Dighalia,	17	16
	Batiaghata	22	21
	Phultala	12	11
Total		108	100

RESULTS AND DISCUSSION

Socio-economic characteristics of the SAAOs

In the present study, seven characteristics of SAAOs were selected for investigation. These characteristics were age, monthly income, service experience, training exposure, job satisfaction, knowledge on e-Agriculture and organizational technological support. The study revealed that maximum (88%) SAAOs of this area were middle to old aged. An old aged person usually showed reluctance to use e-agriculture related media. An investigation conducted by Salau and Singbe (2008) revealed that the elderly people might be less interested in the use of hi-tech innovations in field level work. As the SAAOs are middle to old aged so that highest portion (53%) of SAAOs has long service experience. Naturally with the increase of age, service experience is increased. As the age and service experience increased most of the SAAOs tend to become less active and does not show interest in adopting newer technologies regarding their professional field. This may have contributed to form negative relationship with service experience and their communication exposures towards e-agriculture. It has also a positive side because experience makes a person more skilled and competent in his own work. Surprisingly it was found that a one-third of (75%) SAAOs had no training on e-agriculture. DAE is still in introductory stage of e-agriculture. So, a very few projects addressed e-agriculture. That's why most of the SAAOs had no training on e-agriculture. It was also happened because of their aging condition; they showed unwillingness to get any relevant training. It is well known that training plays vital role for the development of knowledge, skill and attitude of a person, which makes him more capable and competent and helps an individual participate more in the development process more cheerfully with confidence. Maximum (41%) SAAOs had high income.

Because most of the SAAOs were old aged, so that according to increase their age SAAOs are become more experienced and well salaried. The job satisfactory level of maximum (67%) SAAOs were medium, because they are experienced in job but less competent in using ICTs for agricultural cultivation purpose. Knowledge and perception of any individual increases his/her awareness, mental alertness makes him/her familiar or acquaint with facts, objects, concepts, or practices and helps one to become rational which in turn increases his adoption rate of a new technology (Chen *et al*., 2018). But in this area majority (55%) of SAAOs has medium knowledge in e-agriculture, the main reason of this is e-agriculture is a newer concept in Bangladesh and DAE has a very few trainings on e-Agriculture (Table 2). According to Prodhan and Afrad (2014), more than 84.4% of the respondents had medium to high knowledge towards ICT utilization because most of the respondents be aware of that extension work can be greatly enhanced by ICT and Knowledge of ICT use has a great significance in agricultural development. Ahmadpour *et al.* (2016) indicated the knowledge on e-learning improves possibility to adopt e-learning training on the job in the extension workers of Iran. Arokoyo (2005) also identified high level of illiteracy as a serious constraint to ICT utilization by extension workers and farmers. However, it is observed that an overwhelming majority (80%) of respondents in the study area had less to moderate organizational technical support from different relevant GOs and NGOs, which is also a constraint for the SAAOs to develop their efficiency in e-agriculture sector.

Table 2. Socio-economic characteristics of the SAAOs (n= 100).

Characteristics	Categories	Percentage	Mean	SD
Age	Young aged (up to 35 years)	13	45.44	8.74
	Middle aged (36-45years)	34		
	Old aged (>45 years)	53		
Service experience	Short (up to 10 years)	22	21.36	11.10
	Medium (11-20 years)	25		
	Long (above 20 years)	53		
Training experience	No training (0 day)	75	2.04	5.11
	Low training (1-7 days)	19		
	Medium training (8-15 days)	4		
	High training (above 15 days)	2		
Monthly income	Low income (up to 25)	39	30.45	9.04
	Medium income (26-35)	20		
	High income (above>36)	41		
Job satisfaction	Low job satisfaction (up to 10)	10	13.75	2.37
	Medium job satisfaction (11-15)	67		
	High job satisfaction (above>16)	23		
Knowledge on e-agriculture	Low knowledge (up to 7)	36	8.52	4.76
	Medium knowledge (8-15)	55		
	High knowledge (above 15)	9		
Organizational support	Less support (up to 5)	9	9.01	3.05
	Moderate support (6-11)	71		
	High support (above>12)	20		

Table 3. Distribution of the respondents according to their communication exposure towards e-agriculture.

Categories	Respondents		Mean	SD
	Number	Percent		
Low communication exposure (up to 5)	60	60	5.74	3.49
Medium communication exposure (6-10)	28	28		
High communication exposure (above>1)	12	12		
Total	100	100		

Table 4. Regression coefficients between communication exposures towards e-agriculture of the respondents with their selected characteristics.

Independent variables	B	SE	B	t	P	VIF
Constant	4.164	1.090		3.822	0.000	
Training exposure	0.205	0.055	0.301	3.758	0.000	1,542
Knowledge on e-Agriculture	0.351	0.059	0.479	5.975	0.000	1.550
Income	-0.060	0.028	-0.156	-2.187	0.031	1.228
R^2=0.775 Adj. R^2=0.601		F=48.23			P<0.000	

Communication exposure of agricultural extension workers towards e-agriculture

The use of information and communication technology (ICT) is becoming progressively more widespread throughout various sectors including education, business as well as agriculture (Olowa, 2012). ICT as an extension tool could enhance the flow of information in the application of agricultural extension services. Communication exposure of SAAOs towards e-agriculture scores ranged from 3 to 17 against the possible range of 0 to 36. Based on observed maximum and minimum communication exposure score and number of categories, the following categories were formulated in the Table 3.

Results furnished in table 3 shows that an overwhelming majority (88%) of respondents in the study area had low to medium communication exposure towards e-agriculture. It indicates that majority of the SAAOs are out using rarely or often of e-agriculture in our agricultural extension services. Possible reasons for low communication exposure may be lack of organizational policy support, lack of training on e-agriculture and lack of knowledge of SAAOs in e-agriculture. Mugwisi *et al.* (2015) found that there was a high prevalence of ICTs to the extension workers in Zimbabwe (63% had computer in office) and they used online database, journals, internet, e-mails, data storage, video recorder, and information management. This finding suggests extension workers in Bangladesh are far behind the extension agents of Zimbabwe in terms using ICTs in agriculture. It is a wake-up call for government agricultural extension services in Bangladesh.

Regression coefficients between communication exposures of the respondents with their selected characteristics

For predicting the contribution of the factors in the communication exposure of the respondents towards e-agriculture the enter regression method was applied. Among the seven characteristics, five characteristics namely age, income, service experience, training exposure, knowledge on e-agriculture were selected for regression analysis which had shown significance relationship with the communication exposure (dependent variable) in correlation coefficients. Regression coefficients of communication exposure of the respondents with their selected characteristics are shown in the Table 4.

Results furnished in Table 4, shows that the R^2 value is 0.775 and corresponding F value is 48.23 which were significant at 0.000 levels. The R^2 value indicating that 77.5 percent of the total variation in the communication exposure of SAAOs towards e-agriculture were explained by three variables included in the regression analysis. Age and service experience could not be explained in regression analysis because these two factors were showing co linearity in regression analysis. The results show that the communication exposure of the respondents towards e-agriculture is the function of Training exposure (β=0.301), knowledge on e-agriculture (β=0.479) and Income (β=-0.156). The estimates revealed that knowledge on e-agriculture has the strongest contribution to the communication exposure of the respondents towards e-Agriculture. It was therefore, concluded that with the increase of knowledge on e-agriculture and training exposure, the communication exposure of the respondents will be positively influenced. Use of ICT enables extension workers to play complimentary roles of accessing and transferring relevant and pertinent information to farmers (Meera *et al.*, 2004). Considering the urgency of training, there is strong suggestion for providing training to the extension workers and officers on the use of ICT (Leary and Berge, 2006; Mugwisi *et al.*, 2015). Extension agents must have knowledge on e-agriculture and need to understand the importance of these technologies for increasing their efficiency and productivity in relation to technology transfer (Sife *et al.*, 2007). The results also indicated that income had negative contribution to the communication exposure. It is expected as those who had higher income (from salary mainly), were the old extension workers. This result is quite opposite to the findings of Yakubu *et al.* (2013) where with the increase of age and income, extension workers tend to use ICTs more than others. Again this finding is supported by Fawole and Olajide (2012), who found young-aged farmers tend to adopt ICTs than the old one which confirms the general disposition to ICT use that older people are generally least user of ICTs.

Table 5. Distribution of the respondents according to their device preference score.

S.N.	Digital communication media	Name of preferred devices						
		Mobile (%)	Laptop (%)	PC (%)	Tablet (%)	Net book (%)	Television (%)	Radio (%)
1	Website	16	12	4	2	2	NA	NA
2	E-mail	8	9	4	1	2	NA	NA
3	Video chatting	11	3	1	0	0	NA	NA
4	Phone call	95	0	0	5	0	NA	NA
5	Social media	43	4	1	0	0	NA	NA
6	Television program	3	0	5	1	0	17%	NA
7	Radio program	7	0	0	0	0	NA	9%
8	Application (Apps)	15	0	0	0	0	NA	NA
9	Documentary	2	0	3	0	0	0	NA
10	Online newspaper	19	5	1	0	0	NA	NA
11	SMS	33	0	0	0	0	NA	NA
12	MMS	11	0	0	0	0	NA	NA

NA= Not applicable.

Table 6. Constrains of communication exposure towards e-agriculture as faced by the respondents (n=100).

Personal constraints	Percent of respondents	Rank
Unfamiliarity of extension worker with e-agriculture application	79	1
Lack of skill to use e-agriculture	71	2
Lack of knowledge on e-agriculture application	53	3
Lack of interest to use e-agriculture	44	4
Language problem for old aged extension worker to use e-Agriculture	41	5
Organizational constraints	**Percent of respondents**	**Rank**
Lack of training on e-agriculture	89	1
Lack of instrument (laptop, computer, tab)	81	2
Poor internet facility	51	3
Weak mobile networking system	49	4
Lack of ICT related communication in DAE	32	5

Preferred devices in using e-agriculture by the respondents

Agriculture is one of the vital sectors in which ICT can be used reasonably in transferring the modern agricultural technologies to the farmers (Prodhan and Afrad, 2014). Information and communication technology in agriculture includes internet, e-mail, cell phone, computers, radio, television, wireless communication tools, audio visuals, digital camera, CD-ROM, printer, fax which helps in timely communication at agricultural extension services (Fawole and Olajide, 2012; Mugwisi *et al*., 2015). To know the device preference by the SAAOs in using e-agriculture twelve media were selected against 7 devices. Device preference by the agricultural extension worker in using selected e-agriculture media is presented in Table 5.

From data furnished in the Table 5, it was very clear that among those media mobile was mostly used device for making phone call (95%), using social media (43%) and for sending SMS (33%). Mobile phone was also considered effective ICT device by the extension workers and researchers in Zimbabwe and around half of the agents used mobile phone for communicating agricultural information (Mugwisi *et al*., 2015). The 2nd most preferred device by the SAAOs was laptop and it was mostly used in browsing website (12%) and sending e-mail (9%). PC was less preferred device than laptop. Tablet computer was mostly used in making phone call (5%) and website browsing (2%). Net book was the least preferred device and used for only browsing website and email. However, television and radio program were also enjoyed from mobile phone and PC. It was surprising to note that only 15 percent agents used mobile apps to gather agricultural information. Now-a-days, there are a good number of apps available in Google play store for android phones. Lack of introduction and training may be responsible for such poor exposure. Less use of website, documentary, apps, e-mail and high use of phone call suggest that extension agents are comfortable with readily available information from one to one communication either from peers or from experts rather than self-quest for new information.

Constraints of communication exposure towards e-agriculture as faced by the respondents

The major constrains faces by the SAAOs were classified into two categories such as personal constrains and organizational constraints. Constraints faced by the SAAOs in respect of, "communication exposure towards e-agriculture" were constructed in Table 6.

Constraints furnished in Table 6, indicate that "unfamiliarity of extension worker with e-agriculture application", "lack of skill to use e-agriculture" and "lack of knowledge on e-agriculture application" were the most cited personal constraints of communication exposure towards e-agriculture. On the other hand, "lack of training on e-agriculture", "lack of ICT instrument", and "poor internet facility" were the most crucial organizational constraint of using e-agriculture. Lack of skill was not a constraint for Nigerian extension officers rather poor infrastructure, poor connectivity, poor electricity, high price of ICT, and lack of ICTs hindered access to ICT (Akpabio *et al*., 2007). Another study with farmers by Fawole and Olajide (2012), from Nigeria confirmed farmers' illiteracy constrained them to use ICT. Overall, it can be said that extension agents in study area still struggles with very basic access, knowledge and use related problems in implementing e-agriculture.

Conclusion

Despite inevitable future, e-agriculture has not gained much land in government extension service in Bangladesh. Still a good number of extension agents in this study are not well acquainted with e-agriculture and possess insufficient knowledge in ICTs. The situation even worse when we consider two third of the extension agents have no training on e-agriculture. Most of the agents were middle to old aged who generally prefer mobile phone to have interpersonal communication rather than sophisticated use of smart phones like using agricultural applications. Government agricultural extension service provider in Bangladesh, the DAE needs periodic recruitment to inject new ideas, skills, and spirit in the service. Devices preference for using e-agriculture shows the agents are a very basic user of ICT devices. Lack of skill, training, knowledge and availability of ICT devices hindered agents' exposure to e-agriculture. Organizational support through training on e-agriculture and providing more ICT devices along with introduction of digital library, creating digital contents and documentaries may help in increasing use of ICTs in agriculture by the extension agents.

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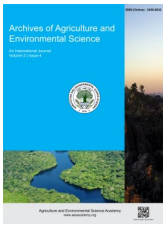

ORIGINAL RESEARCH ARTICLE

Cost-benefit analysis and resource use efficiency of rice production system in different agriculture landscapes in Chitwan district, Nepal

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ABSTRACT

The study was conducted to determine the cost-benefit analysis and resource use efficiency of the rice production system in different agriculture landscapes in the Chitwan district in 2018. The sample size of 102 rice-growing farmers out of 600 farmers, having an area of farm size greater than 0.5 hectares, was determined using Raosoft Inc. Software. A simple random sampling technique was used to collect 102 rice-growing household information in four municipalities (2 in plain and 2 in hilly area) using a semi-structured questionnaire. Data were analyzed using descriptive and statistical tools including Cobb-Douglas production function. Results showed that the use of inputs like seeds, chemical fertilizer and machinery like tractor were found significantly higher in the plain area whereas the use of inputs like labor, farmyard manure (FYM) and bullocks was found in higher in the hilly area. The costs of fertilizer, machinery, pesticide, and transportation were found higher in the plain area whereas the costs of seed, FYM, labor and bullocks were significantly higher in the hilly area. Production of rice per household was 1.87 ton whereas productivity was 5.2 ton/ha, gross profit was NRs. 41435and benefit-cost ratio was 1.59 in the plain area which was found significantly higher than the hilly area. The return to scale was found to be 0.48 which revealed that inputs used in rice production were ineffectively utilized in which organic fertilizer and labor resource were overused and seed, fertilizer, machinery and bullocks, pesticides and transportation were underused resources. The optimal allocation of these resources will increase the profitability of rice farming.

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INTRODUCTION

Nepal is an agricultural country where cereal crops are mostly grown for subsistence as well as for commercial purposes. According to CBS (2017), agriculture alone contributes around 27.04% of total GDP. Agriculture is the bulwark of the Nepalese economy where around 65% of the population is engaged in agriculture (CBS, 2017). Rice (*Oryza sativa*) is the most important food crop of Nepali in terms of both area and production. Rice plays a foremost role in the food security of our country and is regarded as the prime cereal crop of a nation. Rice contributes around 18% to Agriculture Gross Domestic Product (AGDP) of the country (CDD, 2015). The cultivation area and production of rice in Nepal are about 15523 thousand hectares and 5230 thousand ton respectively whereas the productivity is about 3.4t ha^{-1}(MOF, 2017). Nearly, 50% of daily calorie requirement is fulfilled by the rice crops alone. In Asia alone, around 2 billion people derive around 80%of their energy requirement, from rice that contains 80% carbohydrate, 7-8% proteins, 3% fat and 3% fiber (Juliano, 1985). The total dietary

energy supplied by the cereal crops in the context of Nepal is around 56%, among which rice alone share around 30% (MOAD, 2016).

In the context of Nepal average landholding size is comparatively less around 0.68 hectare which is one of the major reasons for impeding the production potential of the nation (NFS, 2010). Due to the decrease in yield and production of cereal crops, farmers have shifted from cereal cultivation to cash crops which ultimately decrease cereal crop production (Deshar, 2013). The major factor affecting the technical efficiency of rice production includes seed, fertilizer labor as well as irrigation (Hasnian and Hossain, 2015). For increasing the production of rice, the use of improved farm mechanization and input is the best way (Nargis and Lee, 2013).

Chitwan district is one of the dominant rice-growing districts in Nepal where rice is grown during spring and monsoon season. Although, it is regarded as the rice hub of the nation the yield in rice production is still comparatively lower as compared to another bordering district with similar geographical characteristics. The major insecurity in rice production is due to lack of quality seed, proper irrigation system, the inadequate linkage between research, extension, and teaching as well as the incapability to use modern technology. From cultivation to harvesting stage, the farmers of Nepal as well as of Chitwan are still using the same conventional tools and equipment which is a major cause for the yield reduction in Chitwan. At the present time also, the farmers of the hilly area are still dependent on the sickles for the harvesting procedure of rice which ultimately leads to a decrease in the efficiency of farmers (Shrestha, 2012). Farmers do not have adequate knowledge of resource optimization and as a result, they are not able to use the resources at their optimum level which is becoming the major cause for the yield reduction in Chitwan. The maximum production of rice is achievable only through improvement in crop productivity which is obtained through the utilization of efficient resources. This optimum utilization of resources ultimately leads to an increase in the profit margin. For obtaining maximum production from any agricultural commodity, resources must be available and available resources must be used efficiently and for this purpose, one must have knowledge about whose quantity rate should be increased or decreased (Alimi, 2000).

For any agricultural production system to be productive and efficient, the input used is the most important parameter. There is no study carried out to date to study the resource use efficiency of input for better production and productivity of rice in Nepal. Such a backdrop, this study is mainly focused to assess the profitability, level of resource uses and efficiency in rice production.

Figure 1. *Map of Nepal with its border countries; India on three sides and china at north sidealong with red region showing study area which is at the southern part of country bordered with India (Source: Osti et al., 2017).*

MATERIALS AND METHODS

Study area

Amongst the various cereals producing districts of Nepal, Chitwan district is one of the highest rice producing districts with great potential in cereal production and regarded as the food basket of the country (MOAD, 2016). So this district was selected for the study purpose. Chitwan district is located at Province no 3 of Nepal which lies between 27E21' to 27E52' North latitude and 83E54' to 84E48' East longitude with a total land area of 218000 ha, located at an altitude of 141-1943 m (Figure 1). The annual rainfall: 1950.7 Mm, mean temperature: 32.2-18EC and average relative humidity: 83%m (Osti *et al.*, 2016). Within the district, four municipalities consisting of two hilly area (Rapti and Icchakamana) and two terai area (Khaireni and Bharatpur) were selected for the study purpose (Figure 1, Table 1).

Sampling design

The numbers of households producing rice commercially having the farm size greater than 10 ropani were purposively selected for the study which was found to be 600. The objective was to find the real rice farmers so to get the valid data covering the whole rice farmers. Raosoft Inc. software, which was considered as a scientific and standard technique for the determination of sample size, was used to determine the required sample size (Raosoft, 2014). Using the software, keeping 95% level of confidence and margin of error 10 %, it recommended the sample size to be 91.The simple random technique was used to select sample to minimize the biasness as possible as the it is considered as the best way which provides an equal chance for selection of the elements from the sampling frame (Scheaffer, 1979). The sample size of 102 was taken for the study (Table 1).

Table 1. Sampling frame used in the household survey, 2018.

S.N.	Area of survey	Municipality	Population size (N)	Sample size(n)
1.	Plain area	Khairani Municipality	177	30
2.	Plain area	Bharatpur Metropolitan City	176	30
3.	Hilly area	Rapti Municipality	172	29
4.	Hilly area	Ichhakamana Rural Municipality	75	13
Total			600	102

Data collection and analysis

At first of all, pre-testing of questionnaire was done in Khaireni Municipality with 10 respondents, which is common in pre-test of questionnaire (Perneger et *al.*, 2015). Along with the improvements in the pre tested questionnaire, it was finally administered in December, 2018. Semi-structured interview schedule was used for the primary collection of data which were further confirmed by the data collected through Focus group discussion (FGD) and key informant interview (KII). The primary data consist of data related to farm input like seed, land size, organic manure, chemical fertilizer, labor, irrigation and output of rice along with their byproduct; their quantity and associated price. The secondary data were acquired through DADO annual report, articles, newspaper, books and Department of Agriculture.

The acquired data were systematically arranged and coded and entered in Ms-Excel and SPSS software for the analysis purpose. The results were derived by using descriptive statistics, mean comparison and Cobb-Douglas production function.

Cost and return analysis

To calculate the total variable cost, inputs like human labor, tractor labor, seed, inorganic or chemical fertilizers, irrigation, pesticides and organic manures including transportation cost-were considered and they were valued at current market prices to calculate cost of production.

Total variable cost = C_{labor}+ $C_{tractor}$+C_{seed}+ C_{fert} + C_{irri} + C_{pesti} + C_{manure}+ C_{trans}Where, C_{labor} = Cost on human labor used (NRs./ha), $C_{tractor}$ = Cost on tractor labor used (NRs./ha), C_{seed} = Cost on seed (NRs./ha), C_{fert} = Cost on inorganic chemical fertilizers (NRs./ha), C_{irri} =Cost on irrigation (NRs./ha) C_{pesti} = Cost on pesticides (NRs./ha), C_{manure} = Cost on organic manures (NRs./ha) and C_{trans}= Cost of transportation (NRs./ha)

Similarly, gross return was calculated as:
Gross Return = (Price of rice seed × Total amount of rice seed) + (Price of Rice by product (*Bhus*) × Total amount of Rice by product (*Bhus*)

Similarly, undiscounted benefit cost ratio was estimated by following formula, as used by Dhakal *et al.* (2015).

Benefit Cost Ratio (BCR) = Gross return/ total variable cost
Furthermore, Gross margin was calculated using following formula;

Gross Margin (NRs./ha) = Gross return (NRs./ha) - Total variable cost (NRs./ha) (Olukosi *et. al.*, 2016)

Resource use analysis using Cobb-Douglas production function

To determine the contribution of different inputs as well as for the estimation of the efficiency of variable production input in rice production system, Cobb-Douglas production function was used as described by Gujarati (2009). The general form of Cobb-Douglas production function was used to determine resource productivity, efficiency and return to scale is as follow:

$$Y=aX_1^{b1}X_2^{b2}X_3^{b4}X_5^{b5}X_6^{b6}X_7^{b7}e^u$$

Where, Y= Gross return (NRs./ha), $X_{1=}$Cost on seed (NRs./ha) , X_2=Cost on Fertilizer (NRs./ha), $X_{3=}$ Cost on manure (NRs./ha), X_4= Cost on machinery and bullock (NRs./ha), X_5=Cost on pesticide (NRs./ha), X_6=cost on labor (NRs./ha), $X_{7=}$cost on transportation, e= base of natural logarithm, u=random disturbance term, a=constant and b1,b2...b7 are coefficient of respective variable.

The resource use efficiency ratio (r), absolute value of percentage change in MVP (D) and return to scale (RTS) was estimated by using the following formula, as calculated by Sapkota *et al.* (2018).

r =MVP/MFC

Where,
MFC=Marginal Factor Cost and MVP= Marginal Value Product of variable input

The marginal value product is as follows:
$MVP = b_i \times APP_i$

Where: b_i= Elasticities of various input and APP= Geometric mean of output Y/ Geometric mean of output X_i

If r = 1,>1 or <1, it indicates the efficient, underused or overused of resources respectively.

Similarly, the absolute value of percentage change in MVP of each resource was estimated as D = (1- MFC/MVP)×100 Where, D = Absolute value of percentage change in MVP of each resource Return to scale analysis (RTS) The return to scale was calculated as follow: RTS= ∑bi If RTS=1,>1 or <1 , it indicates the constant, increasing and decreasing rate of scale respectively.

RESULTS AND DISCUSSION

Input used in rice cropping system in different geographical region

The major inputs used during the rice production includes Seed, Labour, FYM, Chemical fertilizers, Tractors/Bullocks (Table 2). The average amount of Seed, Labour, FYM, Chemical fertilizers, Tractor/thresher and Bullocks were 52.55 Kg, 75.99 man-days, 4411.60 Kg, 117.59 Kg, 16 hour and 10.48 days, respectively. These seeds, labour, FYM and chemical fertilizer have significant effect in the rice production. According to Ogundele and Okoruwa (2006), fertilizer is one of the most critical inputs in rice production. The amount of seed required was significantly higher in plain area (52.19 Kg/ha) than hilly area (43.19 Kg/ha)

Table 2. Input used in rice cropping system in the studied sites.

Variable	Overall	Plain area	Hilly area	Mean difference	T test	
					T value	P value
Seed (kg)	52.25 (29.88)	59.19 (22.07)	43.19 -36.01	15.99***	2.821	0.006
Labour (man- days)	75.99 (48.12)	57.83 (19.94)	101.94 (62.9)	-44.10***	-5.085	0.000
FYM (kg)	4411.6 (4400.6)	3584.54 (3422.2)	5535.55 (4755)	-1951.01**	-2.104	0.038
Chemical fertilizer (kg)	117.59 (98.72)	162.03 (76.45)	70.82 (62.42)	91.20***	5.613	0.00
Urea (kg)	61.49 (57.74)	71.99 (51)	50.44 (42.63)	21.54**	2.045	0.043
DAP (kg)	45.88 (36.87)	73 (40.09)	17.26 (10.36)	55.81***	7.500	0.00
MOP (kg)	10.21 (8.23)	16.96 (18.17	3.11 (2.11)	13.84***	4.854	0.000
Tractor/ Thresher (hour)	16 (5.55)	16 (5.55)	0	16.00	----	----
Bullocks (days)	16.99 (10.48)	0	16.99 (10.48)	-16.99	-----	----

Notes: **, *** indicate significant at 5% and 1% levels, respectively. Figures in parentheses indicate the standard deviation of the means.

Table 3. Comparative cost of rice cropping system (NRs. per hectare) in the major two studied sites.

Costs (NRs./ha)	Overall	Plain area	Hilly area	Mean difference	T value	P value	Overall share (%)	Hilly share (%)	Plain share (%)
Seed cost	5165.97 (3993.2)	4019.41 (3431.06)	6803.91 (4203.36)	-2784.5***	-3.674	0.00	6.88	9.93	4.94
Chemical fertilizer cost	3907.7 (3494.54)	5746.03 (2711.2)	1972.75 (1181.16)	3773.2***	6.91	0.00	5.2	2.88	7.07
FYM cost	8823.21 (7953.13)	7169.09 (6222.49)	11071.11 (9509.92)	-3902**	-2.104	0.038	11.74	16.15	8.82
Tractor/ Thresher cost	28918.88 (9997.48)	28918.88 (9997.48)	0	28918.88	-	-	38.49	0	35.57
Bullocks cost	16990.85 (10484.9)	0	16990.85 (10484.92)	-16990.9	-	-	22.61	24.79	0
Labour cost	37999.81 (24062.3)	28918.88 (9997.48)	50972.56 (31454.77)	-22054***	-5.085	0.00	50.57	74.37	35.57
Pesticide cost	4913.39 (3844.65)	5987.79 (5564.99)	2936.48 (1939.91)	3051.31**	2.155	0.035	6.54	4.28	7.36
Transportation cost	2653.37 (1405.58)	3121.06 (1465.87)	1996.37 (1010.93)	1124.7***	4.295	0.00	3.53	2.91	3.84
Total cost of Production	75139.84 (45471.2)	81302.21 (27576.36)	68537.3 (58494.91)	12764.91	1.519	0.131	100	100	100

Notes: **, *** indicate significant at 5% and 1% levels, respectively. Figures in parentheses indicate the standard deviation of the means.

Table 4. Yield and profitability of rice crop production in the two studied sites.

Variables	Overall	Plain area	Hilly area	Mean difference	T value	P value
Production in household (kg)	1966.73 (1853.22)	2757.88 (2054.32)	881.19 (359.97)	1876.7***	5.81	0.000
Yield (kg/ha)	4422.29 (2342.63)	5201.78 (2443.11)	3327.28 (1684.89)	1874.5***	4.3	0.000
Gross return (NRs./ha)	109330.9 (51273.16)	122737.63 (5034.82)	90176.33 (46796.6)	32870.42***	3.31	0.000
Gross profit (NRs./ha)	23876.88 (22658.06)	41435.4 (36120.9)	-1206.73 (1036.1)	42552.51***	4.33	0.000
B:C ratio	1.43 (0.72)	1.5993 (0.67)	1.1893 (0.74)	0.41***	2.89	0.010

Notes: **, *** indicate significant at 5% and 1% levels, respectively. Figures in parentheses indicate the standard deviation of the means.

at 1 % level of significance. The plain area have more leveled surface which have more surface area and required high amount of seeds. The labour used for rice cropping system was significantly higher in hilly area (101.94 man-days/ ha) than plain area (57.83 man-days/ha) at 1 % level of significance. The FYM used for rice cropping was significantly higher in hilly area (5535 Kg/ ha) than plain area (3584 Kg/ha) at 5 % level of significance. The use of chemical fertilizer was significantly higher in plain area (162.03 Kg) than hilly area (70.82 Kg) at 1% level of significance. For the land preparation, tractor/thresher is used in plain area whereas bullocks is used in hilly area.

Rice production cost

The total cost of production of rice includes cost of inputs (seeds, fertilizers, pesticides), cost of labour/equipment's during land preparation, and, cost of harvesting and transportation. The total cost of production was higher in plain area (NRs. 81302 per ha) than the hilly area (NRs. 68537/ha). This findings was supported by the findings of (Adhikari, 2011) who reported the minimum, average and maximum cost of organic rice production in Phoolbari, Chitwan were NRs. 19485, 32249 and 74005/ha, respectively. The higher cost of production in plain area than hilly region is mainly due to the more requirement of pesticides in plain area. Due to the high temperature and humidity in plain area, there is high incidence of insect pests and disease in plain area. The cost of pesticides in plain area and hilly area were NRs. 5987/ha and NRs.2936/ha, respectively. Almost, all farmer's use the chemical fertilizers like Urea (Nitrogen source), DAP (Nitrogen and Phosphorus source) and KCl (Potassium Source) in plain area and, however, there was exception in the hilly area and amount was also in low quantity in the used cases. The cost of chemical fertilizer was significantly higher in plain area (NRs. 5746/ha) than hilly area (NRs.1972/ha). And, the cost of FYM was higher in hilly area (NRs.11071/ha) than plain area (NRs.7169/ha). Farmer's of hilly area generally prefers FYM due to locally available in farms and less accessibility of chemical fertilizers in time. The high user of chemical fertilizer in plain area was due to easy availability. The cost of seed was also significantly higher in hill area (NRs.6803/ha) than plain area (NRs.4019/ha). During the land preparation, there was a uses of Bullock in hilly area whereas, tractor in the plain area along with human labour in both cases (Table 3).

Yield and profitability of rice production

The total average production in the study household was 1966.73 Kg. The average rice yield in household was 4422.29 kg/ha and it was significantly higher in plain area (5201.78 kg/ ha) than hilly area (3327.28 kg/ha). Due to the more fertile soil and irrigation facilities, there is higher yield in the plain area. The average gross return from rice production is NRs.109330/ ha which was significantly higher in plain area (NRs. 122737/ha) than hilly area (NRs.9017/ha). The higher return of plain area was due to the higher production in plain area (Table 4).

The average gross profit was NRs. 2387.88/ha which was significantly higher in Plain area (NRs.41435.4/ha) than hilly area (NRs. 1206.73/ha). The negative sign in hilly area indicates the loss which was due to the higher cost of production in hilly area. And, the Benefit Cost Ratio (BCR) was also significantly higher in plain area (1.60) than hilly area (1.19). This indicates, spending one rupee provides the benefit of NRs.0.6 in plain area and NRs.0.19 in plain area respectively. Thus, it was more profitable in the plain area and also the plain area is considered as the "Granary of Nepal". The low value of BCR in hilly area than plain area is due to the high cost of production in hilly area in the case of labour and FYM. The average BCR (1.43) of Chitwan contradicts with the mean BCR (1.19) of Kapilvastu (Sapkota and Sapkota, 2019).

Table 5. Estimation of elasticity, MVP and efficiency ratios using Cobb Douglas Production function of rice cropping system in Chitwan.

Variables Cost (NRs./ha)	Coefficients	Standard error	T value	MVP	MFC	r	D
Seed	0.064	0.059	1.085	1.564	1	1.564	36.048
Fertilizer	0.024	0.017	1.406	1.295	1	1.295	22.804
Manure	0.010	0.011	0.925	0.706	1	0.706	41.705
Machinery and bullocks	0.348***	0.090	3.846	1.632	1	1.632	38.718
Pesticide	-0.027***	0.009	-2.934	-46.859	1	-46.859	102.134
Labour	-0.155	0.098	-1.579	-0.463	1	-0.463	315.805
Transportation	0.222***	0.041	5.397	10.057	1	10.057	90.057
Constant	7.276***	0.896	8.122				
R Square	0.428						
Adjusted R Square	0.385						
Observations	102.000						
F value (7,94)	10.030***						
Return to scale	0.480						

Note: *** indicates significant at 1% level of significance.

Estimation of efficiency ratios using Cobb-Douglas production function

Average estimated values of the regression coefficients, allocative efficiency ratio 'r' along with MVP and MFC and their related statistics of Cobb-Douglas production function are shown in the Table 5. Among the seven independent variables; seed, fertilizer, manure, machinery and bullocks, pesticides, labour and transportation, of production functions; machinery and bullocks, pesticides and transportation were significant at 1% level of significance. The regression coefficient for cost of machinery and bullocks were 0.348, which indicates 100% increase in cost of machinery and bullock would lead to increase in gross return by 35%. Similarly increase in cost of transportation by 100% would lead to increase in gross return by 22% (as regression coefficient is 0.222). And increase in cost of pesticides by 100% led to decrease in gross returns by 2.7% (as regression coefficient is -0.027). The efficiency ratio less than 1- manure and labour; were overused in the study area, whereas, efficiency ratio greater than 1- seed, fertilizer, machinery and bullocks, pesticides and transportation; were underused resources. This findings agree with the findings of (Amaechina and Ebhoh, 2017) in which resource-use efficiency in rice production under small scale irrigation in Bunkure was studied. For the optimum allocation of resources, cost of manure and labour should be decreased by 41.70% and 315.80% respectively; and, cost of seed, fertilizer, machinery and bullocks, pesticide and transportation should be increased by 36.05%, 22.80%, 38.72%, 102.13% and 90.06% respectively.

The overall F value was 10.03 and it was statistically significant at 1% level. This indicates explanatory variables included in the model are important for the explanation of variation in production process. The adjusted R^2 value of 0.385 indicates 38.5% variation in the production of rice was explained by the explanatory variables. The return to scale in the study area was observed as 0.480 which is decreasing return to scale.

Conclusion

From this study, it is concluded that benefit cost ratio of 1.59 was found in the case of plain area which was higher than hilly area. Similarly productivity of 5.2 ton/ha was found in plain area which was higher than national productivity of rice (3.39 ton/ha) and hilly area (3.33 ton/ha) in studied site. Production of rice is profitable in plain area whereas hilly area suffered loss although the cost of production is less in hilly area. The reason behind loss in hilly area was due to less production per household (only 0.8 ton) and less use of resources. Among the types of fertilizers, high amount of FYM use was found in hilly area and chemical fertilizer in plain area due to easy availability in respective places. This study identifies the inputs used in rice production were ineffectively utilized in which organic fertilizer and labour resource was overused and seed, fertilizer, machinery and bullocks, pesticides and transportation; were underused resources. The optimal allocation of these resources will increase profitability.

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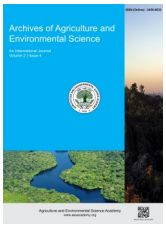

ORIGINAL RESEARCH ARTICLE

Drudgery reduction for women in agriculture sector in Nepal: An analytical study

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ABSTRACT

Analysis of rural womens' livelihood identifies a 'triple burden' of work to in the productive, reproductive and social spheres. Feminization is the common phenomenon in Nepal where the roles of men and women are unbalanced at household and community level. Due to the migration of economically active men to other countries and urban area for better jobs, the agricultural labor is being increasingly feminized. This paper assesses factors influencing the women drudgery in agriculture sector, possible interventions and recommendation for reducing such drudgery. It consisted desk review, key informant interview and stakeholders' consortium meetings to collect information, and triangulation of findings during 2017-2019 at regional and national levels. The study suggests that the workload of women (e.g., time and energy) in the farming activities can be reduced in two ways: (1) making existing tasks easier or increasing the productivity of existing labor, or (2) changing farm practices with new technology. Changes in the existing practice or introduction of new technology often reduces the workload of women in terms of both time and energy, but it requires external inputs and extra knowledge and coaching. Such interventions must consider the aspects of wider acceptance, economic viability and environmental friendliness. Further, the mechanization of agricultural tools and technology have alleviated the burden of tasks traditionally handled by both men and women in the sector. This paper recommends major tools, techniques and skills for women drudgery reduction in agriculture sector in Nepal that will be equally applicable in Asian region.

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INTRODUCTION

Nepal's Gender Inequality Index rating was 0.56 (113 out of 146 countries) in 2011 but it improved to 0.480 (149 out of 189 countries) in 2018 (UNDP, 2018). The country was in the 126th place in the Global Gender Gap Index for 2011, with a score of 0.59. By 2017, the Gender Development Index reached to 0.920 (149 out of 189 countries). This is a case of medium human development (UNDP, 2018). Women perform triple roles, i.e. productive, reproductive and community (World Economic Forum, 2017). A substantial proportion (40 percent) of the Nepalese women employed in agriculture as economically active work force. They work primarily as family unpaid workers in subsistence agriculture with low technology and primitive farming practices. They have to work long hours because they carry double burden of work in the family and farm. With the increasing outmigration and engagement on other non-farming sectors of male members, agriculture is becoming increasingly feminized. round 83 percent of the people lived in the rural area. Agriculture forms the foundation of the economy, accounting for around a third of GDP and providing an income for three quarters of the population. Women supply around 65 percent of labor in agricultural activities (FAO, 2010).

The share of agriculture in the gross domestic production (GDP)

declined to 26.5 percent by 2018/19 (MoF, 2019). The share of agriculture in the employment is also declining. Nepal conducted the Nepal Labor Force Survey (NLFS) (CBS, 1998; CBS, 2008; CBS, 2019). Form these surveys, the employment by industry shows that the share of agriculture in the employment has drastically declined to 21.5 percent as shown in Figure 1 below. It is noteworthy that the share of agriculture in total employment declined from 76 percent in 1997-98 to 74 percent by 2007-08, and further to 21.5 percent by 2017-18 (CBS, 1998; CBS, 2008; CBS, 2019). Part of this decline is due to the definition of the data because the NLFS 1997/98 and 2007/08 took the age group of 10 years of age and above, but the 2017/18 took the age group of 15 years and above. The general trend is that the employment in agriculture has been declining very fast due to the drudgery of the work, out-migration, growth of service sector and other factors. This has adversely affected in the national food security, which is reflected in the rapid increases in the agricultural balance of payments in the international trade. Further among the work force employed in agriculture, majority of them have always been women. This underlines the need to improve the innovations in agriculture such that it is more productive, labor saving and women- friendly.

Women are the most important actors in enhancing the agricultural and rural development in Nepal. However, they are facing greater constraints than their male counterparts in gaining access to public service, control over resource, social protection, employment opportunity, information, innovation and market and institution. A large number of women They are confined in unpaid care-work, and they encounter more difficulties in taking up leadership positions. A number of studies have reported that there is need to conduct gender research and analysis in a wide range of policy areas to support in the gender responsive policy formulation, implementation and social change in the country (World Bank, 2009). In order to rectify these challenges as well as uphold the Government´s political commitment to prioritize the Gender Equality and Social Inclusion (GESI) across sectors, the Ministry of Agriculture and Livestock Development (MoALD) has emphasized GESI integration in the Agriculture Development Strategy (GoN/ADS, 2014). The importance of production of evidence-based/ knowledge products for GESI responsive policy and program in the agriculture sector as stated in the output 1.5 of ADS underlines the scope of this research. Therefore, this study carries out a desk review of existing researches conducted by the government, public and private academic/ research institutions in the agriculture sector for last 10 years (2005-2016) on drudgery reduction for women in the agriculture sector in order to: (1) stock take/ summarize the existing information on relevant subjects, and (2) identify the gaps between available information and required information that would help the Government to make evidence-based policy and programs.

MATERIALS AND METHODS

The study is based on the desk review and few key informant interviews with the concerned stakeholders for qualitative information. The key informant interviews (KII) was applied to verify and/or supplement the secondary data and information with key government officials of line ministries, UN agencies and other donors and major stakeholders.

Data collection methods

The data collection methods mainly consisted of desk review of available documents, literature and findings from Nepal and other South Asia mainly India, Pakistan and Bangladesh from 2005 to 2019 and administration of the KII with the government GESI and ADS focal points, and the private sectors.

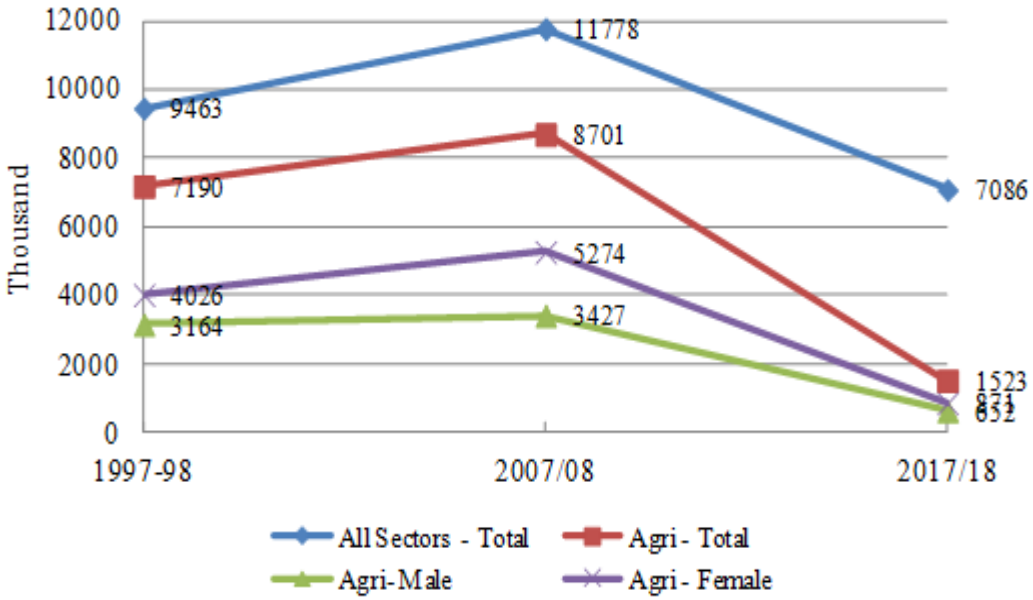

Figure 1. *Employment in the economy, and the agriculture, forestry and fishery sector by male, female category 1998, 2008 and 2017 (Sources: CBS, 1998, 2008 and 2019).*

Criteria for desk review

The following were the desk review criteria and questions to guide this research. The specific data of interest included:

- Contribution of women, and their age, education, years of experience, farm size, property rights, ethnicity, well-being, male-migration, marital status and workload sharing in agriculture and livestock management; these activities included procurement of farming inputs; harvesting, storage, marketing, saving, and technology adoption in farming systems.
- Gender involvement such as the socio-economic aspects in agriculture sector and workload sharing mechanism to reduce drudgery in the rural and urban areas.
- Gender roles and contribution in the farming systems and technology adoption.
- Women's role and contribution in the farmers, groups, cooperatives and other institution.

Key research questions for desk review of research to reduce drudgery for women in agriculture sector were: How to reduce drudgery of women in agriculture sector?, What factors and key variables influence in drudgery reduction for women?, What are the enabling and distracting variables for drudgery reduction of women?, What are the key technology and intervention needed to reduce drudgery of women in agriculture sectors?, Which policy and interventions influenced drudgery reduction for women?, What are the gaps and recommendations?

Key informant interviews (KII)

Face-to-face KII were conducted with project officials and key stakeholders at the national level with the representatives from Government and private sectors as follows:

- GESI and ADS focal points at MoALD.
- Nepal Agriculture Research Council (NARC)' GESI focal points.
- Focal persons of Agricultural Engineering Division (AED), NARC.
- Professors at Agriculture and Forestry University (AFU) and Institute of Agriculture and Animal Science (IAAS)/ Tribhuvan University.
- Swiss Agency for Development and Cooperation (SDC), Helvetas Nepal, ICIMOD key focal persons.
- Agriculture Food Security Project (AFSP)/FAO and OXFAM focal persons and discussed in related and relevant issues related to drudgery reduction for women.

RESULTS AND DISCUSSION

Women in agriculture

There is a vast difference between the male and female engagement rate in agriculture with about 51 percent and 74 percent, respectively (CBS/NPHC, 2011). Overall, literacy rates increased to 67 percent by 2011 from 54 percent in 2001. Female literacy has increased from 43 percent in 2001 to 58 percent in 2011, which places Nepal in fourth position among SAARC countries above Bhutan, Pakistan, Bangladesh, and Afghanistan. In Nepal, about 65 percent of the women contribute their time in agriculture sector whereas male's contribution is only 35 percent (FAO, 2011a). Data recorded in the successive census by CBS reflects that women's participation in agriculture labor force has increased from 36 percent in 1981 to 45 percent in 1991 to 48.1 percent in 2001 and further made a jump about 65 percent in 2011 (CBS, 2012; FAO, 2010). Women are the backbone of agricultural work force but their hard work remained mostly unpaid and not countable. Women do the most tedious and back breaking tasks in agriculture. Female-headed households have increased by 11 percent points from 14.8 percent in 2001 to 25.7 percent in 2011. Among the heads of agriculture holdings, 31.7 percent of males and 44.4 percent of females are still illiterate. Average land holding in Nepal is 0.68 ha, which is higher among the male farmers (0.7 ha) as compared to female farmers (0.4 ha). The land holding size is found higher in terai (0.75 ha) followed by mountain (0.65 ha) and lower in hill region of Nepal (0.57 ha). Out of the total major farmers in Nepal, 8 percent were female in 2001 which was increased by 19 percent in 2011-12.

Government's agriculture policy and strategy has not touch much on women farmers. For example, in the Agriculture Perspective Plan (APP 1995-2015), policy failure is one of the reasons for the increasing trend of outmigration. Despite increasing rate of remittance to GDP (29.1 percent in 2014/15) (MoF, 2016), agriculture has been feminized increasing women's workload because the crops/ livestock management practices are traditional, with limited use of machines and tools, and poses serious health implication for women (LI-BIRD, 2015). Nevertheless, there are certain positive results on socio-economic empowerment of women. The gender responsive budget has been increased from 11.09 percent to 22.27 percent in ten years from 2006 (MoF, 2016).

The gender responsive budget (GRB) in agriculture is oriented primarily towards the livelihood support such as food security, income generation and marketing in total (59 percent), which is followed by budget allocation for extension education (41 percent) during 2014-2018 (Figure 2). The budget allocation for agricultural technology innovation from the gender point of view is very less. The National Agricultural Research System (NARCS) does have a unit to examine the gender implications of the agricultural technology one the technology is generated, but there is no procedure to include the gender agenda in the design of research for technology (Figure 3).

Among the employed labor force, the distribution for economic and non-economic work shows gender gap in the national and the urban and rural sectors. At the national level, 21.3 percent female are engaged in non-economic work whereas only 5 percent male are engaged in such work. In economic work, 37.5 percent female and 44.9 percent male are engaged. This shows a high inclination to economic work by the male while for non-

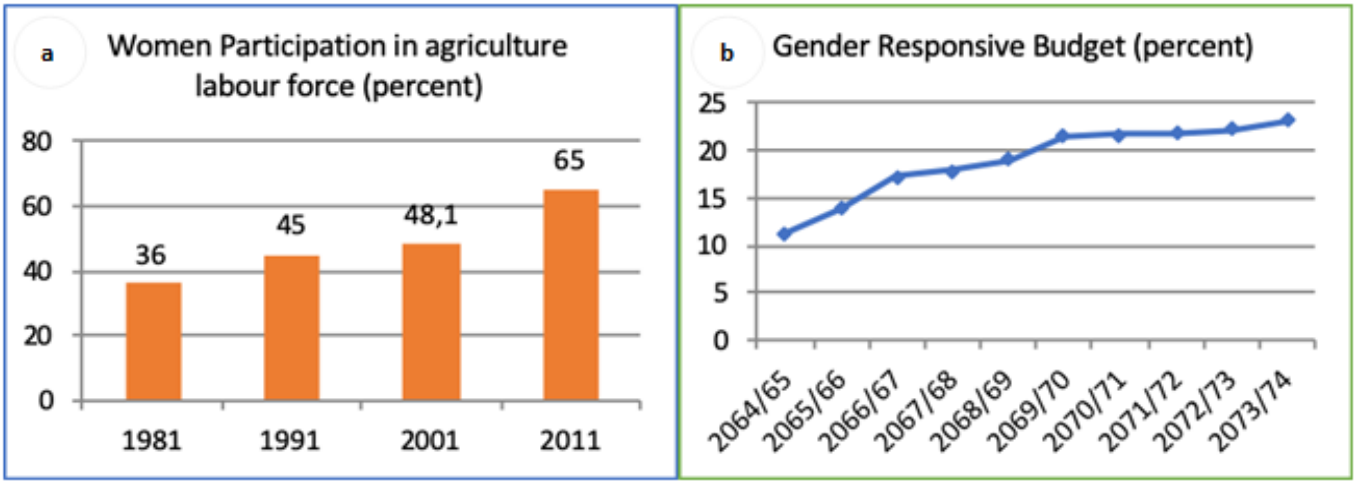

Figure 2. *(a) Women participation in agriculture labor force, (b) Gender responsive budget in Nepal.*

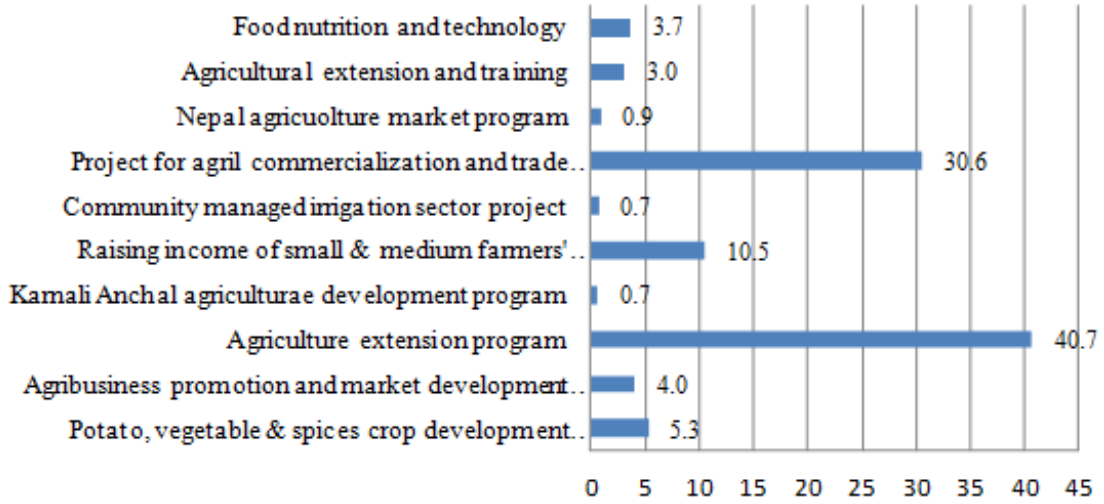

Figure 3. *Scenario of P1 program budget allocation with GRB code 1 in agriculture sector (percent share, 2014-2018) (Source: MoAD, 2018).*

economic work, more females are involved. Such gender gap is more prominently seen in urban area where 21.8 percent female and 5.2 percent male are engaged in non-economic work. In all work, female are found working on weekly average for 58.8 hours, whereas male work for 49.9 hours that shows female work on average 8.9 more hours weekly than male. However, female are highly engaged in non-economical or unpaid types that include household chores, self-agriculture work and so on. On average, female work 16.3 hours more in non-economic works than male whereas male labor is engaged in economic or paid works for 7.4 hours more than female (CBS, 2016).

In agriculture sector, 33 percent male received high wage rate whereas 4.1 percent female received that much among all the participants in rural wage employment (FAO, 2011a). The majority of Nepali women received low wage (61.4 percent) rate in agriculture employment, which is similar to global average (62 percent). However, very few and negligible Nepali women have received higher wage (1 percent) that is very low as compared to global average (19.8 percent). Figure 2 shows the employment in agriculture and percentage of female employment in the world, South Asia and Nepal.

Drudgery for women in agriculture sector

Feminization of agriculture is evident in the outmigration of male from rural areas. Women actively make management decisions on inputs supply, planting, weeding, post-harvest operations and marketing of the produce. The crop management practices they follow are traditional, with limited the uses of machines and tools, causing backache and whole-body pain. FAO (2005) reported that the majority of household labor and their livelihood activities are characterized by mounting drudgery-collecting water and firewood from far distance, and labor-intensive agricultural tasks. This work 'overload' is mostly unpaid and unrecognized. And restricts women's well-being and their engagement in activities of value, including remunerative activities.

In the Feminization, the roles of men and women are unbalanced at household or community level. This is happening due to globalization and advances in transportation and communication because it led the young people to migrate outside of their home country in search of a better life and job. Due to economic active male family member migration for better job opportunity to abroad, the agricultural labor is being increasingly feminized

(Kollmair and Hoermann, 2011; Gartaula *et al*., 2010; Kelker, 2009). Women face a distinct disadvantage since they are the ones who sacrifice education and skill development opportunities to manage land and agriculture. With massive male migration, women have broadened and deepened their involvement in agricultural work. So they are increasingly shouldering the responsibilities for household survival, productive, reproductive and responsibilities work in the household and community (Kelker, 2009). The feminization of agriculture has a deep and wide-ranging impact of agriculture productivity. Numerous studies have shown that with the feminization of agriculture is already happening, its causes and consequences on drudgery for women has been increased due to burden in agriculture work, household other work and off-farm activities simultaneously (Tamang *et al*., 2014; Poudel *et al*., 2012; Amatya Shrestha *et al*., 2010; Gartaula *et al*., 2010; Maharjan, 2010; Kelker, 2009). Out-migration has some positive benefits in the form of skill enhancement of migrants, remittance to the families back home, capital formation (asset creation) and their livelihood diversification. Albeit, there are many negative social impacts from men out-migration to abroad such as family stress, increased drudgery for women in agriculture, family breakdown, children growing up without their father among others (Kattel and Uphadhyay, 2018). Tamang *et al.* (2014) field study suggested that the less labor-intensive agro-forestry approach is a found to be vital for addressing the agriculture productivity issues and increase local food production for food security of the poor and marginalized, restoring abandoned agricultural land in full production cycle. Amatya Shrestha *et al.* (2012) reported that women involvement in agricultural activities was 16 percent higher than that of men in Mangaltar VDC of Kavre district. In the irrigated area, women involved more than 11 hours a day whereas men contributed only 7 hours in agricultural activities. In the rainfed area, women devoted more than 12 hours a day, whereas men contributed only 9 hours. Majority of activities of male farmers were ploughing and levelling the land during land preparation, and hard works like carrying out product loads after the harvesting. The authors argue that as female farmers are more engaged in farming activities than male farmers and sources of drudgery for rural women. Based on the field experience they concluded that technology interventions in agricultural sector in Nepal have hardly addressed the issues and concerns on gender. In this changing context, there is a need to identify an effective and gender balanced technology in the different agro-ecological zones of Nepal. The agricultural technology should be women-friendly to reduce the drudgery of female farmers.

Women continue to have extensive workloads with major responsibilities for agriculture production/marketing, animal husbandry and household chores (Leduc, 2011). Gender stereotypes and outmigration of men to urban areas and foreign countries for employment have increased the responsibilities of women in relation to agriculture production and natural resource management, intensifying their workload (Khadka, 2012). Outmigration is both an enormous challenge for women as well as an opportunity when we consider the empowerment of women and livelihood strategy. However, most of the existing agricultural technologies are not women friendly because the technology are focused on external resources, but not on the intensive workloads and, when appropriate technology are available, they are often expensive and subject limited ownership of the women. In addition to these, several institutional, financial and human resource factors limit agriculture service delivery to farmers in Nepal, especially to rural women in more remote areas. Moreover, access to extension services and skills by women is very limited because of the lack of a gender sensitive extension system (Ghale, 2008); as a result, gender-friendly programs and activities at the beneficiary level are very limited.

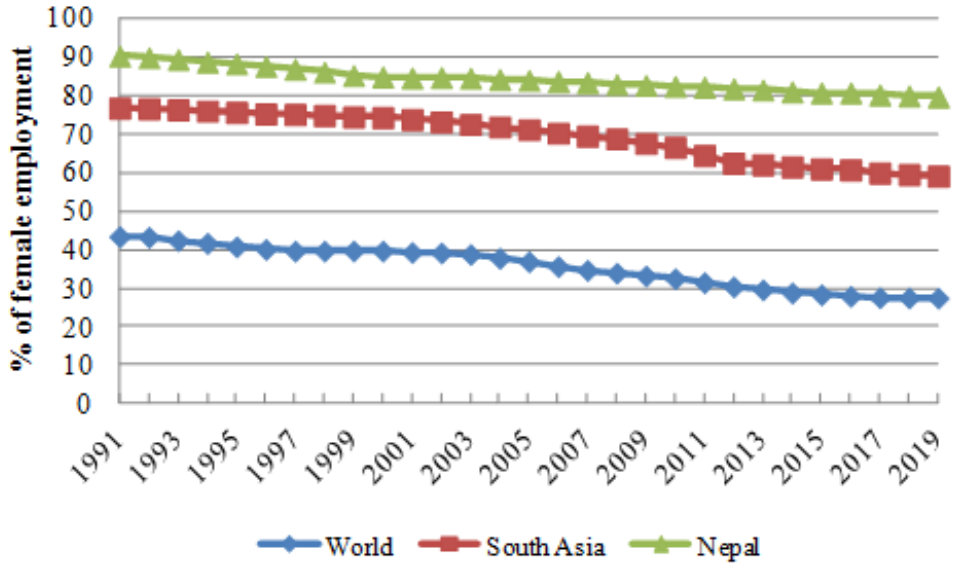

Figure 4. *Employment in agriculture, female (percent of female employment) (modeled ILO estimate) (Source: World Bank Group, 2019).*

Women's drudgery reducing approaches, innovations and technologies

Various research and project assessment studies in Nepal showed that access to road and transportation, sustainable energy, infrastructure facilities, mechanization in agriculture with gender-friendly technology, access to credit, services, water and women's ownership right can reduce drudgery in agriculture sector (Ragasa *et al*., 2014; Tamang *et al*., 2014; Ghebremichael, 2013; UNIDO/UN Women, 2013; Joshi *et al*., 2012; Leduc, 2011; Gurung *et al*., 2011; FAO, 2010; Sharma, 2010; Kelker, 2009; Manandhar *et al*., 2009; Ghimire, 2008; FAO, 2005). Mechanization of agricultural tools and technology alleviated the burden of tasks that are traditionally handled by men, leaving women's burden unrelieved (Shiva, 1991 as cited in Tamang *et al*., 2014). Ragasa *et al.* (2014) analyzed the access to and adoption of technologies that reduced drudgery for women in agriculture sector by looking at both the supply and demand sides of technology and related services (Figure 4). The demand side relates to users of services and technology, while supply side concerns to the developers of input suppliers, technology and service providers. The former includes different types of farmers and other supply chain actors who are the anticipated users of technology and services. The latter includes the (i) research system that provide scientific and technical expertise and indigenous knowledge; and (ii) education and extension systems (trainers, subject matter specialists, front-line field workers either from public sector, private sector, non-government organizations, or other civil society organizations) that provide training, education and advisory services on technology, management practices and livelihood strategies. On the types of technology, improved practices and innovations particularly focus on agriculture/value chain where women are more involved and helped their drudgery reduction, it examines are as follows (Ragasa *et al*., 2014).

- Agriculture production technologies (e.g., improved varieties and seeds, improved production or natural resource management practices, fertilizer, pesticides, knapsack sprayers, plows, irrigation, and other farm power);
- Harvesting technologies (e.g., hand tools, reapers);
- Postharvest operations and processing technologies (e.g., solar drying equipment, threshers, improved marketing or processing practices);
- Labor, time and energy-saving technologies for household tasks (e.g., fuel-efficient stoves, home gardens, technological and institutional innovations for greater access to water and energy);
- Rural transport (e.g., hand carts, bicycles, motorized transport and other means of transport);
- Information and communication technology (ICT) such as mobile phones, rural radio, internet, television, print media.

Access to road and transportation facilities

Many research findings in Nepal show that rural road and means of transportation can reduce drudgery for rural women through market linkage of products, inputs and services and income generation opportunities to the women. For example, women in Kaule village of Chitwan (hilly area) carried load about 30-50 kilogram of rainy and winter season vegetables and walked from Hatibang to Fishling had taken about 4-6 hours a day before rural road connection. Now, their workload to market supply of vegetable has been reduced by 80-90 percent due to rural road connectivity and transport facility in this area. Leduc (2011) reported that construction of road and footpaths under North Eastern Region Community Resource Management Project for Upland Area (NERCORMP), India, reduce women's drudgery, and increases the market linkages for products. Similarly, World Bank, FAO and IFAD (2008) suggest that rural roads increase the productivity and income for men and women farmers by reducing drudgery, time and opportunity cost to marketing and inputs. Gravity ropeway technology was transferred from Northern India to Nepal in collaboration with ICIMOD and private manufacturers/suppliers. An initial study showed that the gravity ropeway system reduced transportation cost of agro products by at least half. It gave villagers and women confidence to supply vegetables, milk and other perishable agricultural and forest products in larger amounts, and to enter the competitive market in cities. It reduced drudgery for load carrying by women, and improved their socio-economic conditions (health, education, and convenience), created employment opportunities and supported the business of local manufacturers and service providers (Biggs and Justice, 2011; Manandhar *et al*., 2009).

Sustainable energy

Among the several renewable resources, the biogas, micro-hydropower, improved cooking stove (ICS), rice husk stoves for cooking reduce the drudgery for women by increasing access to modern agro-processing mill, time saving for cooking and other household chores. Several studies in Nepal reported that renewable and sustainable energy promotion help reducing women's drudgery in agriculture sector. For example, a study conducted by Gurung *et al.* (2011) in Parche VDC, Kaski district revealed that access to electricity reduces drudgery for women in rural areas allowing them to have enough time to be involved in other household related activities including the income generation, social and community development and self-employment activities. Similarly, biogas reduces drudgery and save work time, and rice husk stoves for cooking reduce women drudgery for fuelwood collection (Manandhar *et al*., 2009). The ICIMOD project findings showed that improved cooking stove in Nepal and solar dryer in Bhutan helped drudgery reduction for women through production, marketing and utilization of these technologies using productive and strategic gender participation approach. This brought gradual change in the traditionally defined gender roles with women taking up so-called 'male responsibilities', and men showing increased involvement in household chores previously considered as 'women responsibilities' (Sharma, 2010).

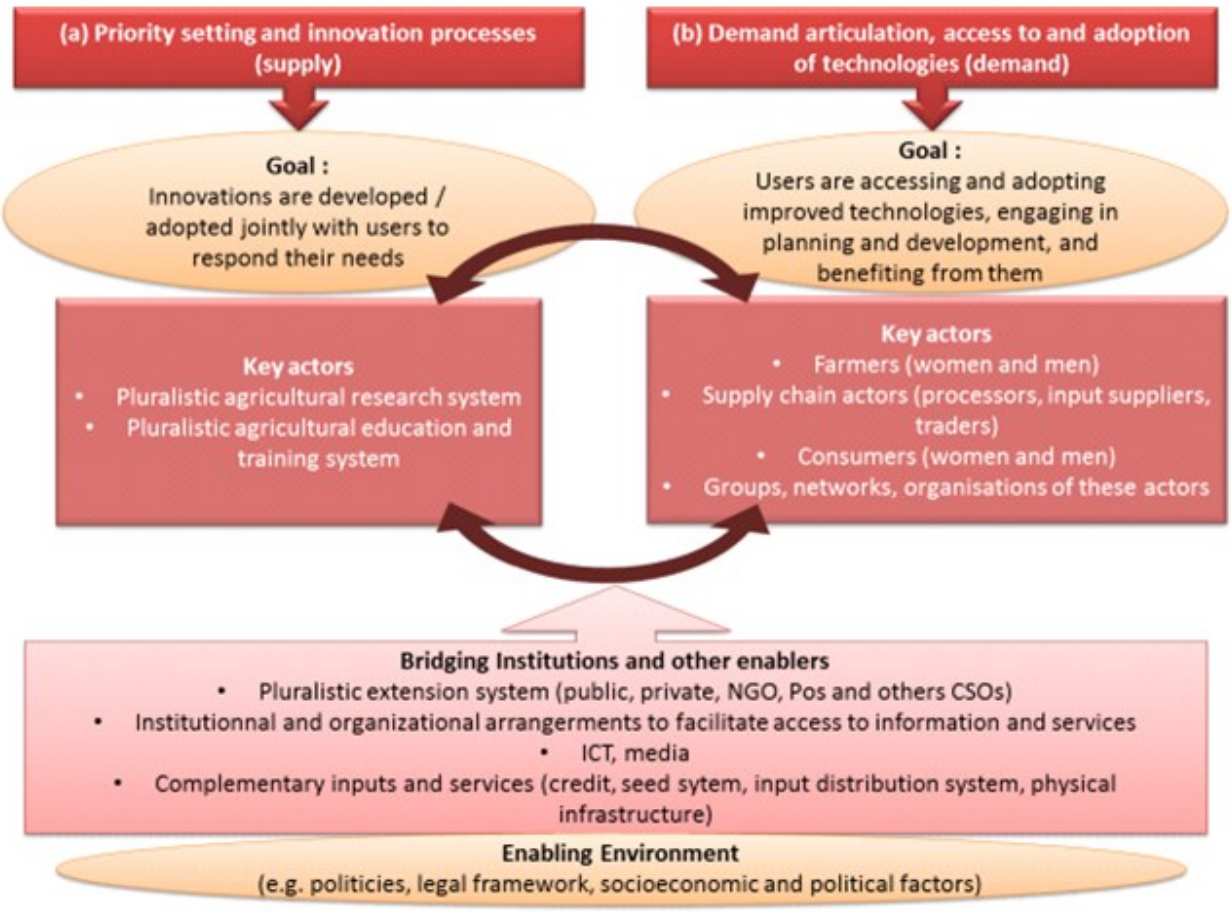

Figure 5. *Conceptual framework in analyzing the demand and supply side of technological innovation while analyzing the role of institutions as catalysts and using a gender lens (Source: Ragasa et al., 2014).*

Small infrastructures and micro-irrigation

Leduc (2011) under Western Upland Poverty Alleviation Project (WUPAP), Nepal, reported that the installation of small infrastructure and equipment in rural areas such as piped water equipment, water reservoirs, latrines, smokeless stoves, mills, pre-primary school, and roads have contributed to significantly reduce women's drudgery in the mountains, which are well appreciated by women. These types of intervention not only reduce the workload of women, they also improved their health and increase the opportunities for the girls, to access education. Upadhyay *et al.* (2005) demonstrated that the drip-irrigation systems in Nepal help in reducing women's workload and have a significant positive impact on family food and nutritional intake. Likewise, women's participation in vegetable farming under drip -irrigation tends to improve their rights to household resources, including food and cash. Since women are more involved in overall vegetable production, they have greater access to the cash generated from the sale of these vegetables. This improves their bargaining power and decision-making roles in the household. Moreover, women's participation in self-help groups, meetings and interactions among non-governmental organization staff and groups have helped them build their capabilities. In general, total time (mean hours) spent by women in vegetable production is significantly higher than those spent by their male counterparts. The analysis of time allocation data revealed that women's drudgery has been reduced by 50 percent with the drip irrigation as compared to conventional irrigation methods.

Small scale waste/roof water harvesting technologies (e.g. earthen pond, plastic sheet lining pond) are applicable, especially during the dry period; many disadvantaged households can partially supply water to vegetables, cash crops and help to reduce the workload of women for fetching irrigation water. ICIMOD, IFAD, FAO, Plan International Nepal and other many organizations have promoted and recommended this technology to reduce drudgery for women as well as crops diversification from low value cereal to high value vegetables for fetching higher income. Some research and project studies in Nepal showed that small scale irrigation system like treadle pump in Terai, drip irrigation systems in hills, sprinkler system connected to drinking water tap as a part of multiple water use system and rainwater harvesting plastic pond as well as ferrocement rainwater harvesting tank in hills reduce drudgery for women in agriculture sector (Dixit *et al.*, 2013; Manandhar *et al.*, 2009). Households can benefit from access to clean drinking water, irrigation facilities and other uses like water for livestock and cleaning from these small-scale irrigation technologies promotion and adoption. It also reduces the drudgery for women and small children who typically are forced to travel long distances and in hazardous conditions to collect water. The time saved would allow women to increase their income (productive needs) and improve their status in society (strategic need).

Mechanization in agriculture and gender-friendly technologies

Mechanization in agriculture reduces the drudgery of agriculture. However, the agricultural mechanization is low in Nepal, which is reflected in the types of agricultural machinery, tools and equipment used by the farm households. In this regards the data from the National Sample Census of Agriculture (NSCA) 2011/12 are summarized in Figure 5. The incidence of farm households with access to power tillers (2 percent), deep tube wells (4.2 percent), shallow tube wells (9.6 percent), pumping sets (14.3 percent), thresher (21 percent), tractor (22 percent) and iron ploughs (28 percent) are indicative of very low mechanization in agriculture in Nepal as of 2011/12 (Figure 6). The question here is how to promote capital formation at farm level that would have positive impact on reducing drudgery on labor and increases productivity.

A research conducted by LI-BIRD (2016) in Kaski and Dhading districts of Nepal showed that adoption of the jab planters and corn sheller help to reduce drudgery among rural women. About 80 percent of jab planter users liked the jab planter while all women liked the corn sheller for reducing drudgery. However, low access to input market of both these technologies, and the high price of jab planters might be a barrier to wider adoption and their up-scaling.

Out-migration of men and labor shortage has had a distinct influence on the mechanization of agriculture in Nepal, which has accelerated in the last two decades (Joshi *et al*., 2012). This is also partly due to the lack of attention in reducing drudgery in agricultural and rural operations for women, poor farmers and workers. Several power-operated agricultural machines are now in use in Nepal, including the following that reduce drudgery for women and poor farmers: water pumps, tractors both 4 wheel and 2 wheel, harrows, rotavators, seed drills; threshers; combine harvesters (for rice and wheat); agricultural processing machines; rice, oil and pulse mills; and laser and land-levelers. Biggs *et al.* (2011) reported that the mechanization technology and machines available across the long open border with India influenced mechanization patterns in the Nepal Terai. Minimum tillage by power tiller drills has been popular among small and medium farmers performing three operation of soil tilling, seed sowing and planking. It saves on cost, overcomes the problem of poor plant-stand and reduces women's workload for seed sowing that can result from poor tilth and manual broadcasting. Minimum tillage by participatory technology development has produced an extra 600 kg per hectare mean grain-yield of wheat with typical yield based on farmers' practice (Manandhar *et al*., 2009).

Both wheat and rice threshers are becoming popular in most parts of the Terai because farmers see a clear advantage in terms of saving time, resources and labor. In addition, threshers reduce drudgery for women from manual threshing activities. The use of machines to thresh wheat is much higher than for rice, although rice threshers are beginning to spread in Nepal's eastern Terai (Joshi *et al*., 2012). Pedal millet thresher developed by AED/NARC and tested by LI-BIRD found that it has reduced women farmers' workload in threshing and pearling millet about 65-85 percent. Among the users, a total of 83 percent respondents (94.7 percent women) found pedal threshers to be important alternative for manual threshing. Farmers found pedal thresher effective for easy grain separation, cleaning, and removing husk while they reported that the pedal thresher requires less time and effort to operate, most importantly it avoids injuries on feet, and reduces backache compared to the manual threshing. However, identification of model with lighter weight, portability, and affordable price could help farmers reduce the labor and drudgery to address labor scarcity that are related with out-migration. Women farmers have demanded an electric thresher where they have access to electricity, they felt the leg pain while operating the pedal of the thresher (LI-BIRD, 2015).

Some agricultural machinery developed by NARC's AED like hand maize sheller, coffee pulper, thresher-cum-peeler for millet, and low-cost solar dryers are commercialized and adopted by farmers in various part of Nepal. The hand maize sheller reduces drudgery for women farmers. The coffee pulper has been adopted on a commercial scale at the community level, and has increased capacity and efficiency by 50 percent compared to manual operations related to these commodities (AED/NARC, 2014; Joshi *et al*., 2012; Manandhar *et al*., 2009). AED/NARC (2008) reported that adoption of small dryer for early rice (Mini SRR) means not only the conservation of the early rice varieties products or seed during rainy season but also enabling the farmers to wait for better prices. The dryer for early rice would also help in reducing women drudgery as they are mainly involved in crop drying (Table 1).

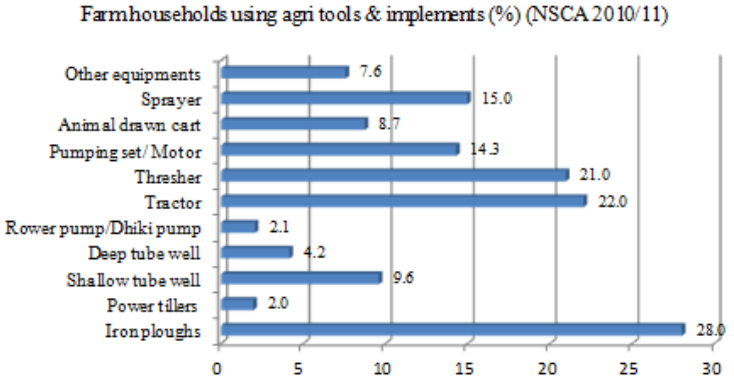

Figure 6. *Farm households using agriculture tools and implements in Nepal (Source: CBS/NSCA 2012).*

Table 1. Some agricultural technology and machinery developed by AED/NARC that can reduce women's´ drudgery in agriculture sector.

S.N.	Agricultural technology and machinery
1	Zero minimum tillage technology
2	Rice weeder
3	Pedal paddy thresher for wheat thresher
4	Manual corn sheller
5	Water management technology for early rice and wheat
6	Low cost solar dryer
7	Improved cardamom dryer
8	Improved plastic house for off-season vegetable cultivation
9	Jab seeder/planter
10	Coffee pulper
11	Millet thresher cum pearler
12	Mini SRR-Dryer
13	Improved rotary quem
14	Vegetable seed cleaner
15	Pedal operated rice cum wheat thresher
16	Ginger washing machine
17	Dry land weeder
18	Aerator
19	Potato grader
20	Solar tunnel dryer

Source: AED/NARC (2016)

A consultation meeting with Ishwori Prasad Upadhyay (Post Harvest Engineer) and Ganga Ram Bhandari (S1 Scientist), Agricultural Engineering Division/NARC, reported that small tractor (2 wheel) and hand machines are found more women friendly. Power tiller, drum seeder (for direct seeded rice), mini-tiller, rice weeder, corn sheller, dry land weeder, pedal thresher (for rice and wheat), dryer (solar/cabinet), pedal/ electric millet thresher, coffee pulper, potato grading machine, rainwater harvesting plastic pond, plastic tunnel for off-season vegetable production are women friendly technologies; these can help in reducing drudgery for women in agriculture sector. However, these technologies are not scaled up and have low adoption rate due to the poor information and dissemination strategy at local, regional and national level. The seventies emphasized that verification and testing of the technologies at farm level from gender perspective and awareness, and the capacity development training and programs during transitional phase should be needed for promotion of these technologies to a wider scale. Although government has provided up to 35 percent subsidy in machinery (25 percent in Terai, 30 percent in Mid-hills and 35 percent in High-hill Mountains), the small-scale farmers and women could not afford these technologies due to high costs, monopoly trade and lack of commercial agricultural machinery industries in Nepal. In this scenario, the private sectors´ involvement for technology trading in collaboration of NARC and government and non-government sectors are visualized (I.P. Upadhyay and G.R. Bhandari, Personal Communication at AED/NARC office, Khumaltar, 3rd October, 2016). Manandhar *et al.* (2009) also reported that the tubular corn sheller in maize growing areas, mini SSR dryer rice in early rice growing area during rainy season and low-cost solar dryer in drying agro commodities (apple, apricot fruits and vegetables) in the remote mid hills have high potential to reduce women's drudgery in agriculture sector effectively. Sapkota *et al.* (2007) reported that there is lack of technology that really support or reduce the drudgery and time used by women for tedious work as drying of seed for storage, shelling maize and weeding.

A consultation meeting with Agriculture Food Security Project, FAO, Dr. Bishnu Dhital, Agriculture Specialist, reported that power tiller, threshers (paddle and electric), corn sheller (hand and electric) are major technology promoted by FAO in western development regions of Nepal that help to reduce women's drudgery (Dr. B. Dhital, Personal Communication, 1st October, 2016).

Some of the identified and tested women's drudgery reduction technologies in India are:

- Row manual rice trans planters: Singh (2009) from Bhopal India reported that two-row and four-row manual rice trans-planters could reduce drudgery by 36 percent and 70 percent, respectively in term of physical cost/ha as compared to traditional practices;
- Improved lighter tools, cattle troughs, rice mills, home garden;
- Single wheel hoe for weeding;
- A number of small tools and equipment have been designed by ICAR institutes, Universities and other agencies/ industries in India. Some of them that can be easily used by women and reduce drudgery are: Dibbler (suitable for drilling wheat, field pea, and maize in small plot); Dibbling Stick (sowing for seed); Rotary Dibbler; Paddy drum seeder; blade hand hoe, Three tined hand hoe (grubber), Single wheel hoe (for weeding of vegetable crops); Double wheel hoe (weeding and inter-culture for upland row crops); Cono -weeder (weeding for paddy); Groundnut decorticator;

Tubular maize sheller; Fertilizer broadcaster for women; Hanging type grain cleaner; Transplanting trowels; Khurpi (for weeding); Hand fork; Hand sprayer; Sickles and Dao (cutting tools); Plucker; Pedal operated thresher; and Self-propelled riding type reaper.

Sustainable agriculture, resource conserving technologies and agro forestry

Nepal is one of the few countries (after India in 2014) to have the Agro-Forestry Policy 2019. Such policy have big importance to reduce the drudgery of work on woman in agriculture, livestock and forest related activities especially in the rural areas. This Agro-Forestry Policy 2019 (2076 BS) has the its objectives as follows: i) To increase productivity of the land and its multiple uses and thereby increase the output of agriculture, livestock and forest-based products; ii) To reduce pressure on forest and thus preserve the environment and bio-diversity, soil health (quality) and natural-ecological system restoration; iii) To make intensive uses of agro-forestry for the local people's food security, livelihoods, employment and income-generating opportunities; iv) To mobilize resources for agro-forestry for its commercial development for contribution in the economy; and v) To enhance capacity in the areas of agro-forestry for capacity building, study and research. There are some studies which indicate possible agency and methods to develop agro-forestry with reduced work burdens.

From field observation and farmer's experiences, it is found that there are many types of technology for reducing the world load for women; such technology include the on-farm green manuring, growing a green manure crop together with the main crop, incorporating the former at an early stage of the main crops, use of effective micro-organisms to shorten the composting period, vermi-compost, composting on planting pits, growing peas on the ridges after the rainy season potato harvest, cultivating potato under minimum tillage practice (bung system- as practiced in some eastern hills of Nepal), production of some high value perennial crops like *akabare* chilies, and kitchen gardening. Conservation agriculture (CA) and resource conserving technology (RCT) save time, inputs (fertilizers, fuel and labor) and natural resources (soil and water). Research findings showed that the RCT like minimum tillage by power till drill (PTD), direct seeded rice (DSR), zero tillage by zero till drill (ZTD) and system of rice intensification (SRI) help in reducing drudgery for women (Manandhar *et al*., 2009). Herbicides help to reduce drudgery for women in agriculture sector through saving weeding time that are mainly done by women. In cases where CA system are based on manual weeding, the labor burden of women and men can actually increase to an unsustainable level (Nyanga *et al*., 2012; Giller *et al*., 2009). Labor drudgery in manual weeding will be reduced, especially for women from application of herbicides (Nyanga *et al*., 2012).

Adoption of agro-forestry at homestead is found effective and relevant for reducing drudgery in rural areas of Nepal. A consultation meeting with Mrs. Rashmi Padit, Agriculture Officer, OXFAM reported that agro forestry promotion at homestead helps to reduce women's workload and save time to collect fodders and firewood from forest (Personal Communication, 4th October, 2016). Tamang *et al.* (2014) in their study focus that less-labor intensive agro-forestry approach can be vital for drudgery reduction of women and thereby address the prevailing injustice in the agriculture sector. Karki *et al.* (2015) in their research study compared the hill leasehold forestry and forage development project (HLFFDP) intervention on curtailing gender dimension found that the participation of women in leasehold forestry in small group helps to reduce their drudgery in the livestock farming and agricultural production as compared to the non-project intervention. This is due to the high involvement of the project women in group activities such as training, group meeting, plantation of fodder, forage cultivation, nursery management and land terracing, track construction and other activities as well as easily availability of the fodder, forage for livestock feeding and the firewood from the leasehold forestry system. Consultation with Agriculture and Forestry University (AFU)' horticulture manager revealed that plastic mulching in vegetable farming help to reduce work load for weeding and increase productivity (R. B. Neupane, Horticulture Manager, AFU, Rampur, 7th October, 2016).

Access to information, communication and technology (ICTs) and finance

Some research conducted in Asian countries indicated that adoption of mobile phone and ICTs by women help in drudgery reduction for women in agriculture sector, and improve their access to inputs, services and market linkage, and the women empowerment. For example, Sylvester (2016) reported that gender does have some effect on how the phone is used. Women use it more for coordination whereas men, on the other hand, seem to use it more for livelihood activities and for making and maintaining social connection. However, men in general have greater decision-making power in phone purchase even for their spouse. The relative difference between men's and women's access to and usage of ICT like, mobile phones is diminishing. Many studies have shown that in rural areas men are more likely to won and have access to phones than women. Other factor associated with more access to phones are greater levels of illiteracy, cultural barriers, and less available cash and access to credit (Ragasa *et al*., 2014).

A number of studies highlight the lack of access to information about technologies or the lack of required complementary knowledge and skills to use technologies as hindrances to a faster adoption of new technologies and improved management practices (Tiwari, 2010; World Bank and IFPRI, 2010). Mobile phones also offer great opportunity for women and men, especially in remote area, to be connected with information relevant for their livelihood and reduced drudgery for poor farmer and women. The Grameen Phone Project-2005 that specifically targeted women in Bangladesh is a good example of the successful use of mobile phones in agriculture extension. Women received learning the modules related to goat and sheep enterprises through their mobile phones while they tended to overcame the

barrier imposed by time constraint and save their time. Other ICT like FM, community radio, internet-based posting of questions and answer (only for commercial and well-educated farming women) including mobile phone and computers have played a key role in empowering women and strengthening women knowledge base. In the developing countries, ICTs have been increasingly used to disseminate information about technology, market, management practices, and to reduce women's drudgery and increase their decision-making power on use and control over the resources. The women in Nepalgunj mentioned that mobile phone helped to reduce transaction costs and increased profit. They no longer have to pay for transport costs to sell their produce to the local markets as their clients came directly to their homes. They were also able to establish loyalty with existing clients and increase clientele base (UN Women, 2016). In this regard, women can also make best use of mobile phone and other ICTs (FAO, 2016).

Access to credit from the financial institutions (bank, cooperatives, micro-finance institutions) and access to the extension services among women can help for reducing the women's drudgery in agriculture sector by empowering them on the use and control over resources, agribusiness promotion and marketing. For example, Khadka (2014) reported that access to credit among women from Small Farmer Cooperative Limited in Sarlahi empowers them in the level of confidence, ability to communicate, make a decision and acknowledgement by family that ultimately helps in drudgery reduction of women. Further, complement this with the access to collection centers, storage facilities, technology for processing, certification for exporting, other technology to reduce drudgery, specialization, crop and livestock insurance and use of ICTs.

Women, small-holder and excluded group's access to credit remains very limited. Although microfinance has played a vital role in strengthening women's access to credit over the years, the Nepali microfinance system has reached only 37 percent of the population, and even that in the most accessible areas. Microfinance has not helped women's access to credit from banks and financial institutions. Lack of land and other productive resources prevent women from meeting the collateral requirements for accessing larger amounts of credit. About 72 percent of small holders still rely on the informal sources of credit, which often charge the exorbitant amounts of interest. Women and excluded groups often have low mobility and, therefore, low access to information about financial services (UN Women, 2016). A case study in Baglung and Palpa districts from Community Base Maize Seed Program (CBMSP) by Sapkota, Shrestha and Joshi (2007) highlighted that women's limited control over agricultural resources is a barrier to their access to the production credit, equipment and resources. Increase the capacity of women and excluded groups to gain access to the market information (prices) and increase market intelligence (viz capacity of knowing and understanding opportunities for exchange and investments) through training, awareness, development of pro-poor ICT products helps to reduce drudgery (UN Women, 2016).

Socio-demographic and institutions factors

Many studies show that socio-demographic characteristics (such as location, age, marital status, family type, education, occupation and male out-migration) and institutional aspects (like capacity development, awareness, memberships, access to financial service) may have positive or negative effect on reducing women's drudgery in Nepal. Education of women can help reducing women's drudgery in agriculture sector through better information, communication and awareness on farm technologies whereas better occupation may also help in drudgery reduction for women in agriculture sector. However, educated and professional occupation women can have less drudgery in agriculture but increase drudgery in household chores due to socio-cultural structure (Y. Ghale, SDC, Personal Communication, 1stOctober, 2016).

Ghimire *et al.* (2015) in their study in central Nepal revealed that access to education, extension services and seeds play significant roles in adoption decisions of new improved rice varieties. Similarly, Paris and Thi Ngoc Chi (2005) in Southern Vietnam reported that progressive farmers - who have more frequently contact with extension workers, who have better-educated wives and who use low seed rates -- are more likely to adopt row seeders for rice transplantation that reduced drudgery for women.

Many studies show that out-migration of men household members and remittance received both positive and negative effect on drudgery reduction for women. Tamang *et al.* (2014) reported that feminization of agriculture has impacts on both the social and economic spheres. The study specifically focuses on the change in women's workload, the expansion of their roles, their ownership and access to productive resources, and the part they play in household decision making. The study conducted by Maharjan *et al.* (2012) in rural areas of Nepal suggest that women have broadened and deepened their involvement in rural society as a result of male out-migration, which could lead to either the empowerment or disempowerment of women. Several project reports show that the self-help groups (SHG), group membership in saving credit groups and cooperatives, women's land ownership and land right can reduce women's drudgery in agriculture sector in South Asia (Leduc 2011: project assessments findings from Nepal and India). The women, Dalit and members of other excluded groups' participation in lucrative markets has been limited due to the lack of capital, restrictions on mobility, inability to access strong commercial networks and knowledge of demand and supply, and other socio-cultural determinants. Under development in rural infrastructure is also a cause for concern – although good practices are proliferating (UN Women, 2016).

Agribusiness and commercialization in agriculture

Agribusiness development through the value chain approach and through the products to market linkage activities can help women's drudgery reduction, and empower them on decision-making. In addition, it helps women to use and to have control over the financial and other resources in the product-process function and in value-chain upgrading with improved governance. Many project studies and gender-inclusive value chain

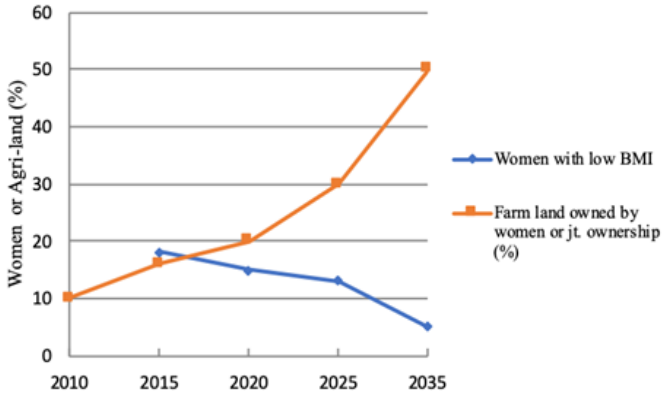

Figure 7. *Place of women in the ADS in Nepal.*

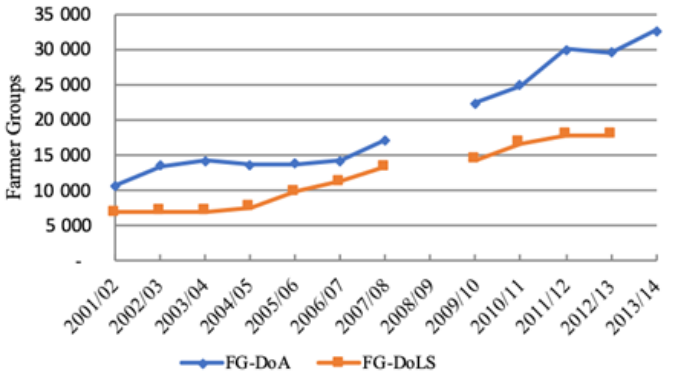

Figure 8. *Agriculture extension coverage to the farmer groups in DoA and DoLS in Nepal.*

analysis reports have highlighted the women empowerment and their drudgery reduction through the technology intervention in inputs, production, processing, and through the collective marketing approach. Here some examples include the findings from bi-lateral and multi-lateral projects value chain assessment in Nepal by Landon-Lane *et al.* (2016). Further, Gurung *et al.* (2016) in Bangladesh reported that the transformation from rice farming to commercial aquaculture not only decreased the workload of women but also, on the contrary, weakened their access to and control over agricultural products.

Engendering value chain development in agriculture and forest sectors can empower women and workload sharing between family members for value chain functions and upgrading practices that help reduced the women's drudgery (for examples, Bhattarai *et al.*, 2009; ICIMOD, 2009; Hoermann *et al.*, 2010). Women involvement in value chain development can reduce household chores. Adhikari (2006) reported that the commercialization and feminization of vegetable farming have empowered women on decision making, income sharing as well as reduced their drudgery in household chores. Insufficient business skills and lack of access to marketing also hinder the growth of women's enterprises. Lack of skills in entrepreneurship, product development, insufficient theoretical and practical training are major obstacles identified by some women entrepreneurs (Amatya Shrestha *et al.*, 2010).

Engendering in research and extensions

The issues of gender in agricultural technology research are about how to involve the women-farmer clients in setting the research agenda around three areas, namely, i) agricultural production and post-harvest processing, ii) information technology, and iii) energy. There need to be in place a National Agricultural Research System (NARS), which should have a substantial presence of the women-farmers in its governing body to define the research agenda and strategy. Such things are limited in Nepal´s NARS. Similarly, the Nepal need to have National Extension Strategy (NES) to include at least to issues, namely, the women have larger presence in the cadre of the extension staff, and the extension staff would need to function not merely as carrier of the technology-messages bust as facilitators with women-farm clients for collaborative approaches to manage the farms profitably. The NARC's Strategic Vision for Agricultural Research (2011-2030) has mentioned that the technological development and dissemination need to be sensitive to the conditions of rural women, whose contribution is often greater than that of men in the production, storage, processing and marketing of crop, livestock and fishery products, and in the collection, use, and management of natural resources. Under the new strategy, agricultural research has prioritized to ensure that the gender concerns are properly accounted, but it does not specify how to mainstream the gender roles in agriculture and reduce women's drudgery through the gender-neutral and sensitive technology development and its disseminations (NARC, 2010).

The gender sensitive research projects should contribute to reducing gender inequality by women's participation in technology and inputs development and dissemination through the research and extension bridging. One of the tools that agriculture research project can consider is the Participatory Action Selection (PAS) and Community-Based Participatory Research (CBPR). For example, Deuti maize variety released by the National Seed Board (developed from NARC) is not women-friendly and the women from mid-hill have not preferred this variety due to its deep-root system, which needs more energy for uprooting (Dr. K. K. Mishra, Chief, M & E Division, NARC, Personal Communication, 2nd October, 2016). Thus, in participatory variety trial and selection process women involvement would be needed for testing and verification of seeds and other inputs.

Maize qualities preferred by men and women are quite similar. But the women farmers need a variety with longer storage durability as they generally use their leisure period to shell the maize. It is essential to add the longer storability character of maize into the research program to emphasize in the needs of the women and their for the welfare of society and gender encouragement by growing gender-biased variety of maize; thus the scientist need to include the preferred attribute quality of maize to reduce the women's drudgery (Sapkota *et al.*, 2007). Women exclusively carry out certain maize production activities /operations. This the gender gap in agriculture research and extension is addressed. Research should focus on those women specific activities/operations in order to reduce their workload and increase their working efficiency. Therefore, women

involvement should be increased in the research programme so that the women feel more enthusiastic to participate, can gain more knowledge and skill, and feel free to cooperate ; such approaches will be accelerating factor to generate the need-based technology from the gender perspectives (Sapkota *et al*., 2007). Various findings show that the conservation agriculture, resource conserving technology and sustainable agriculture practices related research, extension and dissemination can help to reduce women's drudgery (SSMP, 2010b; Manandhar *et al*., 2009). However, very few research study and extension activities have been done at the research stations (NARC) and other government sectors in Nepal. In addition, more research and extension is necessary to engendering in agribusiness development through value chain approach, to increase competitiveness from the point of view of the women's workload reduction, and sharing of such outputs. NARC needs to have focus on participatory technologies development (PTD) and scaling-up strategy by adopting emerging model of technology develop and transfers e.g. the AKIS and NSI perspectives on GESI inclusion in the core activities.

Agriculture Development Strategy (ADS)

The ADS of Nepal is a 20-year strategy of agricultural development (2015-2035). The importance of integrating GESI provision has been recognized throughout the ADS process. GESI provisions are more explicitly integrated in the 'Governance' pillar of the ADS. But the GESI inclusion is equally importance in other three pillars pertaining the productivity, profitable commercialization and competitiveness. The ADS envisages a high progress about welfare of the women in terms of reduction in the incidences of low body mass index (BMI) from 18 percent to 5 percent during 2015-35. Part of this improvement is expected to occur through improvements in the landownership by women from 16 percent to 50 percent during 2015-2035 as indicated in Figure 7 . However, the ADS is silent on quantifying either the proportion of the women in the agricultural research or technology cadre. Similarly, the extension system is based on farmers groups, which are available for the farmer groups (FGs) under the Department of Agriculture (DoA) or the FGs under the Department of Livestock Services (DoLS) as shown in Figure 8 . However disaggregated planning by gender-specific farmers groups are lacking. Thus, at the policy, planning and program levels, there is need for gender-disaggregated data for technical modernization of agriculture.

In the ADS, it need to address the agricultural labor shortage due to migration of youths particularly men to third countries. Further, the gender equality and social inclusion (GESI) focal points at NARC and GESI-staff at the central level and at district level should promote GESI-responsiveness in program design and implementation mentioned in ADS. The findings show that ADS need to mainstream women in its all four pillars (governance, productivity, profitable commercialization, and competitiveness) to reduce their drudgery in agriculture sector; this can be done by embedding the women-friendly programs and innovations throughout the ADS process in the development programs at the district, municipal and community levels.

Conclusion

Feminization of agriculture in Nepal is evident from the out-migration of male for better job opportunities to abroad or city areas. It has increased burden for women to sustain the agriculture sector inputs the household chores. Many scholars have shown that women´s work load has been increasing as compared to men counterpart in agriculture sector. The findings from desk review of existing research studies reveals that the multidimensional factors to contribute for women's drudgery reduction in the agriculture sub-sectors in Nepal. The desk reviews show that various characteristics and variables act together to influence the drudgery reduction for women in agriculture such as: i) socio- demographic (location, age, marital status, family type, education, occupation and outmigration); ii) economic (access to road, energy, infrastructure, technologies, land ownership, other property right, access to ICT, agribusiness development through value chain approach); iii) institutional (capacity development, awareness, memberships, access to financial and service); and iv) other framework variables (like access to extension service, work load and income distribution and sharing).

Considering above aspects, the workload of women (time and energy) spent on on-farm activities can be reduced in two ways:

- Making existing tasks easier or increasing the productivity of existing labor, and
- Changing farm practices and/or introducing new technologies and practices.

It is further suggested that the Nepal Agricultural Research Council (NARC) need to have women farmers´ represented in its governing body to set agenda for women-friendly agricultural technology. Similarly, Nepal needs to have a national extension strategy (NES). The agricultural technology (research and extension) should be client based, collaborative, pluralistic, market-oriented as well public-service oriented. The agricultural technology and other support institutions are overdue for redesigning also from the point of federal governance, which has three-tiers, namely, the Central, Provincial and (rural) Municipal levels. More specifically, the programs of NARC, DoA, DOLS and cooperatives need to build up for the women coverage through: i) effective extension service based on two-way communication of the technology and farmers´ problems and approaches; ii) functional and business literacy for farmer-based knowledge, agribusiness, farming, iii) support for financial, technical, agro-processing, irrigation and water management, labor management, and tools and technology; iv) priority in exposure training for women farmers; v) access of women to land and their entry in the ward levels cooperatives and groups; vi) marketing support to women for their products through municipal level worn farmers associations, and empha-

sis on whole farm management and household technology and well-being. Such measures will also contribute to implementing different indictors of the SDG 2030 agenda (SDG 1-8 and 10: no poverty, zero hunger, good health and wellbeing, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, and reducing inequality) as well.

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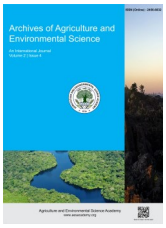

ORIGINAL RESEARCH ARTICLE

Agro-tourism: Prospects, importance, destinations and challenges in Nepal

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ABSTRACT

Nepal, being an agrarian country and having diverse geography, has tremendous potential for both agricultural and tourism development. In addition, the synergistic effect on national income would have resulted if both agriculture and tourism is practiced in an integrated approach. Keeping this point in view, a study was undertaken to realize agro-biological aspects of Tourism, prospects, importance, destinations, challenges, and suggestion for the improvement in the present chaos of agro-tourism in Nepal. Pieces of Literature were collected from different Journal articles, Government institutes and other relevant reports were studied and the major findings were summarized. Nepal has innumerous tourists destination hubs like majestic and ancient Hindu architect of Kathmandu valley, the serene and tranquil natural beauty of Pokhara, high mountainous emblazoned with snow and diverse flora and fauna; in addition, Ghandruk, Illam, National parks and conservation areas across various ecological zone, Mustang, Dolakha, Solukhumbu, traditional communities, and so on add natural beauty. Agro-tourism in Nepal is in its very beginning and there are many weaknesses, challenges, and threats that retard the successfulness of Agro-tourism which need to be solved soon as "Nepal Tourism vision-2020" is near to mouth. The contribution of the tourism part on Gross Domestic Product has remained mediocre despite regardless of prodigious potentiality. In later days, the homestay and agro-tourism activities have started in different parts of the country in pursuit of noteworthy progress in the tourism sector. After analyzing the relevance of Agro-tourism in Nepal, the possible promotional strategies have been suggested.

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INTRODUCTION

Nepal, small landlocked, autonomous, mountainous country; is located between Tibet (China) to its North, and India to its East, West, and South. Stretching approximately 193 km North-South and 885 km East-West and 1127 km far from the approach of the sea, Nepal spreads to an area of 1,47,181 sq.km(56,827 sq. miles) at a latitude between 80° 4' N latitude, 88° 12' E longitude. Its altitude varies from 70 meters in the Terai to the highest point in Earth, the summit of Mt. Everest at 8848 meters, all inside a distance of about 160 km, resulting in climatic conditions varying from sub-tropical to arctic. Agro-tourism, is, literally defined as the Tourism activities exercised by farmers through the utilization of their own farm in consonance with the rationale of "connection," "complementarity" and "non-prevalence (Sonnino, 2004). It is the amalgamation of tourism and agriculture. Agro-tourism is constantly hybridizing and evolving which promotes excitement, discovery, and anticipation (Ogidi and Odiba, 2014). Agro-tourism is defined as any custom developed on a working farm with the objective of attracting tourists (Barbieri and Mshenga, 2008). It is one of the most extensive and influential forms of tourism in Austria (Sharpley and Vass, 2006), Germany (Oppermann, 1995), Norway (Haugen and Vik, 2008), Greece, Poland, and China (Upadhyaya, 2006) and other parts of Europe and America. The main objective of the study is to figure out the possible achievable benefits from the agro-tourism as well as the strategies to promote the agro-tourism sector. Due to the generation of low

revenue from farming activities, it has led farmers to diversify from the agricultural base (Fleischer and Pizam, 1997; and Rickard, 1983). The journey towards a sustainable development paradigm arises from the local actors, especially the farmers, who are looking for "new ways" of doing business, analyzing the viability of alternative economic schemes (McGehee and Kyungmi, 2004). However, the standard of tourism inclusive with agro-tourism is moving forward in an inclining graph. Encouraged and motivated by the 2018 tourist arrivals, Tourism in Nepal commenced its 2019 journey on a positive note (Figure 1). Right from the very first month of the year 2019, the country has already started acquiring the interesting no. of Tourists from all around the world. Tourist's arrival increased by 8% to 975,557 visitors between January-October, 2019, compared to the same duration of time last year (Sansar, 2019). The maximum number of tourists arrived from India 169,952 followed by China (134281), US (77798), Sri-Lanka (57240), and UK (50393) (Sansar, 2019). However, lots of barriers and challenges are seen in agro-tourism development through the study report for which the possible promotional strategies are to be discussed and implemented strictly.

Relevance of agro-tourism in context of Nepal

Nepal is a developing agrarian country, having high than 66% of people directly engaged in farming, employing two-thirds of the country's labor force and contributing nearly 28% of the Total Gross Domestic. One-third of the Gross Domestic Product is contributed by agriculture and due to diversified agro-climate prevailed in the country there are plentiful opportunities in Agriculture (Paudel, 2016). Agriculture is the main element of the Nepal economy. The sustainable use of the potentials of tourism handicrafts, high value low-volume agricultural products, non-timber forests, and human products determines the socio-economic development of Nepal (MA and Pandey, 2011). Nepal is richly endowed with agro-biodiversity. Agro-tourism in Nepal emphasized on local foods, small rural businesses, Homestays, handicrafts, and low impact transportation (Park and Yoon, 2011). Nepal boasts immaculate natural beauty, sky-high Himalayas Range and boundless culture and traditions spread out all over the country. In Nepal, the agriculture sector encompasses forestry, fishery, hunting, and farming and, the Nepali industrial activity also chiefly the processing of agricultural products, including pulses, jute, sugarcane, tobacco, and grain. Looking at it the other way, Tourism is the largest industry in Nepal and is the largest source of foreign exchange and revenue (Figure 2). As reported by lonely planet, Kathmandu has made entry as the 5th top travel destination while tripadvisor.com has ranked Kathmandu at 19th out of 25 best tourist destinations in the world for the year 2019. These facts affirm that there are many places like Kathmandu that could fascinate tourists from all around the world. The year 2020 is declared to be celebrated as "Tourism Year for Nepal". Therefore, the development of agriculture and Tourism is a key factor for the national economy and, agriculture is the backbone of the country's rural and national economy. That is why agro-tourism is one of the most attractive and fashionable ways of doing Tourism in Nepal. In this context, a study was embarked/ undertaken to figure out the status, prospects, challenges, and destination of agro-tourism, solely for creating awareness among tourists all around the globe. Agro-tourism can take three forms: can be developed as alternate industry to agriculture which has failed to evolve despite constant focus or can be developed to preserve the viability and durability of rural localities, and can be developed as an activity to rejuvenate non-profitable agricultural activity.

Why agro-tourism?

Country farmers are working hard to meet their demands and fulfill their desires. Even if they work hard they are not pleased with their income. They can almost not meet their household expenses and other expenses. They cannot afford a good quality of life for them and their families. Because of the low income from their occupation, they have a poor financial condition. Every year, due to poverty, the suicide rate of farmers is tremendously increasing in South-Asian countries including Nepal. Thus, Agricultural development in Nepal is crucial to provide daily needs to those hard-working farmers, slow down imports, increase trading, solve the unemployment and provide raw materials to industries that can be mutually and thoroughly achieved with Tourism as Agro-tourism. It can be used to persuade and inspire farming communities to raise their crops in an eco-friendly demeanor and to conserve the biodiversity of farms (Dangol and Ranabhat, 2007). It allows tourists to come in close contact with the dwellers of small, rural villages and to be engaged in traditional ways of agriculture still prevailing in this age. Tourists can get a chance to know about different indigenous agricultural practices, such as how crops are harvested, marked and conserved, how vegetables can be raised organically, how freshly picked fruits are converted into delicious marmalade, and so on (Pandey and Pandey, 2011). Nepal is endowed with the agro-biodiversity and embellished with the geographical tranquil sight and landscape. Being an agriculture country, there is an unlimited scope of the agro-tourism. With the development in the realm of the technological sector and city orientation settlement of the people, many children as well people are not well familiar with the agricultural practices and management. Still, many people from the world are not known about the plantation of rice. The technique of plantation varies with the region to region. The hard-working farmer converts the field into an opera house theater where they sing the local songs (asare geet) and exchange their days going on for avoiding the sense of hardworking. Exchanging of the feeling of life and the mutual understanding in the course of working along with other time could be the way for fascinating the tourists easily. Rice, maize, and wheat are the main crops in Nepal. Terai is regarded as the storehouse of Nepal which has the eye-catching potential for the tourists. Buckwheat, millet, barley are the major crops in the high hills. Citrus along with the important cash crops like ginger, coffee, cardamom, tea, etc. The practice of on season and off-season vegetables is all over the nation which could be the milestone for the improvement of agro-tourism. Similarly, many

pocket areas are flourished throughout the nation like a mushroom for Chitwan, off-season vegetables for Dhading, tea for Illam, etc. are the benchmark for the scope of expansion of agro-tourism through which tourists can get the field trial and production which furnishes their boundary of knowledge. Agro-Tourism is an intricate network, an opportunity maybe today to this contemporary society to assure both farmer's assets and national Gross Domestic Product. It provides additional income source and employment opportunities to the traditional farmer which is a better alternative way than migrating to the Gulf countries in search of employment. The fashion of welcoming to tourists, the hospitality of villagers, sharing and helping custom, working with tourists are the basic features of a rural society which develop keenness for visiting Nepal repeatedly and this helps for the flourishing of agro-tourism. Homestay in the village can be run satisfactorily in which the whole member of the society accommodate to entertain the tourist. It provides appropriate paths to protect natural habitats, natural resources, special places, and naturally beautiful scenic areas (Singh and Mishra, 2016). One of the prime rationales of agro-tourism is to create the opportunity to contribute to one's community, develop the hospitality tradition of the people, build-up morals and cultural discipline and combine agriculture with recreation (Getz and Carlsen, 2000; Maude and van Rest, 1985; Putzel, 1984; Weaver and Fennell, 1997).

Destinations of agro-tourism

National parks and conservation areas as a prime destination of agro- ecotourism in Nepal

Within the small area of the country territory, Government of Nepal has established 12 National Parks, 20 protected areas, 3 Wildlife reserves, 6 Conservation areas, 1 hunting reserve, and 9 Ramsar sites. Sagarmatha National Park and Chitwan National Park (oldest of Nepal) were enlisted in the world heritage site by UNESCO in 1979 A.D. and 1984 A.D. respectively. Chitwan National Park is recognized as the best conservation area in all of Asia with a fascinating range of wildlife roaming free in its jungles and grasslands. Sagarmatha National Park, is situated at high altitude, possesses much alpine agricultural vegetation; *Cordyceps sinensis* is the most important one of the types. Chitwan National Park, Bardiya National Park, Parsa Wildlife Reserve, and Shuklaphanta National Park are home to incredible varieties of flowering plants, wildflower varieties, shrubs, alluring vegetation, great-looking trees, and additionally vines, air plants and creepers and so on. These protected areas are very crucial for conservation efforts in Nepal, as 80 of the 118 ecosystems identified in Nepal are included within them. These areas cover a wide range of forest zone inside where different types of trees grow. Every year, millions of tourists visit these areas just to enjoy the nature of such agro-biodiversity. The area is also high potential for producing crops and vegetables. The elementary direct target beneficiaries are the poor farmers, unemployed youths and women mainly engaged in small scale agriculture activities. Moreover, it brings tourists more close to nature and rural activities in which they can participate, be entertained and feel pleasure via exploration.

High altitudinal destinations

The myriad of Floras found in Nepal offers to explore our national flower *Rhododendron arboreum* that has 32 species at about 1200 m to 3500 m altitude. It has a white, pink, red, and mixed color. There are altogether 319 species of the orchid flowers. Caterpillar fungus is called Yarsha gumba in the Nepali language that is found above 4000 meters. *Stellaria decumbent* is the very important flower found only in Nepal which grows at the highest altitude in the world. There are unique species of mushroom named *Traphina nepalensis* which is found only in Nepal. Livestock farming also enhances Agro-tourism. Over 6500 species of flowering plants, 1500 fungi species, over 350 lichen species are found in Nepal. Particularly, in the Himalayan region there are different animals like Yak, Donkey, Mule, Sheep, chauries (yak-cattle crosses), Himalayan goat, Horse, etc. through which the tourists who are not familiar with such animals or those who have not ever seen them get the opportunity to collect the lifetime experience and knowledge about animals. Jumli Marsi Rice is one of the healthiest and tastiest rice of Nepal that is farmed at chill fresh weather and highest altitude of the world which can foster agro-tourism in rural hilly areas.

Traditional agro-tourism community

No doubt to say, Nepal's agricultural product is one of the best qualities in the world. Many tourists intended food brands are made accessible concerning the interest of tourists. Rural economies have been profoundly changed with time due to universal restructuring, change in consumer needs, including free trade and enhanced production (Mascarenhas, 2001). Considerable productions of traditional products are produced within the community by locally accepted technology. These include Chhurpi or Durkha production from traditional cheese of domestic yak and cattle in the Himalayan region. Dheedo with Gundrook is one of the most splendid and noteworthy Nepali identity foods for tourists. Vegetable form of Spinach, Aaloo Tama is legitimately alluring the tourists towards the rural community. Most importantly, Nepalese wine like Dadaghare, Hinwa, Grapple, Divine and many others are globally renowned that are prepared from the agricultural products like Rice barn, Wheat, Millet. Chauri's milk and meat are also equally amiable and favored. The community offers special Nepali food "daal bhat tarkari" with local ingredients. A rural community is attributed by diversified autonomous entities (organization and people) that dwell in rural community i.e. of cultural, physical, social and technical backwardness and through agro-tourism, these areas can be developed properly (Ilbery *et al.*, 2004).

Agricultural fair and exhibition

Different agro-organizations have been organizing a lot of promotional activities such as training, workshop publication,

trade and exhibitions, among these activities The Floriculture trade fair is the most important one. Agro-trade fairs are recognized all over the world as one of the most effective tools of marketing for floriculture, olericulture and pomiculture business. The expo manifests the contemporary developments in farming sectors of the Nepalese economy. While on the consumer sector it serves to instigate new brands and put on display a wide collection of agro-products, its business section attracts a large number of visitors from all Nepal and abroad. Animals are also kept there along with their products. Some eye-catching and heart-touching traditional rural agro-architect may be of something very new scene for tourists that encourage them to buy these products, learning the way to make them, and their traditional importance. Exhibition directly benefits the farmers, exhibitors, and the visitors as well as tourists and ultimately the entire nation through economy elevation. The agro-exhibition is a remarkable terrace for interaction, power of live communication and marketing to showcase vision, exchange and trade for all the stakeholders, and demonstrate products. International Fair of Economy, Agriculture, Food and Tourism performed Nepal poultry expo, Fair of Apple, Fair of wine, Fair of livestock animals, seeds, agro-machineries, exportable decorative flowers, Tea, Cardamom, medicinal plants and so on.

Others

Traditional Plantations , Green healthy gardens, Farm museums, Rural village rum shops, Herb/Exotic plots, created and Craft Markets, Agricultural fairs, indigenous festivals, Memorable events, Agricultural tours, Village bed and breakfast, Spas, Alternative medicines, Farm-processing, Farm-trade with Tourism Operators are the most notable agro site and destination for international tourists (Waithe, 2006).

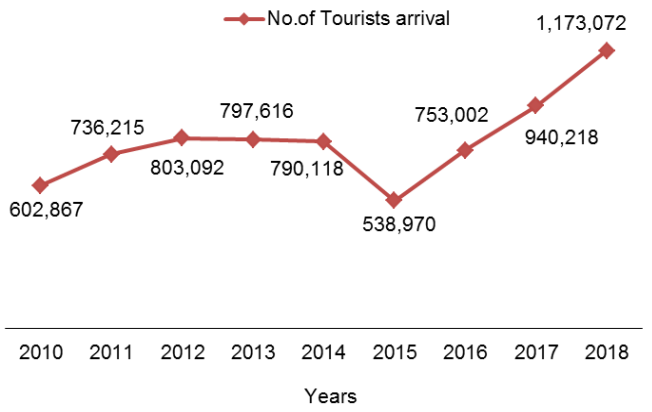

Figure 1. *Trend of tourist arrival in Nepal (Source: Nepal Tourism Board, 2019).*

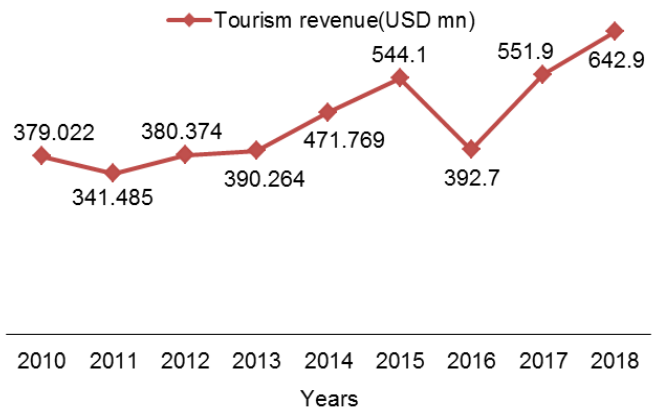

Figure 2. *Revenue from tourism in Nepal (Source: Nepal Tourism Board, 2019).*

Elements of Agro-tourism development

Primary criteria for defining agro-tourism destination are local attraction, homogeneity or heterogeneity, the cardinal of visitors and the status of development of tourist destinations. In the field of Hospitality and Tourism Research, many studies have been performed to analyze the level of tourist satisfaction. For e.g. Bowen and Clarke, 2002: Ryan and Cessford, 2003; and Yuksel and Yuksel, 2001a,b have done research on tourist satisfaction. Tourism is realized in a particular environment so the environment and its quality can favor or disadvantage tourism activities. Elementary variables and component of the attractiveness of any destination and the main elements of the tourist product and its further development as an agritourist destination are: elements of accommodation; attractiveness of tourist destination; environmental elements; socio-cultural; elements of the offer; infrastructure facilities; political stability; the local involvement in tourism; elements of promotion; marketing; information system. It has three elements: Accommodation, Food, and Entertainment (Table 1).

Importance of agro-tourism for rural settlements in Nepal

Agro-tourism is one of the most crucial parameters to improve the nation's economy of a country like Nepal where major occupation is Farming and having lots of potential tourist destination hubs. Rural areas where agro-tourism will be exercised will become the places where all elements of local sustainable development will be collected. Agro-tourism authorizes new businesses and jobs on the local level. It can also act on the policymaking system of the locality; forcing it indirectly to find sources of financing for achieving objectives. It also expands the farmer's income. Civilization, education and cultural factors get promotion positively. It depicts the identity of popular rural localities. Agro-tourism can be a good way of diversifying rural economies in rural areas and can provide alternative incomes for the farmers of those areas. There will appear the concern in remodeling the infrastructure, of creating a spiritual life of rural localities, strategic objectives may be achieved regarding the human factor; technical endowments, and heritage conservation. It also establishes social and economic connections between urban and rural inhabitants. It changed the thoughts of the people and increases the reputability of agricultural activity from the urban peoples' perspective. It works to enhance the ability to bring the main primary industry (agriculture) and the major service sector (tourism) together, by creating a win-win situation for both parts. Tourism is a tool of economic development that improves investment opportunities, tax revenues, cultural and natural attractions, accommodation services and outdoor recreation opportunities (Andereck *et al.*, 2005; Kiriakidou and Gore, 2005; Kandampully, 2000).

Balancing must be established between three pillars of Agro-tourism development: Agro-economic, Environmental, and Socio-cultural aspects in order to achieve long-term sustainability (Latip *et al*., 2015). Tourism contributes to national profitability, employment generation, and economic diversification (Ismail and Turner, 2008). Sustainable agro-tourism fosters the social and economic activities in rural area without altering social and artistic heritage and natural environment (Ammirato and Felicetti, 2014. Tourists can involve in various agro-tourism activities at the farm at the same time and will get a better opportunity to enjoy Nepal in a different way. Agro-tourism does the work of branding local agro-architectural products bringing progress in entrepreneurship in rural areas, generating employment opportunities capitalizing the youth for the development of the nation (Bhusal *et al*., 2018).

Homestay agro-tourism

So far, homestay tourism has been exercised in Nepal from prehistoric age, as tourists are respected as Atithi Devo Bhava (Guests are God), in the Nepali society. Due to innumerable ethnic community with a mosaic of cultures, ascribed to diverse social practices, has a huge possibility for the enthusiasts to enjoy homestay tourism in Nepal. Ghandruk is one of the most important places for homestay. Sirubari, Similarly, another homestay tourism destination is "Sirubari"(Syangja) for importing most of the consumable goods for tourists. Mustang has become one of the best homestay destinations of Nepal due to the availability of local homemade products and has been alluring many tourists since a few years. Others are Besi Sahar, Mustang, Illam, Pokhara, Chobhar hill, Parbat, Chitlang, Diktel, Namche bazar, Jiri, Kalinchowk and so on. The economic, environmental, and socio-cultural nature of farmer's community is affected by the tourism activities that are highlighted by the studies conducted by Ogorelc (2009), Vargas-Sánchez *et al*. (2009), Diedrich and Garcia-Buades (2009), Kayat, (2002), Andereck and Vogt (2000) and Long *et al*. (1990). Nepali villages are admirable; they are there for, to be exploited; nevertheless, we are not realizing the profit of our unrecognized, unexplored pristine villages of rural Nepal. Therefore, the Government of Nepal should begin promoting homestay tourism in Nepal. Every tourist enjoys the hospitality environment of the family such as dal, bhat, roti, fish, meat, milk, homemade yogurt and alcohol produced from millet.

SWOT (Strength, Weakness, Opportunities, Threat) analysis of agro-tourism in Nepal

The SWOT analysis helps to identify lists of important factors regarding agro-Tourism development. Towards the strength, many farmers have owned their own farm/land and other requirements of farming. These farms possess area specific crops, livestock species and tress contributing a unique agricultural landscape for the area. Beautiful natural landscapes consisted of forests, mountains, and grasslands that provide immense value for the environment. Farming activities are well performed by knowledgeable and experienced farmers in these areas. These young enthusiastic and diligent farmers can work hard throughout the year without any complication as there is no seasonal difference in the country. The availability of sufficient family labor at a significant level is also a positive plus point for agro-Tourism. Farmers practice both traditional farming activities together with modern farming techniques. Currently, there is a drift towards organic farming. Besides, these areas are prosperous in traditional (cultural) such as cane weaving, pottery making art, and craft industry.

There are still many weaknesses too. In spite of having basic knowledge about agriculture, the farmers have low awareness of the profit of agro-tourism and related aspects. To begin an agro-tourism, it needs at least three acres of land including primary agricultural activity with some livestock and accommodation facilities for 6-8 visitors but most of the farm in Nepal is small in size, Farmers have a weak level of leadership, entrepreneurship, and management and decision-making skills that are crucial in agribusiness activities. There lacks the concern for agro-tourism products and their quality standards. The standard of infrastructure facilities such as transportation, water, and power supply are not just enough for the determination of tourism destinations. It can lead to negative impacts on farmer's quality of life by changing the host's lifestyle (Tosun, 2002; Brunt and Courtney, 1999; McCool and Martin, 1994). The investment problem is also of a great deal and they have low accessibility of external resources required for the arrangement of facilities. Likewise, there is still a lack of relevant rural policies and regulations for the development of agro-tourism.

Table 1. Elements offered to tourist (Source: Ammirato and Felicetti, 2014).

S.N.	Elements offered to tourists
1.	Overnight accommodation
2.	Academic farm (e.g. milking cows, sheepdog display, cattle drives, feeding or petting animals)
3.	Dancing in agricultural occasion like planting of Rice.
4.	Active involvement in the life of the farm ('pick-your-own' facilities, participation in farm tasks)
5.	Tasting of self-made food
6.	Selling of self-made food
7.	Tasting of goods of other local farms
8.	Selling of goods of other local farms
9.	Horse riding
10.	Meal provision

There are some opportunities the farmers have with which agro-tourism can be flourished successfully. Numerous tourist destination places make easy to attract visitors. They are rich with agricultural, natural, cultural and religious attractions. Furthermore, bilateral co-operation among farmers and other organizations in these areas reveals the social capital that can be used for the development of the agro-tourism industry. Because of the presence of innumerable tourist destinations in these areas (ecotourism, culture tourism, adventure tourism, health tourism), mutual benefits can be obtained by having close relationships with them. Through horizontal linkages with other tourism-based activities, agro-tourism can generate new sources of income (Veeck *et al*., 2006). Since unemployment of the youth of these areas is high, these unemployed people can be employed. Both unemployment problem, as well as rural-urban migration can be somehow mitigated by agro-tourism. Also, many threats appear in the agro-tourism industry, the agricultural farm is all covered by the non-degradable wastes. So a need to apply appropriate waste management procedures for maintaining clean surroundings is essential. On this subject, the 3R technique (Reduce, reuse and recycle) of waste and production of compost from the decaying waste are essential. Urbanization, Industrialization, and Modernization in the cultivable area are of great concern to be checked immediately.

Promotional strategies for the development of agro-tourism in Nepal

There is the proverb "where there is greenery there is peace and happiness". Concerning to this Nepal, being rich in the agro-diversity is a suitable nation for tourism development throughout the world. So, respecting the potential of agro-tourism in the sustainable promotion of ecology and the economy of the nation, there is immediate need of maintaining sustainable policy and long term vision along with the productive action which conclusively assists to raise our nation's name and fame in the world. In Nepal, Agro-tourism can be a new way to improve income by utilizing traditional knowledge, preserving biodiversity, maintaining a rural and agricultural way of life to motivate and encourage farming communities and enthusiastic youths to raise the crops in an eco-friendly manner (Maharjan and Dangol, 2018).

The rural tourism of Nepal is in its very beginning. However, there is not sufficient budget passed in the parliament in the name of agro-tourism development. Nepal depicts enormous untapped potential; potential centers of rural tourism are many villages, especially in the broad environment of major cities. The critical mass of resources and attractions can be achieved by a group of small scale operators for effective promotion to provide geographic identity and to target markets (Weaver *et al*., 1996). For every stakeholder, tourism is a socio-cultural event (Murphy, 1985). Tourism development can change the structure of the society in positive (Lankford, 1994) and negative too (Ap and Crompton, 1993). So, the impacts of tourism on society should be considered so that the benefits can be optimized (Brunt and Courtney, 1999). That is why the effective plans and policies for agro-tourism development are very important. Following are the strategies implemented and to be implemented:

Strategies no. 1 (Nepal Tourism vision-2020

The Ministry of Tourism and Civil Aviation in the conference with its industry partner has produced Nepal Tourism Vision-2020 to guide tourism development throughout the nation. The vision complements the national effort of economic reform and integrates the soul of inclusiveness for a broad-based enabling environmental that sets the pace of gradual but focused change in the Tourism sector. The program will have ample space for agricultural market and agro-tourism.

Strategies no. 2 (Bettering livelihood and spreading benefits of tourism)

- Increased spending of Government in the Tourism sector to create infrastructures.
- Attract investment from private companies in generating tourism facilities. e.g, Hotel, Cable cars, Theme parks, etc.
- Identify and modify tourist places as tourism satellite sites around each hub.
- Conduct awareness campaigns that one may maintain and protect intellectual creations by deprecated groups and women.

Strategies no. 3 (Expanded product offering)

- Make better linkages of agro-tourism with other branches of the economy.
- Minimize the negative environmental impacts and maximize local ownership, community initiatives, employment opportunities, self-reliance, and economic benefits by applying sustainable development principles in Tourism.

Strategies no. 4 (Destination marketing)

- Established Tourism brand and other sub-brands of the country will be promoted as destination marketing.
- Internet marketing will be used to promote Nepal in the global source market.
- The capacity of Nepal Tourism Board will be strengthened as a National tourist organization.

Strategies no. 5 (Aviation)

- Tribhuvan International Airport (TIA), which has already reached a saturation point, is the only international airport in the country. It is difficult for tourism development, if not possible, to house more airlines. So, it will be re-constructed with a full plan.
- Transform seasonal airports into year-round operational airports.
- Airports in the hilly and mountain region will be upgraded.
- More regional air service agreements to enhance air connectivity within the region.

- Fully fledged other international airports will be constructed to accommodate the amplified demand for air travel and to enhance their connectivity.

Strategies no. 6 (Attract new investment)

- International and native investors investing in rural and remote areas shall be provided with incentives.
- Encourage investment with the enactment of operational friendly laws and policies for the tourism sector.

Immediate and long term action

Immediate actions

- Nepal Tourism year-2020 shall be celebrated with the active participation of people, public and private sector.
- Tourism awareness campaign shall be arranged all over the country.
- The agricultural products will be positioned in the conventional and emerging markets. Appropriate market segmentation will be emphasized.
- Request international airlines to enhance air connectivity to operate flights to Nepal.
- Attracting investment to create tourism attractions and facilities.
- Assist the local bodies in preparing tourism management plan and in integrating it with other development plans.
- Linkages will be built up between tourism and agro-based as well as cottage industries.
- Ample focus on the security issues.
- Homestay marketing to be adopted as a key agenda by the local Chamber of Commerce.

Long term actions

- To improve cross-border agro-tourism activities like celebration of field transplanting of rice as muddy festivals based on mutual benefits, coordination will be maintained with neighboring nations.
- Development and betterment of home-stay and community -based tourism products.
- Development of Tourism Master plans, Integrated Tourism management plans of all five development regions and corresponding long term tourism strategic plan.
- Management of investment friendly policies.
- Initiate to mitigate the negative consequences of climate change.

Conclusion

Nepal has a lot to offer to experience seekers of the world who look for adrenaline thrust through agricultural tourism. However, the country is yet to realize the potential in this regard. Though there is a great potential of agro-tourism, Nepal has faced lots of ups and down. Tourists always have inner keen to involve in different agricultural activities directly or indirectly. Nepal, being an agricultural country and tourism as one of the major economic sectors, agro-tourism can be one of the new emerging tourism industries. It gives farmers considerable revenues being an alternative way of selling farmer's products and services. Hence, there is an utmost need to work for uplifting the Agro-tourism industry from governmental, non-governmental, private and community sectors. Nepal has passed through a decade long civil war between the Maoist rioter group and the nation. Naturally, the country's economy has suffered even more because of the political turmoil. Tourism is the primary source of revenue for this small country sandwiched between the big China and India. However, the prevailing tourism does not seem to be progressing which demands other alternatives. One of the best potential alternatives could be agro-tourism development. Thus, Agro-tourism can surely do a lot of help for Nepal to improve people's social as well as economic status.

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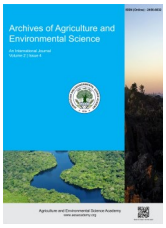

ORIGINAL RESEARCH ARTICLE

Price behavior, marketing and consumption pattern of tomato in selected region of western Nepal

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ABSTRACT

Tomato is an important marketable vegetable commodity of Nepal; but, due to involvement of middlemen farmers are receiving low price margin, meanwhile, consumer are compelled to pay higher. Keeping these points in view, an attempt has been made to study price behavior, marketing and consumption pattern of tomato in Western Nepal. Pre-tested semi-structured questionnaire was administered among randomly selected 90 tomato producers and 10 retailers during march-April 2018. Reports from ministry of agricultural development and journal articles were sources of secondary data. The empirical evidences revealed that, farm gate price, retailers' price, and price spread was higher for off-seasonal tomato production while producers share was higher for seasonal production; in addition, price of tomato, for both seasons, was increasing. Market analysis depicted, producer-wholesaler-retailer-consumer was the major market channel involved. Low market price, dominancy of wholesaler in price determination, storage problems (mainly in off-season), and malpractices during post-harvest handling were the major problems of marketing. Overall, our study point out that, addressing the mentioned problems, accessing new markets, checking unscrupulous middlemen, and value addition are crucial for sustainable market development.

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INTRODUCTION

Tomato (*Solanum lycopersicum*) belongs to night shade family; with edible soft red fruit, often known as berry, served as salads and part of the main dish-vegetable. Consumer's increasing desire for high quality and nutritional foods has created a need for longer market demand of vegetables for both domestic as well as foreign markets; similar is the scenario for tomato in western Nepal. Market is the area or place where movement of goods take place resulting in exchange of the title of goods (Backman and Davidson, 1962); similarly, Kotler and Armstrong, (1991) stated marketing as the social and managerial process of creating, attaining and exchanging products of value to others, such that the individuals involved get what they want or need. The marketing of vegetable crop is a complex activity and special management or intervention is needed (Sharma, 2009); it begins at farm as farmer expects to meet demands of the market (Awasthi, 2007). Marketing system are the overall activities through which commodity undergoes, before reaching to the next level in the marketing channel (Acharya and Agarwal, 1999); it involves wide range of activities for delivering goods from one hand to another. The vegetable marketing system of Nepal is still in the developing stage which is characterized by unequal distribution of opportunities between producers and traders (Adhikari, 2002). Efficient marketing system minimizes the costs and provides benefit to all sections of the society (Acharya and Agarwal, 1999); but, due to unfair trading, producers are compelled to receive unfair price while consumer are forced to pay higher. The high markeing cost of vegetables is partly due to higher post harvest loss (Poudel, 2013); in addition, scarcity of produce duing off-season is the another cause of price flucation. This is especially true for tomatoes,

which ranks number one among vegetables contributing vitamins and minerals (Chapagain, 2010) to Nepalese. Changing consumption pattern and escalating market demand every year has resulted in the cultivation of tomato in new location (PACT, 2014), but still larger profit was shared by middlemen. When price of tomato fetches NRs 5/kg during major harvesting time, it goes as high as NRs 75/kg during off-season. The buyers fix price with respect to the market demand and export/import opportunities (Bhandari *et al.*, 2016). Thus, a dynamic and vibrant marketing system without least involvement of unscrupulous middlemen, but with decent supply chain infrastructure has been felt necessary to keep balance with ballooning market demand and changing agricultural production. To achieve such a magnificent goal, agriculture produce must be regulated to protect farmers and consumers from exploitation by enacting policies; for this, in depth study of price behavior, marketing, and consumption pattern is felt necessary. Keeping these points in view, a study was undertaken to determine price behavior, marketing and pattern of tomato consumption in selected part of Western Nepal.

MATERIALS AND METHODS

The study was conducted in Salyan district, a typical mid-hill of Karnali province. Subtropical being dominant, climate here ranges from tropical to sub-temperate. Average annual maximum and minimum temperature were recorded as 31°C and 3°C respectively. The area was purposefully selected as there were identifiable numbers of farmers involved in production and marketing tomato since last five years. Pre-tested semi-structure questionnaire was administered among randomly selected 90 producers and 10 traders involved in tomato enterprise since last five years. Primary data was obtained by using simple random sampling without replacement technique; however, Ministry of agricultural development, journal, kalamiti vegetable market were the sources of secondary data. Face to face interview was scheduled to obtain data during March-April, 2018. One Focus group discussion and two Key Informant Interviews were conducted to validate the data obtained from survey. The data collected from the study were coded, tabulated, and analyzed by using Microsoft excel and SPSS. Price behavior and marketing of tomato in the study area was carried out by using descriptive statistics (like mean, standard deviation), Inferential statistics (like chi-square test, t-test) and Analytical statistics (trend analysis), with the help of different statistical software like Microsoft Excel, SPSS and STATA.

Analysis of price spread and producer's share

Price spread is the difference between the retailers' price and farm gate price, which was calculated by the formula:

Price Spread = Retailers' price – Farm gate price

Similarly, producer's share is the price received by the farmer expressed as percentage of the retail price (Ahmad *et al.*, 2017). An increase in the producer's share is the indicator of increase in the efficiency of marketing system in the favor of producers/ farmers and vice-versa; a decrease in the producers share indicates that the middlemen are controlling market. Producers share was calculated by the following formula:

Producer's Share (PS) = {Farm gate price/Retailers' price} X100

Trend analysis

Trend analysis is a technique used for extracting and underlying pattern of behavior in time series. Trend analysis is based on the idea that what has happened in the past, gives traders an idea of what will happen in the future. Trend analysis involved the collection of information of the last three years data on farm gate price and retailers' price, and plotting the information on a horizontal line. The intent of this analysis is to spot actionable patterns in the price trend as well as price spread trend. The linear trend model is:

$$Y_t = \beta 0 + \beta 1\ t + et$$

Where,

β0 = Constant

β1 = Average change from one period to the next

t = value of the time unit

et = the error term

Indexing of marketing problem

Scaling technique provides the intensity of respondents towards the propositions. Farmers' and traders perception towards the marketing problems was presented in the five point scale comprising most severe, severe, moderate, mild and most mild. The scale values of 1, 0.8, 0.6, 0.4 and 0.2 was used to most severe, severe, moderate, mild and most mild problem, respectively. It was computed using the following formula:
Mathematically,

$$I_{imp} = \sum = (Sifi/N)$$

Where,

I_{imp} = Index of importance

Si = Scale value

fi = Frequency of respondents

N= Total number of respondents

RESULTS AND DISCUSSION

Demand, supply and consumption trend of tomato

The national demand or daily consumption of tomato has increased from 881.5 mt in 2012 to 932.6 mt in 2016, indicated tomato is highly demanded vegetable crop in Nepal (Bhandari *et al.*, 2016). But, Far western region required 73.5 mt in 2012, the lowest compared to other regions, while it has reached to 74.7 mt per day in 2016; the region has lowest consumption of tomato (9.87 Kg/year /person) in comparison to other four development region—around 12 Kg. Consumers from Mountainous belt consumed low amount of tomato (51.2mt per day), in 2015,

Table 1. Percentage of tomato consumption by source.

Region	Home production (%)	Purchase (%)
Nepal	21.80	78.20
Eastern	270	73.00
Central	9.20	90.90
Western	20.60	79.40
Mid-western	51.00	49.00
Far-western	51.70	48.30

Source: (Ghimire *et al.*, 2017).

compared to other geographical regions. In 2016, the demand of tomato has reached to 51.6 mt in Mountainous region while it has reached to 485.3 mt per day in terai (Ghimire *et al.*, 2017). More than half (about 57 percent) of tomato production was consumed by producers themselves and remaining 43 percent enters into marketing chain (CBS, 2010). In terms of trade, the lowest volume (low demand) was recorded in September/ October while the highest volume (high demand) of tomato trade was found in May/June; this can be ascribed by the fact, Sept-Oct is the off season and May-June is the main season. In addition, tomato production is higher during main season as tomato cultivation can be done with least investment in an open field.

The results showed that consumption of tomato through purchase was highest in central development region (90.9%) followed by western, eastern, mid-western and far-western region. (Table 1). A plausible explanation to this statement is ascribed by the fact that, people of central development region have high purchasing power (Vandernoot and Hove, 2014). In addition, rapid urban growth of Kathmandu valley, a part of central Nepal, has increased consumption of tomato (Ishtiaque *et al.*, 2017). Consumer from mountain belts purchased lesser than other geographical region (Ghimire *et al.*, 2017), the reason besides higher consumption of tomato through purchasing in terai might be due to the fact that, about 50% of the population lives in Terai (CBS, 2011).

Monthly price variation

If the sector is fragmented into a large number of small-scale farmers and producers, it was found that, prices was largely controlled by wholesale traders (ILO, 2014). The price of tomato ranged from Rs 80 in Oct-Nov to Rs. 50 in March-April in Salyan (DADO, 2016); similar variation of price was found all across the country (Prasain, 2019), presented in Figure 1.

Farm gate price

Farm gate price is the price attained by producers or farmers in the marketing chain. Comparison of off-season and seasonal tomato production at the farmers' level showed that, the difference between farm gate prices was statistically highly significant at 1% level of probability. The price of off-season and seasonal tomato in the year 2072 was NRs. 35.75 and NRs. 24.27, in the year 2073 was NRs. 39.53 and NRs. 27.43, and in the year 2074 were NRs. 43.75 and NRs. 30.00, respectively (Table 2). Increasing trend of farm gate price is in accordance with (Bhandari *et al.*, 2015 and Prasain, 2019).

Price spread and producers' share of tomato

The marketing margin and producers' share of tomato in the last 3 years from 2072 to 2074 of the study area at different marketing chain revealed that, the farm gate price for the off-season produce in the year 2072, 2073 and 2074 was NRs. 35.75, NRs. 39.53 and NRs. 43.75, respectively whereas for the seasonal tomato, farm gate price was NRs. 24.27, NRs. 27.43 and NRs. 30, respectively. The farmers generally sold their produce either directly to wholesaler or retailer. The retailers' price for off-season tomato in the year 2072, 2073 and 2074 are NRs. 56.5, NRs. 63 and NRs. 67.5, respectively whereas for seasonal tomato, retailers' price was NRs. 36.5, NRs. 41 and NRs. 46.5, respectively. The producers' share in the off-season and seasonal tomato in the year 2072, 2073 and 2074 are 63.3%, 62.8%, 64.8% and 66.5%, 66.9% and 64.5%, respectively. The producers were more or less constantly getting the equal share of returns in both the seasons. According to the study, it was found that the price spread for off-season and seasonal tomato in 2072, 2073 and 2074 are NRs. 20.75, NRs. 23.47, NRs. 23.75 and NRs. 12.23, NRs. 13.57, NRs. 16.5, respectively (Table 3). The data were based on the household interview on 60 samples obtained from off-season growers, 30 from the seasonal growers and 10 were collected with the retailers' from diverse locations within the vegetable block area.

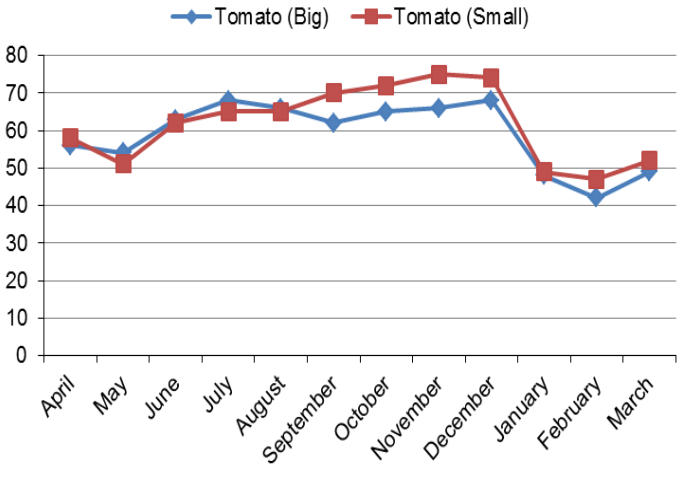

Figure 1. *Monthly national retail price of tomato (MoAD, 2015/16).*

Table 2. Farm gate price trend analysis.

Year	Price in different years (NRs.)		Overall	Mean Difference	t- value	p-value
	Off-Season Growers (n=60)	Seasonal Growers (n=30)				
2072	35.75 (6.63)	24.27 (5.44)	31.92 (8.27)	11.48***	8.203	0.001
2073	39.53 (5.59)	27.43 (6.62)	35.50 (8.24)	12.10***	9.099	0.001
2074	43.75 (5.87)	30.00 (6.70)	39.17 (8.94)	13.75***	9.994	0.001

Figures in the parenthesis indicate standard deviation. *** indicate level of significance at 1%.

Table 3. Producers' share and price spread in seasonal and off-season tomato.

	Variables	Year 2072	Year 2073	Year 2074
Off-Seasonal Tomato	Farmgate Price (NRs.)	35.75	39.53	43.75
	Retailers' Price (NRs.)	56.50	63.00	67.50
	Producers' Share (%)	63.3	62.8	64.8
	Price Spread (NRs.)	20.75	23.47	23.75
Seasonal Tomato	Farmgate Price (NRs.)	24.27	27.43	30.00
	Retailers' Price (NRs.)	36.50	41.00	46.50
	Producers' Share (%)	66.5	66.9	64.5
	Price Spread (NRs.)	12.23	13.57	16.50

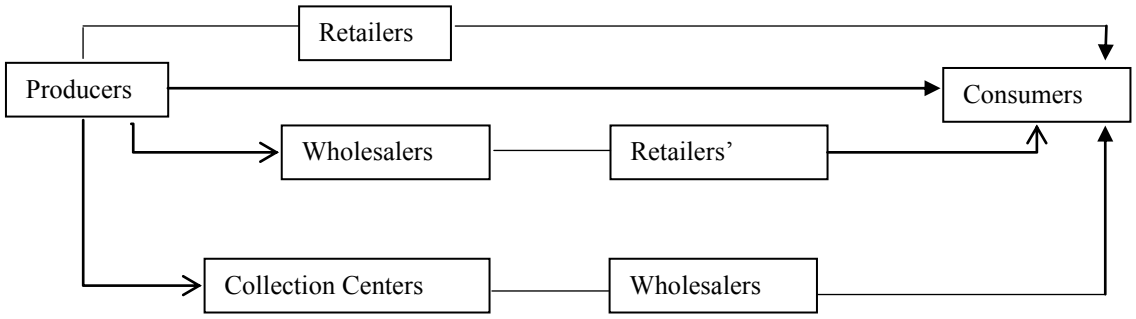

Figure 2. *Marketing channels of tomato growers in the study area.*

Table 4. Market channel and its actors.

Variable	Farmers category		Overall	Chi square	P value
	Off-Season Growers (n=60)	Seasonal Growers (n=30)			
Producer-Wholesaler-Retailer-Consumer	38 (63.3)	19 (63.3)	57 (63.3)	2.200	0.333
Producer-Retailer-Consumer	14 (23.3)	4 (13.3)	18 (20.0)		
Both	8 (13.3)	7 (23.3)	15 (16.7)		

Figures in the parenthesis indicate percentage.

Marketing channel and involved actors

The marketing channel of tomato, starting from producer to the consumer is presented in the Figure 2. Shreenagar, the biggest city of study area is near to the producers thus farmers had access to district wholesale and retail markets. Major retail spots were Dhorchaur, Barala, Shreenagar, Khalanga and Lanti where farmers sold their produce to vegetable retail shops. Sometimes, farmers sold their produce to the consumers directly from the farm, although in small bulk.

The survey in the study site showed two major types of marketing channel; but, when small bulks and frequency were considered, four types of marketing channel were identified. The farmers of the study site have majorly used Producer-Wholesaler-Retailer-Consumer channel; 38 (63.3%) of the off-seasonal and 19 (63.3%) of seasonal farmers were using this channel for marketing. Similarly, Producer-Retailer-Consumer channel was used by 14 (23.3%) of the off-seasonal and 4 (13.3%) of seasonal tomato growers of the study site; the remaining farmers rather used both the channels equally (Table 4). Similar result on marketing channel of off-season vegetables was obtained by (MoAD, 2011 and Bhandari *et al.*, 2016). The major price determining actors were wholesalers as responded by 48 (80.0%) and 24 (80.0%) for the off-season and seasonal tomato growers respectively.

Table 5. Marketing problems of tomato producers in the study area.

Problems in Marketing	Production type	Index	Rank
Low price	Off-Season	0.744	I
	Season	0.854	I
Lack of market information	Off-Season	0.614	IV
	Season	0.654	III
Wholesaler dominancy	Off-Season	0.634	III
	Season	0.754	II
Lack of storage	Off-Season	0.730	II
	Season	0.480	IV
Malpractices in market	Off-Season	0.280	V
	Season	0.260	V

Problems of marketing

The details of marketing problems faced by the tomato growers are presented in the Table 5. The result showed that low market price received by farmers was the major marketing problem realized by both the sampled off-seasonal and seasonal tomato producers, similar result was obtained by Ghimire *et al.*(2017). The second major problem was lack of storage in case of off-season growers and wholesalers' dominancy in case of seasonal growers. The storage problem observed in off-season is ascribed by the fact that climate in the rainy season do not favor the longer shelf life of tomato but in the winter season, temperature itself favors the longer post-harvest life; the findings is in accordance with Timsina and Shivakoti (2018). Wholesalers' dominancy was seen as the next major problem in off-season but lack of market information was the third major problem in the seasonal tomato production. The other problem faced by the farmers was the malpractices in the market which was low in the study site. This might be due to the fact, Nepalese farmers have paucity of knowledge in post-harvest handling of vegetables.

Conclusion

The results from the study revealed that, farm gate price, retailers' price, and price spread was higher for off-seasonal tomato production for all the three year and they were following increasing trend but producers share was higher for seasonal production; in addition, trend analysis revealed that retail price of tomato was increasing. Further, producer-wholesaler-retailer-consumer was the major market channel involved; wholesalers are the major factors that determine the price of tomato. Low market price, dominancy of wholesaler in price determination, storage problems (mainly in off-season), and malpractices during post-harvest handling were the major problems of marketing. The storage problem of tomato in off-season is ascribed by the fact, off-season tomato production was done during monsoon; higher humidity and temperature during this period shortens the storage life of perishable commodity like tomato. Overall, from our study it would be better to suggest policy makers and concerned bodies, to address the mentioned problems, access new markets, check unscrupulous middlemen, and value addition are crucial for sustainable market development. In addition, developing good cold-storage facility could solve the problem of price fluctuation.

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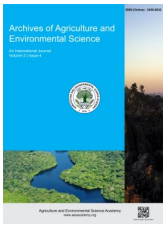

ORIGINAL RESEARCH ARTICLE

Ichthyofaunal diversity of Basurabad *Beel* in regards with threat factors and conservation measures, Bangladesh

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ABSTRACT

The present study was conducted to assess the temporal distribution of ichthyofaunal composition of Basurabad *beel* in Khulna, Bangladesh and investigated the fish biodiversity and core threats to biodiversity to provide recommendations for conservation in the *beel*. During the study period, total 33 fish species were recorded belonging to 6 orders. The order wise fish species availability was maximum in Perciformes (39.40%) and minimum in Beloniformis (3%). The value of Shannon-Weaver diversity index was found higher in Fultola (1.19±0.41) and lowest in Basurabad (0.68±0.17) while the maximum value of Margalef richness index found in Basurabad (1.12±0.35) and lowest in Debitola (0.68±0.34). The value of Pielou's evenness index was higher in Boroitola (0.61±0.20) and lowest in Basurabad (0.31±0.16) however the Pielou's index showed an uneven distribution of fish species in the Basurabad sampling point. The value of Simpson dominance index was higher in Fultola (0.58±0.10) and lowest in Kishmath-Fultola (0.39±0.16). Ten different kinds of fishing gears were identified under 5 major groups in the *beel*. Among all the gears operated, seine net (Jagat Ber Jal) had the highest catch 31.3±4.1 CC/haul/day/gear (kg) followed by current jal 10.5±2.5 CC/haul/day/gear (kg). This study suggests that comprehensive studies on fisheries biology including reproductive biology, growth, stock assessment and their association with existing laws are essential for the sustainable management and conservation of fish species in the Basurabad *beel*.

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INTRODUCTION

Aquatic biodiversity has enormous economic value and is mostly accountable for keeping and supporting overall environmental health (Hossain, 2012). The conservation of aquatic biodiversity has gained great environmental importance over recent years (Hossain *et al*., 2012) though fish biodiversity and management of associated habitats is a great challenge (Dudgeon *et al*., 2006). Biodiversity of freshwater has diminished quicker than either terrestrial or marine biodiversity over the years (Jenkins, 2003; UNESCO, 2003). However, fishes of freshwater are one of the most vulnerable groups (Darwall and Vie, 2005) because of their highly sensitivity to the qualitative and quantitative change of aquatic habits (Sarkar *et al*., 2008; Kang *et al*., 2009). The base of the management problems of freshwater fish is the fact that the freshwater fish inhabit reasonably restricted space with very condensed ability for movement (Hocutt and Wiley, 1986; Unmack, 2001). Moreover, fishes of freshwater are often

used as bio-indicators for assessment of water quality (Chovance, 2003). Decreasing in the richness of fish species from the inland waters of Bangladesh is a burning (Galib *et al*., 2013). However, Fisheries play an important role in the economy of Bangladesh in terms of nutrition, employment and income generation (Uddin *et al*, 2019). The population of numerous fish species has reduced promptly or on the verge of extinction due to over exploitation by destructive fishing gears, various ecological and environmental changes and degradation of their natural habitats (Chakraborty *et al*., 2006; Siddik *et al*., 2014, Saha *et al*, 2019). According to IUCN Bangladesh (2015), nearly one fourth of the species are under threat inclusive of 9 critically endangered, 30 endangered, 25 vulnerable and 27 species as near threatened. That is why, water body specific comprehensive biodiversity studies are prerequisite to assess the present status and for the sustainable management of any water body (Saha and Hossain, 2002; Galib *et al*., 2013; Imteazzaman and Galib, 2013).

Basurabad *beel* is one of the most important wetland (Batiaghata Upazila) in Khulna District, Bangladesh. The main river of Batiaghata is the Kajibacha River which feeds the Basurabad *beel*. The average depth of the *beel* become 5-6 ft during rainy season. The local respondents reported, diversity of fish species from Basurabad *beel* is gradually decreasing with increasing excess fishing pressure and other possible factors. Some studies have been conducted on several aspects of fish diversity, habitat, fishing gear and conservation status of available fishes in some *beels* of Bangladesh but the researchers could not find any research work related to the fish biodiversity, abundance and their status in the Basurabad *beel*. Fruitful research work is much required with updated list of fish species to take necessary management steps to conserve the fish biodiversity in this *beel* (MoL, 2017). As it is one of the important *beel* in the southwestern coastal Bangladesh therefore the authors' want to explore the fish assemblage of the *beel* focusing the present status and possible threats along with conservation measures.

MATERIALS AND METHODS

Study area

The Basurabad *beel* of Batiaghata Upazila under Khulna District, Bangladesh has purposively been selected as the study area (Figure 1). It is located in the southwestern coastal area of Bangladesh, between 22°42'45" to 22°43'46" north latitudes and between 89°29'54" to 89°31'15" east longitudes. The study area occupies an area of 2.43 sq. km. The *beel* is 2.21 km long from east to west and 1.86 long from north to south. The sampling points (Table 1 and Figure 1) were selected in such a way that they cover the entire major parts of the *beel*.

Data collection

Data were collected on spot from local fishermen on monthly basis from July, 2017 to November, 2017. The study was set up based on both primary and secondary data. Primary data were collected from fishermen through well-structured questionnaire. Besides, secondary data were collected from the Upazila Fisheries Office, relevant research articles, reports etc. Finally, each single species found in the sampling station was preserved in 10% buffered formalin solution in an earlier leveled plastic jar. After transporting to the laboratory, all collected specimens were identified to species level with the help of standard taxonomic keys of Talwar and Jhingran (1991), Nelson (1994), Rahman (2005) and Hossain *et al*. (2007). Moreover, FishBase was also used as a guide (Froese and Pauly, 2015).

Data analysis

In the present conducted study, diversity of fishes were calculated by means of Shannon-Weaver diversity index (H′) (Shannon and Weaver, 1949), species richness by Margalef index (*d*) (Margalef, 1968), evenness by Pielou's index (*J′*) (Pielou, 1966), and dominance by Simpson index according to the following equations:

Shannon-Weaver diversity index (H') = Sum [pi x log (pi)]. Where, H' = Shannon-Weaver diversity index; Pi = ni/N; ni = no. of individuals of a species; and N = Total number of individuals. Margalef species richness (d) = (S-1)/log (N). Where, S = Total species; and N = Total individuals. Pielou's evenness index (J´) =H(s)/H (max). Where, H(s) = Shannon-Weaver information function; and H (max.) = Theoretical maximum value of H(s). Simpson dominance index (C) = $\sum_{i=1}^{s}(ni/N)^2$.

Where, ni = number of individuals in 'each' species; N = total number of individuals; and S = total number of species. The Statistical Package for the Social Sciences (SPSS) software version V25.0 was used for data entry, pre-processing and analyzing the collected data. PAST (Paleontological Statistics) version 2.16 was used to assess biodiversity indices. Mapping of the study area and representing study/sampling points was done by ArcGIS 10.0 software with the help of global positioning system (GPS). Both qualitative and quantitative analysis was done. Finally, data were presented as tabular or graphical format.

Table 1. Sample collection points in the Basurabad *beel*.

S.N.	Name of the point	Latitude	Longitude
1	Kishmath-Fultola	22° 42.898'N	89° 30.638'E
2	Basurabad	22° 43.227'N	89° 30.185'E
3	Fultola	22° 43.070'N	89° 31.032'E
4	Boroitola	22° 43.540'N	89° 31.172'E
5	Debitola	22° 43.002'N	89° 30.797'E

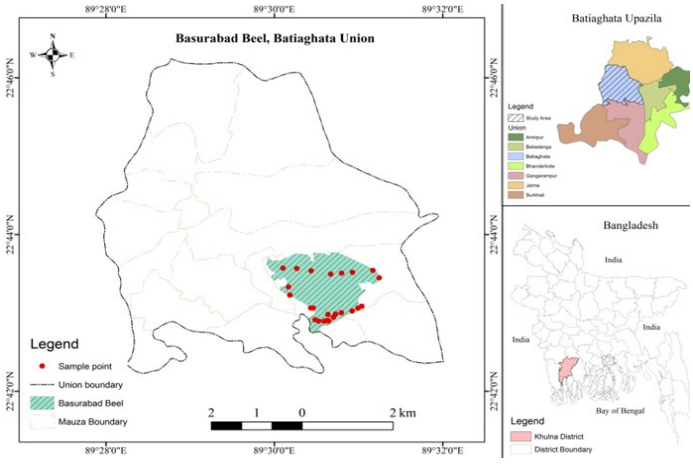

Figure 1. *Map showing reference of record of Basurabad beel, in Batiaghata Upazilla,*

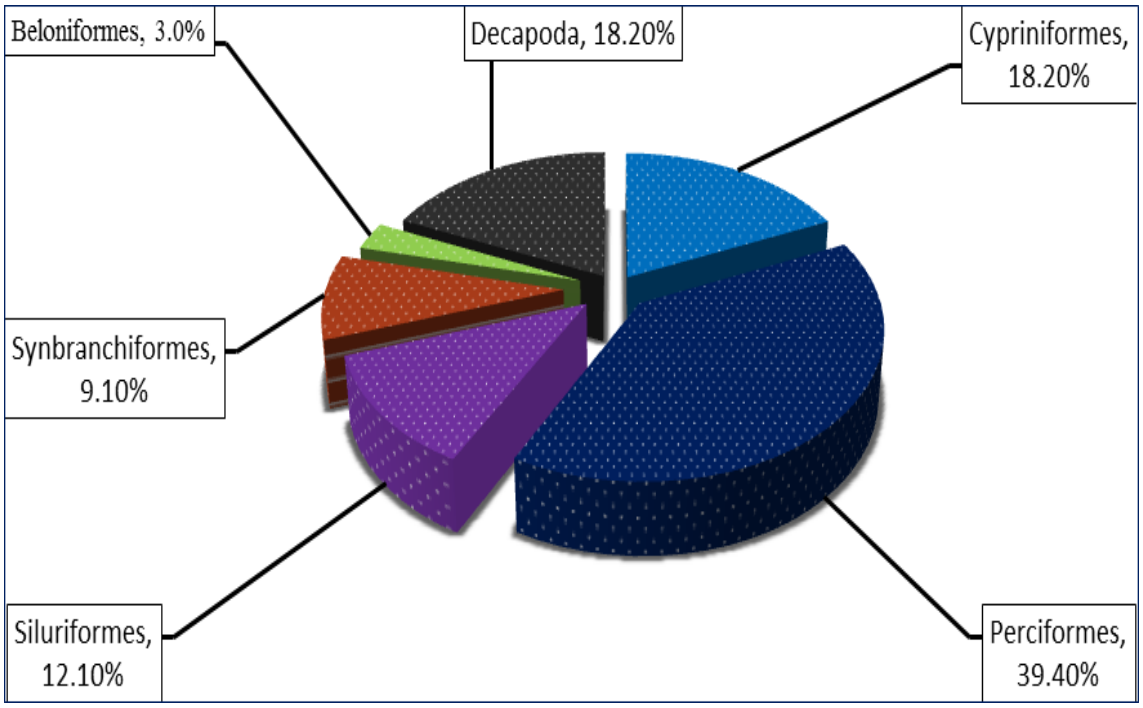

Figure 2. *The abundance of fish species (on the basis of order) in the study area.*

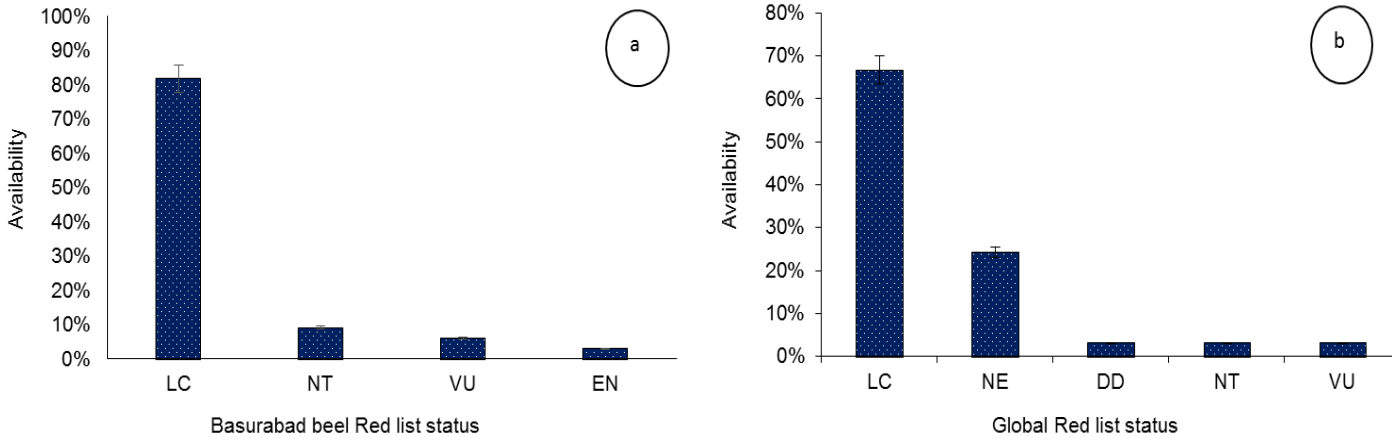

Figure 3. *IUCN local (a) and global (b) status along with percentage (%) of threatened fish found in the study area.*

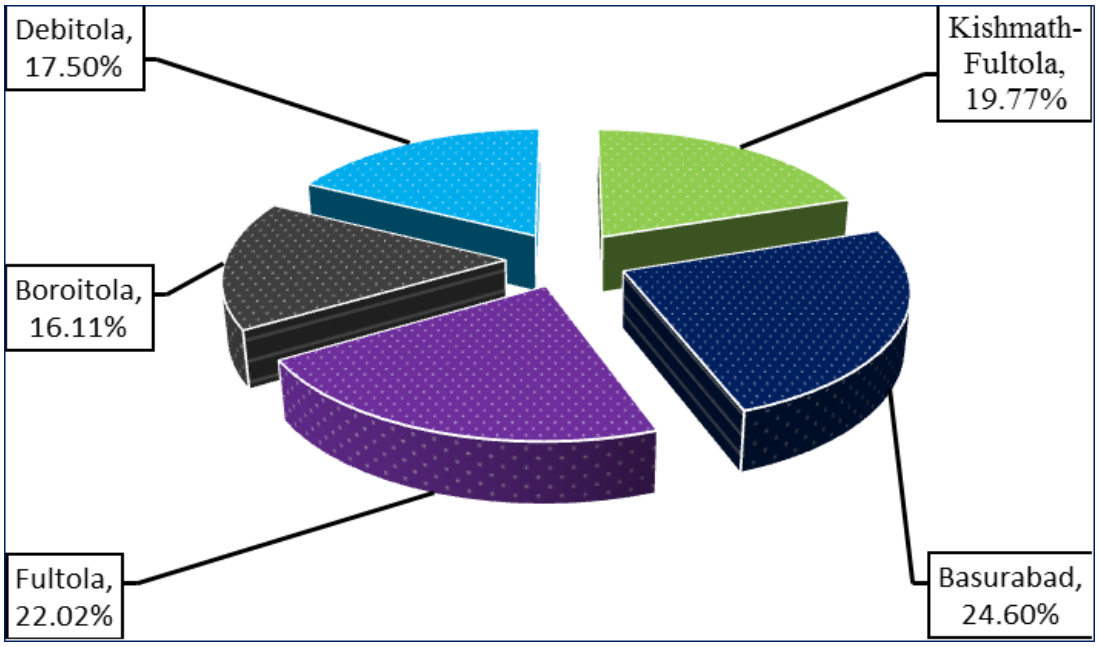

Figure 4. Status of fish species in Basurabad *beel.*

RESULTS AND DISCUSSION

Order based fish species availability

Basurabad *beel* supports a wide variety of fish species under different orders. Perciformes (39.40%) was the dominant order followed by Cypriniformes (18.20%), Decapoda (18.20%), Siluriformes (12.10%), Synbranchiformes (9.10%) and Beloniformes (3%). It is also explored that Beloniformes order is rarely found in the study area (Figure 2).

Fisheries diversity and status of fish species in the Basurabad *beel*

A total of 33 species were recorded under the identified 6 orders in the study area (Table 2). Amongst them, few of the species were facing some degrees of threat to cope up with the present circumstances. It is examined that out of the recorded species only 3% was found as endangered, 6% as vulnerable, 9 % as nearly threatened and 82% as least concerned (Figure 3a). After comparing IUCN local and IUCN global status (Figure 3) it is evident that the status of some fishes in the Basurabad *beel* is poor which may be resulted from over-exploitation.

Total average fish catch in different sampling points

Weight basis study of fish catch was explored during the research work at the sampling points. It is revealed that the highest occurrence was found in the Basurabad point (24.60%) followed by Fultola (22.02%), Kishmath-Fultola (19.77%), Debitola (17.50%) and Boroitola (16.11%) (Figure 4).

Ecological indices

Four ecological indices were calculated i.e. Shannon–Weaver index (H'), Simpson dominance index (c), Pielou's Evenness Index and Margalef index. The ecological status of the Basurabad *beel* was determined based on the Shannon-Weaver diversity index (H') value (Staub *at al*., 1970) (Table 3). Table 4 shows that, the average pollution level of Kishmath-Fultola, Basurabad and Debitola is less than 1 which indicates heavy level of pollution in the stated sampling points. These results may be influenced by some unrecognized driving forces which caused low level of species diversity in the study area. The pollution level of the Basurabad *beel* was also estimated based on the Margalef's Richness Index (Table 5). The Margalef Richness index (d) shows that Fultola (1.12 ±0.34) and Basurabad (1.12 ±0.34) point had the most rich and diverse fish community followed by Debitola point (0.68 ±0.34) (Table 6). From the findings, the health condition of the Basurabad *beel* was found seriously polluted to more serious pollution (d=1-2 to 0-1) according to the pollution level (Table 6). The value of Pielou's evenness index (J') shows that more even distribution of all the individuals among the different fish species in Boroitola (0.61 ±0.20) point than the Basurabad point (0.31 ±0.16) (Table 7). The value of Simpson Dominance index was found maximum in Fultola (0.58 ±0.10) point and minimum in Basurabad point (0.40 ±022) (Table 8). This result simply indicates that the Basurabad point (0.40 ±022) has the uppermost species dominance then Fultola (0.58 ±0.10) as maximum value results lowest dominancy.

Availability of threatened fish species

Basurabad beel supports some ecologically threatened species in its habitat. This beel harbors two vulnerable species i.e. *Puntius ticto*, *Monopterus cuchia* and an endangered species called *Mastacembelus armatus*. Although, *Puntius ticto* is vulnerable in Bangladesh but it is considered as least concern in global status. However, Basurabad beel supports this *Puntius ticto* vastly through its boundary.

Exotic fish species

During this study, two exotic fish species are found abundantly in the Basurabad beel namely Tilapia (*Oreochromis mossambicus*) and Thai Rajputi (*Barbonymus gonionotus*). These species can pose threats to indigenous species in terms of food consuming competition and as well as in niche occupying.

Fishing Gear Operated in the Basurabad Beel and Catch per Unit Effort (CPUE)

Total 10 types of gears under 5 groups were found to be used for catching fish. Amongst them, seine net (Jagat Ber Jal) had the highest catch 31.3 ±4.1 CC/haul/day/gear (kg) followed by current jal 10.5 ±2.5 CC/haul/day/gear (kg). The efficiency of Jagat Ber Jal in this beel found to be very high due to low depth of water (5-8 ft). Some other gears were also used in the study area such as fishing trap including Chari, Dhor, Ghuni, Pata/Tana. Jagat Ber Jal and Current Jal are found to be most destructive and the main fishing instrument in the study area (Table 9).

Relationship between Catch and Rainfall

The statistical analyses were performed to show correlation between the total fish catch and rainfall (Figure 5). It is evident from the value (r2 = -1.392) that in Basurabad beel there was negative correlation between monthly average rainfall and monthly fish catch. The rainfall data was collected from Bangladesh Meteorological Division (BMD), Khulna.

During the entire study period, 33 species were recorded under 6 orders from the Basurabad *beel* and few species were found to be commercially important. Rahman (1996) identified a total of 47 species of fish in the catches of different gears by the fishermen in BSKB *beel*. Chakraborty and Mirza (2007) recorded 70 fish species so far from the Gharia *beel* and Ehshan *et al.* (2000) reported 40 species including three exotic species from Chanda *beel*. A total of 76 fish species belonging to 76 genera, 26 families and l species of prawn were identified so far from the kumarai *beel*. *Cypriniformes* and *Siluriformes* were recorded as the most dominant fish in the Hail haor (Mazumder *et al*., 2016). Identical findings were also reported from many other rivers of Bangladesh such as the river Choto Jamuna (Galib *et al*., 2013), the river Mahananda (Mohsin and Haque, 2009), the river Tista (Khan *et al*., 2013) and the river Padma (Rahman *et al*., 2012). A total of 68 fish species recorded in water bodies of Itna, Kishoregonj (Sakawat, 2002) and 38 fish species including 34 native and 4 exotic fish species were recorded from Basuakhali *beel* (Rahman *et al*., 2019). About 260 species of freshwater fish recorded belonging to 55 families in Bangladesh (Rahman, 2005).

Table 2. Systematic position of the recorded fish species in the study area (2017) with their common name, local name, scientific name and IUCN local and global red list status.

Order	Family	Local Name	Common Name	Scientific Name	IUCN Status BD, 2015	Global Status, 2015
Cypriniformes	Cyprinidae	Mola	Mola Carplet	*Amblypharyngodon mola*	LC	LC
		Darkina	Indian Flying Barb	*Esomus danricus*	LC	LC
		Jat Puti	Spot fin swamp barb	*Puntius sophore*	LC	LC
		Tit Puti	Fire-fin barb	*Puntius ticto*	VU	LC
		Catla	Indian Major Carp	*Gibelion catla*	LC	NE
		SharPuti / JapaniPuti	Silver Barb	*Barbonymus gonionotus*	-	LC
	Cobiidae	Bele	Scribbled Goby	*Glossogobius giuris*	LC	LC
	Eleotridae	Bhut Bele	Dusky Sleeper	*Eleotris fusca*	LC	LC
	Gobiidae	Chewa	Mud Skipper	*Pseudapocrypteselongatus*	LC	LC
	Centropomidae	Lomba Chanda	Elongated glass perchlet	*Chanda nama*	LC	LC
		Lal Chanda	Indian glass perchlet	*Chanda ranga*	LC	NE
	Channidae	Taki	Spotted snakehead	*Channa punctatus*	LC	LC
		Cheng	Walking snakehead	*Channa orientalis*	LC	LC
		Shol	Snakehead murrel	*Channa straita*	LC	LC
Perciformes	Cichlidae	Tilapia	Mozambique Tilapia	*Oreochromismossambicus*	-	NT
	Nandidae	Veda	Mud perch	*Nandus nandus*	NT	LC
	Anabantidae	Khalisha	Striped gourami	*Colisa fasciata*	LC	LC
		Choto Khalisa	Honey gourami	*Colisa chuno*	LC	LC
		Koi	Climbing perch	*Anabas testudineus*	LC	DD
Siluriformes	Bagridae	Choto Tengra	Day's Mystus	*Mystus bleekeri*	LC	LC
	Bagridae	Boro Tengra	Long Wiskers Catfish	*Mystus gulio*	NT	LC
	Heteropneustidae	Shing	Stinging catfish	*Heteropneustes fossilis*	LC	LC
	Clariidae	Magur	Walking Catfish	*Clarias batrachus*	LC	LC
Synbranchiformes	Mastacembelidae	Tara Baim	One-Striped spiny eel	*Mastacembelus armatus*	EN	NE
		Guchi Baim	Striped spiny eel	*Macrognathus pancalus*	LC	LC
	Synbranchidae	Kuchia	Gangentic Mud eel	*Monopterus cuchia*	VU	VU
Beloniformes	Belonidae	Kakila	Freshwater Garfish	*Xenentodon cancila*	LC	NE
Decapoda	Penaeidae	Harina Chingri	Speckled Shrimp	*Metapenaeus monoceros*	LC	NE
		Kotke / Gura Chingri	Monsoon river prawn	*Macrobrachium lumarrei*	LC	LC
		Bagda Chingri	Giant Tiger Shrimp	*Penaeus monodon*	LC	NE
		Beel / Chamni Chingri	River prawn	*Macrobrachium daganum*	LC	NE
	Palaemonidae	Golda Chingri	Giant Freshwater Prawn	*Macrobrachium rosenbergii*	LC	LC
	Varunidae	Choto Kakra	River Swimming Crab	*Varuna litterata*	LC	NE

Note: LC=Least Concern, NO=Not Threatened, NT=Near Threatened, VU=Vulnerable, EN=Endangered, NE=Not Evaluated.

Table 3. Shannon-Weaver diversity index and pollution level (Staub *at al*., 1970).

Value Range (H')	0-1	1-2	2-3	3-4
Interpretation	Heavy	Moderate	Light	Slight

Table 4. Month Wise and Average Shannon-Weaver Diversity Index (H') Value with Standard Deviation.

Fishing point	Month					Average ±SD
	July	August	September	October	November	
Kishmath-Fultola	0.77	0.76	0.86	0.56	0.45	0.68 ±0.17
Basurabad	1.52	0.98	0.58	0.98	0.46	0.90 ±0.38
Fultola	1.29	0.8	0.88	1.42	1.58	1.19 ±0.41
Boroitola	0.43	1.19	1.34	0.97	1.35	1.10 ±0.41
Debitola	0.87	0.66	0.86	0.39	1.2	0.8 ±0.39

Table 5. Margalef's Richness Index (d) and pollution level (Lad, 2015).

Value Range (d)	0-1	1-2	2-4	4-6	>6
Interpretation	More serious pollution	Serious pollution	Moderate pollution	Light pollution	Clear water

Table 6. Month Wise and Average Margalef Richness Index (d) Value with Standard Deviation.

Fishing point	Month					Average ±SD
	July	August	September	October	November	
Kishmath-Fultola	0.46	0.71	0.67	0.85	0.88	0.71 ±0.18
Basurabad	1.14	0.84	0.99	1.42	0.46	1.12 ±0.35
Fultola	1.20	1.15	0.93	1.31	1.03	1.12 ±0.34
Boroitola	0.49	0.78	1.02	0.79	1.13	0.84 ±0.33
Debitola	0.27	0.43	0.79	1.00	0.91	0.68 ±0.34

Table 7. Month Wise and Average Pielou's Evenness Index (J') Value with Standard Deviation.

Fishing point	Month					Average ±SD
	July	August	September	October	November	
Kishmath-Fultola	0.54	0.37	0.39	0.25	0.22	0.35 ±0.13
Basurabad	0.57	0.37	0.22	0.24	0.16	0.31 ±0.16
Fultola	0.40	0.25	0.30	0.6	0.4	0.39 ±0.13
Boroitola	0.38	0.82	0.63	0.44	0.77	0.61 ±0.20
Debitola	0.79	0.48	0.34	0.18	0.41	0.44 ±0.23

Table 8. Month Wise and Average Simpson dominance index (C) Value with Standard Deviation.

Fishing point	Month					Average ±SD
	July	August	September	October	November	
Kishmath-Fultola	0.51	0.44	0.53	0.24	0.17	0.39 ±0.16
Basurabad	0.71	0.53	0.23	0.38	0.17	0.40 ±022
Fultola	0.62	0.48	0.53	0.68	0.60	0.58 ±0.10
Boroitola	0.20	0.67	0.66	0.52	0.69	0.55 ±0.21
Debitola	0.55	0.41	0.46	0.13	0.65	0.44 ±0.20

Table 9. Fishing Gear used in the Study Area with CPUE.

Types of Gear	Name of the gear	Gear Specification	Species caught	*CC/haul/day/gear (kg)
Seine Net	Jagat Ber Jal	Rectangular shape with two border lines. Upper borderline contains float and sinker in the lower portions. Sometimes it is as long as 250m.	All species	31.3 ±4.1
	Current Jal	Poly amide, Polypropylene nylon	Punti, Bele, Gulsha, Veda, Koi, Chewa	10.5 ±2.5
Gill Net	Poa Jal	Poly amide, Polypropylene nylon	Koi, Veda, Punti, Gulsha	6.8 ±1.4
	Koi Jal	Poly amide, Polypropylene nylon	Koi, Veda, Punti	6.695 ±1.2
	Chari	Bamboo splits, nylon thread	Koi,Puti, Chanda,Tengra	2.3 ±.4
	Dhor	Bamboo splits, nylon thread	Taki, Mola, Chanda, Baim, Tengra	1.4 ±.2
Fishing Trap	Pata/Tana	Bamboo splits, nylon thread	Darkina, Bele, Baim, Puti	3.6 ±.6
	Ghuni	Bamboo splits, nylon thread	Chingri, Chanda, Tengra	2.7 ±.8
Hook & Line	Borshi	Nylon ropes, hooks	Kalibaus, Koi, Shing, Punti, Tengra and some carp species	0.57 ±.1
Wounding Gear	Koch	Bamboo, sharp iron	Kalibaus, Koi, Shing, Taki, Punti, Tengra and some carp species.	0.4 ±.1

*CC=Catch composition.

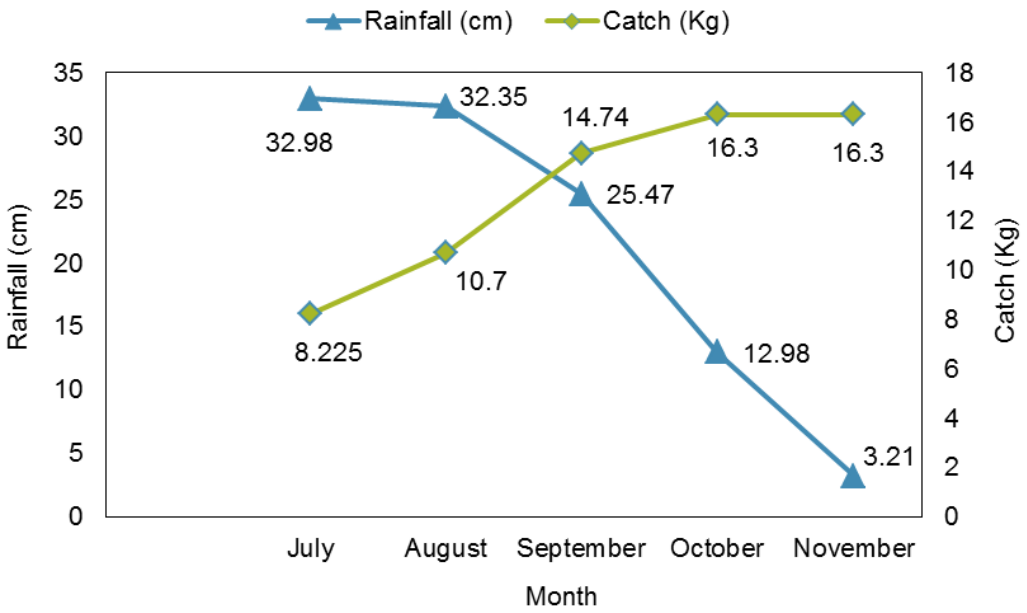

Figure 5. *Rainfall versus fish catches in the study area.*

During the study period, average Shannon-Weaver diversity index (H') value was highest in Fultola *beel* (1.19 ±0.41) and lowest in Basurabad (0.68 ±0.17). Margalef richness index (d) value was highest in Basurabad (1.12 ±0.35) and lowest in Debitola (0.68 ±0.34). Pielou's evenness index (J') value was highest in Boroitola (0.61 ±0.20) and lowest in Basurabad (0.31 ±0.16). Simpson dominance index (C) value was highest in Fultola (0.58 ±0.10) and lowest in Kishmath-Fultola (0.39 ±0.16). Shannon-Weaver index value typically ranges from 1.5-3.5 for ecological data that can hardly exceed 4.0 and it can be above 5.0 when the samples hold 100,000 species (Hanif *et al*., 2015). Nabi *et al*. (2011) found the Shannon-Weaver diversity index values as 0.95 to 2.62 in the Bakkhali River estuary. In every case, high Shannon-Weaver diversity index denotes high individuals and low diversity involved with low number of individuals. Simpson's dominance index and diversity index value were highest 0.95 and 3.49 respectively and lowest were observed 0.94 and 3.29 correspondingly in the upper Halda River which indicates that the dominance was shared by more species for the highest value. The highest and lowest evenness values were recorded as 0.61 and 0.50 respectively (Alam *et al*., 2013). The Margalef richness value is used as an indicator to compare the sites, generally show deviation depending on the species number (Vyas *et al*., 2012). Margalef richness value was observed maximum 7.91 and minimum 6.60 in the upper Halda River (Alam *et al*., 2013). Margalef index was encountered ranging from 3.71 to 6.70 in the Betwa River in Madhya Pradesh of India (Vyas *et al*., 2012). The value of Shannon-Weaver diversity index, H' increases when both the number of species and evenness, J' increases. For a given number of species, the value of H' is maximized when all species are equally abundant. However, quantifying biodiversity is a complicated task. A value near 4.6 would indicate that the numbers of individuals are evenly distributed between all the species (Bibi and Ali, 2013).

In this conducted study, 1 endangered, 2 vulnerable, 3 near threatened, and 27 least concern species were recorded from the sampling area. Ahsan (2008) recorded a total of 105 fish species where 45 were threatened including 25 endangered, 14 vulnerable and 6 critically endangered in the Chalan *beel*. Sayeed (2010) reported 106 species of fishes including critically endangered (6), endangered (20), vulnerable (10) and threatened (18) from Chalan *beel*. At a time, small fishes were abundant in the rivers, *beels*, *jheels*, canals, streams, ponds etc. in Bangladesh (Shafi and Quddus, 1982; Ahsan, 2008). In this research work, maximum catch was found in the Basurabad point (24.60%) followed by Fultola (22.02%), Kishmath-fultola (19.77%), Boroitola (16.11%) and Debitola (17.50%). In Basurabad *beel*, average fish catch was observed as 2.76 ±0.38 kg per hour including all the gears operated in the *beel*. In the chalan *beel*, fish catch was 2.08 ± 0.49 kg and 1.29 ± 0.32 kg per hour per person, by suti jal (set bag net– the most common gear used in the *beel*) in 2005 and 2006 respectively. In 2005-2006, the annual fish production in Chalan *beel* was 12217 tons, being less than half of the production observed in 1982 (Hossain *et al*., 2009). In Chandagari *beel*, average fish production was 20.90 MT approximately (Halim *et al*., 2017). But, in Basurabad *beel*, yearly average fish production was 9.48 MT. This study revealed that the health condition of Basurabad *beel* was not satisfactory according to the pollution level (Staub *et al*., 1970; Lad, 2015) based on ecological indices like Shannon-weaver diversity index and Margalef Species Richness index respectively.

In the current study, 4 types of net, 4 types of traps, 1 type of hook, and 1 type of wounding gear were recorded. The fishing technique that are currently used by the fishermen of Bangladesh are netting, trapping, de-watering, spearing, angling and hand picking (Dewan and Mazid, 1994). Saha *et al*., (2005) encountered 7 different types of gears under 3 categories (nets, traps and wounding gears) in the Gawha *beel*. According to BCAS (1991), approximately 30 different types of fishing gear have been identified to use in halti *beel*. Rahman *et al*. (1993), reported that fishing gear operating in the floodplains (chanda, BSKV and halti *beel*) comprised four groups: fish net (7 types),

fish trap (5 types), hooks and line (5 types) and spears/harpoon (4 types). Rahman (2001) identified total 38 fish in the catches of different gears in the haor which is congruent to the present findings.

The study unveiled that month wise maximum fish catch was in October and November (16.3 kg) when rainfall was 12.98 cm and 3.21 cm respectively and lowest in August (10.2 kg) when rainfall was 32.35 cm which indicates that rainfall influences the amount of fish catch and shows negative relationship between the rainfall and the total catch of fish. This factor also influences the transparency and carries out sediment from surrounding land area. Results of the present study were found similar with the findings of Siddiq *et al.* (2013). They recorded the maximum fish catch in October (402 kg/month) and minimum in June (213 kg/month) in Dogger *beel*.

Threats to Biodiversity of Basurabad *Beel*

In the world, wetlands are perhaps losing faster than any other types of habitats. In truth, siltation of water bodies contributes specially to the aquatic habitat loss and degradation (Craig *et al.*, 2004). Rivers carry annually 2.4 billion mt silts, which is deposited on the river beds, floodplains and *beel* bottoms (Spillmann and Bachler, 1993). The peripheral areas of the *beels* have been converted to agricultural fields and this process is still continuing in this area. For this reason, most of the species of the Basurabad *beel* is at a stake now. In addition, overfishing not only affects the fishes but also affects the other aquatic resources as by-catches. Overfishing is considered as a key reason for the decline of fisheries (Zalinge *et al.*, 2001). Fishing by dewatering of water bodies and poisoning particularly in winter (dry season) are apparently destructive fishing methods that are usual in the Basurabad *beel*. Boosting up the crop production involves the use of pesticides and fertilizers in the crop fields. Pesticides are mainly poisonous and thus are hazardous to aquatic organisms and affect ecosystem integrity and disrupt its functioning (Parveen and Faisal, 2002). Many pesticides are used in the fields adjacent to the Basurabad *beel* that are carried out by the rain water and degrade the quality of *beel* water that is incredibly great threat to the aquatic organisms. The impacts and consequences of climate change are too much dangerous. A recent work shows that the potential consequences of climate change across the world habitats reduced abundance and altered species composition (Ashely *et al.*, 2007). The combined effects of these threats (siltation, habitat loss, conversion of wetland to agricultural fields, overfishing, dewatering during lean season, poisoning, pesticides and fertilizers, climate change etc.) may be damaging the entire fisheries resources of this *beel*.

Conservation implications

Freshwater fishes is the world's most threatened group of vertebrates after amphibians (Bruton, 1995; Hiddink *et al.*, 2008; Liu *et al.*, 2017) and without protection, 20% of the world's freshwater fishes may become extinct in the next 50 years (Moyle and Leidy, 1992; Fu *et al.*, 2003). In this study, the first component to protect fish biodiversity assumed to be the establishment of protected areas in the Basurabad *beel*. Most of the aquatic ecosystems are degraded due to the habitat loss (land filling and conversion) that should be minimized as soon as possible. Secondly, the fish acts and rules should be implemented rigorously and illegal fishing tackles like small mesh size nets and monofilament gill nets should be prohibited in the *beel* area. Overfishing and dewatering of the *beel* area need to be stopped. Thirdly, the use of inorganic fertilizers and pesticides should be banned and a guideline for the use of fertilizers and pesticides must be developed and implemented for the environment and fisheries protection. However, awareness rising on the impacts of loss of biodiversity, destructive fishing, overfishing, use of destructive gears, fertilizers, and pesticides etc. should be conducted and strong monitoring against these should be imposed. Therefore, the reported threats could be managed through proper awareness campaigns, billboards, bottom-up communication approach, ban on fishing in the particular season, keen monitoring by concern authority etc.

Conclusion

The fish diversity of the world is indisputably undergoing critical stage than the past. To achieve the conservation goal, in depth research on different arenas such as minimizing the pollution threats from the industries and agrochemical inputs should be carried out. Currently, the fish biodiversity of the Basurabad *beel* is under great threat due to fishing pressure, pollution, siltation, urbanization and other anthropogenic causes. These have been creating a great impact on the *beel* ecology. As a result, the water quality is deteriorating day by day and the availability of fish species is decreasing gradually. In the present study, total 33 species under 6 orders were recorded in Basurabad *beel*. There has been no Governmental and non-governmental survey introduced to estimate the fish biodiversity and fishing gears of Basurabad *beel*. During the study period, it was found that the fish abundance of Basurabad *beel* is declining at an alarming rate. The causes of these biodiversity declining are complete drying up in many parts of the *beel* during lean season, which is detrimental to fish populations and ecosystem. Some *beel* management policies should be adopted to protect the species which are at the degree of extinction and to recover sustainable production of the *beel*.

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ORIGINAL RESEARCH ARTICLE

Assessment of the ichthyofaunal diversity in the Juri River of Sylhet district, Bangladesh

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ABSTRACT

This study was conducted to assess the present status of ichthyofaunal assemblages in the Juri River of Fenchuganj upazila in Sylhet district, Bangladesh. Survey works were made in three different locations of the river during May to December, 2018 comprising direct fish catch observations, questionnaire interviews, focus group discussions with fishers, fish traders, *aratders* (wholesalers) and river bank community members, and key informant interviews with upazila fisheries officer, district fisheries officer, non-governmental organization officials, and local leaders. The results revealed that a total of 75 species of fishes under 25 families were available. Among these species 11 were commonly available, 32 were moderately available, 25 were less available, and 7 were rarely available. Cyprinidae was the leading family consisting of 27% of the total fish population of the study area. However, 10 vulnerable, 8 endangered and 1 critically endangered fish species were also found in small amount. During this study the highest number of species (61) was found in the catches in October and lowest number of species (22) was recorded in July. According to the perceptions of fishers and resource person degradation of habitat, climate change, and human activities are the triggering agents for declining ichthyofaunal diversity in this river. Therefore, this study recommends application of proper management measures including community participation to conserve the ichthyofaunal diversity and enhance fish production in the Juri River.

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INTRODUCTION

Bangladesh is blessed with vast and diversified fisheries resources which include rivers, estuaries, *beels*, *haors*, *baors* (ox-bow lakes), floodplains, and huge area of marine water resources (DoF, 2018). These productive water resources support many fish species which ultimately afford the country's total fisheries production (Shamsuzzaman *et al.*, 2017). Throughout the world fish form an indispensable part of the daily food intake. Fish and fisheries have become a vital part of Bangladeshi diets from ancient time and presently play a dynamic role in nutrition supply, employment generation, foreign currency earnings and other economic aspects of the country (DoF, 2018; Hossain, 2014). However, many fish species in the natural waterbodies are under different levels of threats.

During the last century, riverine ecosystems have endured from passionate human intervention, resulting in habitat degradation and loss of aquatic ecosystems. Consequently, many fish species have become highly threatened, particularly in rivers where substantial demand is placed on freshwaters (Rahman *et al.*, 2012). According to IUCN (2015), there are 253 species of inland freshwater fishes; among those 9 species are critically endangered (CR), 30 species are endangered (EN), 25 species are vulnerable (VU), and 27 species are near threatened (NT), 122 species are least concern (LC), and the rest 40 species are considered data deficient (DD) throughout the country. Due to overharvesting, degradation of habitat and consequent declining fish production from natural waterbodies, contribution of inland capture fisheries has been reduced from 50% to 35% of annual fisheries production, and production of marine capture

fisheries has remained static over the last decade (Mazid, 2010). Overfishing, siltation, indiscriminate fishing of larvae and juveniles, and water pollution are recognized as the major worries linked with the declination of ichthyofaunal diversity (Islam *et al.*, 2015a).

The Juri River is one of the important waterbodies in the northeastern part of Bangladesh in terms of fish production and income generation of many fishermen surrounding that wetland. This river originated from the hilly region of the Tripura state of India and enters into Bangladesh towards Dharmanagar at Kulaura upazila of Maulvibazar district. Another vital flow of this river named the Sonai River also originated from India and joins to this river at Sonai-Bardan point and their joint flow supports a rich diversity of fishes in the surrounding waterbody. The Juri River flows through the Hakaluki *haor* at different upazila in Maulvibazar district and falls into the Kushiyara River at Fenchuganj upazilas of Sylhet district. In the monsoon season it merges with the flooded Hakaluki *haor*. Due to these circumstances the Juri River is very significant for the availability of diversified aquatic species, especially fishes, and believed to be an essential spawning and feeding ground for *haor* and riverine fish species.

Maximum number of wild populations have been disappeared from the rivers and streams of Bangladesh due to overexploitation augmented by various environmental changes and degradation of the natural habitat (Galib *et al.*, 2009, 2013). Nowadays, gradual reduction of aquatic biodiversity from natural waterbodies is a vital problem in Bangladesh (Galib *et al.*, 2009, 2013; Imteazzaman and Galib, 2013; Chaki *et al.*, 2014; Mohsin *et al.*, 2013, 2014). These brief discussions indicate the necessity for in-depth study of biodiversity which is essential to assess the present status and sustainable management of any wetland (Imteazzaman and Galib, 2013).

Some research activities have been conducted on ichthyofaunal diversity in different waterbodies of Bangladesh (Galib *et al.*, 2009, 2013; Imteazzaman and Galib, 2013; Ahmed *et al.*, 2004; Zafar *et al.*, 2007; Mohsin *et al.*, 2013; Saha and Hossain, 2002). However, yet no research work has been published on ichthyofaunal diversity of the Juri River. Therefore, the present study was undertaken to prepare a checklist of fish species focusing on their relative present availability status compared to the national conservation status of Bangladesh by IUCN (2015). Thus, the information from this research work is supposed to provide a baseline dataset for carrying out further in-depth investigation on aquatic ecology, conservation, and sustainability for the proper management of fisheries resources of this river.

MATERIALS AND METHODS

Study area

This study was carried out at three fishing spots of the Juri River: Gilachhara and Purbo-Badidewli under Gilachhara union, and Pitaitikor under Fenchuganj union of Fenchuganj upazila in Sylhet district. Among 56 km of the total river length about 12 km from connecting point from the Kushiyara River to the Sonai-Bardan point was selected for data collection (Figure 1). The primary criteria for the selection of study area were a suitable geographical coverage for wide variety of fish biodiversity and good numbers of fishermen depended on fishing for their livelihood.

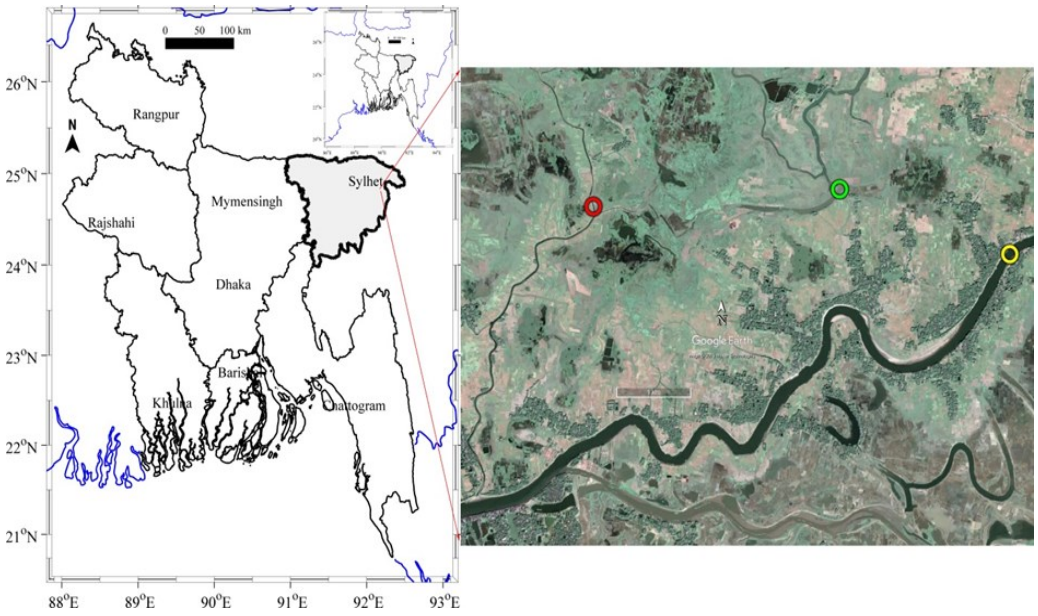

Figure 1. *Map showing locations of the study sites in Google Earth Pro map (Pitaitikor, Gilachhara, and Purbo Badiadewli are shown by red, green and yellow circles, respectively).*

Study period and target group

This study was conducted for a period of eight months from May to December, 2018. During the study period several field visits were made to collect necessary information. Different levels of stakeholders of fisheries like fishermen, *aratdars* (wholesalers), fish retailers and local leaders engaged in fishing, fish marketing and other related activities in the study areas who were well-known about the Juri River biodiversity were considered as target group. A total of 90 fishermen, 20 fish retailers, 10 *aratdars* (wholesalers) , and 5 local leaders were randomly selected for questionnaire interviews from the selected three study sites.

Preparation of questionnaire

A draft questionnaire was prepared keeping in view the objectives of the study. Then that draft questionnaire was used for pre-testing with few sample respondents. In pre-testing, attention was paid to incorporate any new information, which was not designed to be asked and filled in the draft interview schedule. The questionnaire was then modified and rearranged according to the experience gathered from the pretest. Thus, the questionnaire was finalized by arranging the questions in such a logical sequence so that the fishermen could answer chronologically.

Collection of data

Both primary and secondary sources of data were considered for collection in the present study. Primary data were collected from fishermen, *aratdar*s and fish traders through direct catch observation, questionnaire interview (QI), focus group discussion (FGD), and key informant interview (KII) (Arefin *et al.*, 2018; Gebre, 2015). The secondary information was collected from upazila fisheries office of Fenchuganj, district fisheries office of Sylhet, books, journals, MS thesis, published articles, and different internet sources.

Focus group discussion

A total of 3 FGDs were made at the three villages as mentioned before. The participants of FGD were fishermen of different ages: young, middle aged and old aged.

Questionnaire interview

A total of 90 fishermen, 10 aratders and 20 fish retailers were randomly selected for QIs from 3 selected villages.

Cross checking of information with key informants

After collection of data through FGDs and QIs the information were justified by KII. KIIs were conducted with key resource persons, such as highly experienced fishers, upazila fisheries officer (UFO), district fisheries officer (DFO), local leaders, and workers from non-government organization (NGO) like Center for Natural Resource Study (CNRS).

Identification of ichthyofauna

Samples of different fish species were collected from the fishermen's catch landed at different fish landing centers of the selected sampling stations and from fish markets as well. The fish species were identified and sorted based on their external morphology (Rahman, 2005; IUCN, 2015). Then, on the basis of QI and catch records of 90 fishermen the collected species were categorized in four statutes: commonly available (CA) which were observed throughout the year; moderately available (MA) which were observed infrequently in the study area; less available (LA) which were observed infrequently and less amount in the study area, and rarely available (RA) species which were observed fortuitously once or twice in a year. The species of the collected fishes were verified based on IUCN red list (IUCN, 2015) and internet source (http://www.fishbase.org).

Statistical analysis

After the collection the data were documented in a computer, and were analyzed by using Microsoft Office Excel 2010 to assess the present status of fish biodiversity in the Juri River. For the presentation of the analyzed data, table, pie-chart and bar diagrams were used in the results.

RESULTS AND DISCUSSION

Ichthyofaunal diversity status

The Juri River is naturally rich in aquatic biodiversity, mainly fishes, because of its location as an interconnecting water body with the Hakaluki *haor* and as a tributary of the Kushiyara River. This river ecosystems play a vital role in supporting the biodiversity of fishes, and contributes in animal protein supply as well as to the economy of Bangladesh. For the estimation of abundance and biodiversity status, the identified ichthyofauna were characterized as different levels of threatened conditions such as critically endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT), and least concern (LC) (IUCN, 2015).

During the study period in accordance with the speech of local fishermen as well as direct catch observation and market visits' the fishes were categorized as 11 species were CA, 32 species were MA, 25 species were LA, and 7 species were found as RA in the study area (Figure 1). The recorded total number of fishes with their family details, present status and IUCN status are described in Table 1. In the present study a total of 75 fish species under 25 families were recorded which is higher than the results of Rahman *et al.* (2015) who recorded a total of 56 species of fishes belonging to 21 families from the Talma River at northern part of Bangladesh. Kamrujjaman and Nabi (2015) documented 48 species of fishes belonging to 18 families in the Bangshi River of Savar. Ali *et al.* (2014) found 53 species of fishes in the Chitra River at the south-western part of Bangladesh. Mohsin *et al.* (2014) documented 53 fish species belonging to 28 families at the Andharmanik River in Patuakhali district. Galib *et al.* (2013) found a total of 63 fish species in the river of Choto Jamuna at Naogaon district, Bangladesh. Islam *et al.* (2015c) recorded 61 species of fishes from the Sibsa River at south-western part of Bangladesh. Thus, the species diversity of the Juri River is much higher than those rivers. However,

Gain *et al.* (2015) identified a total of 95 finfish species contributing to 45 families at the Passur River of Bangladesh that is higher than present study. Joadder *et al.* (2015) identified and recorded 71 fish species belonging to 26 families from the river Padma which is closely similar with the present study.

Table 1. Fish species occurrence in the studied area with their IUCN (2015) status.

S.N.	Family name	Local name	Common name	Scientific name	Present status	IUCN status
1	Cyprinidae	Jatpunti	Punti barb	*Puntius sophore*	CA	LC
2		Sarpunti	Olive barb	*Puntius sarana*	LA	NT
3		Tit punti	Ticto barb	*Puntius ticto*	RA	VU
4		Mola punti	Glass barb	*Puntius guganio*	MA	LC
5		Gonia	Kuria labeo	*Labeo gonius*	CA	NT
6		Kalibaus	Black rohu	*Labeo calbasu*	CA	LC
7		Bata	Bata labeo	*Labeo bata*	MA	LC
8		Rui	Rohu carp	*Labeo rohita*	LA	LC
9		Agun chokha	Angra labeo	*Labeo angra*	RA	LC
10		Naukka chela	Gora chela	*Securicula gora*	MA	NT
11		Fulchela	Finescale razorbelly minnow	*Salmostama phulo*	CA	NT
12		Narkali chela	Large razorbelly minnow	*Salmostoma bacalia*	LA	LC
13		Chap chela	Sind danio	*Dvario devario*	LA	LC
14		Mola	Mola carplet	*Amblypharyngodon mola*	LA	LC
15		Dhela	Cotio	*Osteobrama cotio*	RA	NT
16		Darkina	Flying barb	*Esomus danricus*	LA	LC
17		Lachu	Reba carp	*Cirrhinus reba*	MA	NT
18		Mrigel	Mrigal	*Cirrhinus cirrhosus*	LA	NT
19		Carpu	Common carp	*Cyprinus carpio*	LA	LC
20		Catla	Catla	*Catla catla*	LA	LC
21	Bagridae	Tengra	Striped dwarf catfish	*Mystus vittatus*	MA	LC
22		Kalo bujuri	Tengara mystus	*Mystus tengara*	MA	LC
23		Gulsha	Gangetic mystus	*Mystus cavasius*	CA	NT
24		Loitta Tengra, Gulsha	Day's mystus	*Mystus bleekeri*	MA	LC
25		Gang Tengra	Menoda catfish	*Hemibagrus menoda*	LA	NT
26		Rita	Rita	*Rita rita*	RA	EN
27		Ayre	Long whiskered catfish	*Sperata aor*	MA	VU
28		Guizza ayre	Giant river catfish	*Sperata seenghala*	RA	VU
29	Siluridae	Boal	Freshwater shark	*Wallago attu*	CA	VU
30		Kani pabda	Two spot glass catfish	*Ompok bimaculatus*	LA	EN
31	Channidae	Madhu Pabda	Butter catfish	*Ompok pabda*	MA	EN
32		Taki	Spotted snakehead	*Channa punctatus*	CA	LC
33		Cheng	Walking snakehead	*Channa orientalis*	MA	LC
34		Shol	Striped snaked	*Channa striatus*	LA	LC
35		Gozar	Giant snakehead	*Channa marulius*	MA	EN
36	Mastacembelidae	Boro baim	Tire-track spiny eel	*Mastacembelus armatus*	CA	EN
37		Guchi baim	Striped spinyeel	*Macrognathus pancalus*	MA	LC
38		Tara baim	One-stripe spinyeel	*Macrognathus aculeatus*	MA	NT
39	Anabantidae	Koi	Climbing perch	*Anabas testudineus*	MA	LC
40	Osphronemidae	Khalisha	Banded gourami	*Trichogaster fasciata*	MA	LC
41		Lal khalisha	Dwarf gourami	*Trichogaster lalius*	MA	LC
42	Notopteridae	Chital	Humped featherback	*Notopterus chitala*	MA	EN
43		Foli	Grey featherback	*Notopterus notopterus*	LA	VU

Table 1. *Continued*.....

44	Sisoridae	Baghair	Dwarf goonch	*Bagarius bagarius*	LA	CR
45	Cobitidae	Bou, rani	Necktie loach	*Botia dario*	CA	EN
46		Gutum	Guntea loach	*Lepidocephalus guntea*	MA	LC
47		Gutum	Annandalei loach	*Lepidocephalichthys annandalei*	LA	VU
48		Puiya	Burmese loach	*Lepidocephalichthys berdmorei*	LA	LC
49	Clupeidae	Ilish	Hilsa shad	*Tenualosa ilisha*	RA	LC
50		Chapila	Indian river shad	*Gudusia chapra*	MA	VU
51		Kachki	Ganges river sprat	*Corica soborna*	MA	LC
52	Schilbeidae	Bacha	Batchwa vacha	*Eutropiichthys vacha*	MA	LC
53		Gharua, laira	Garua bacha	*Clupisoma garua*	LA	EN
54		Batasi	Indian potasi	*Neotropius atherinoides*	MA	LC
55		Kajuli	Gangetic ailia	*Ailia coila*	MA	LC
56		Hilon	Silond catfish	*Silonia silondia*	RA	LC
57	Palaemonidae	Golda	Gaint freshwater prawn	*Macrobrachium rosenbergii*	MA	LC
58		Gura icha	Kuncho river prawn	*Macrobrachium lamarrei*	CA	LC
59		Kaira icha	Kaira river prawn	*Macrobrachium dayanum*	MA	LC
60	Nandidae	Meni	Mud perch	*Nandus nandus*	MA	NT
61	Heteropneustidae	Shing	Stinging catfish	*Heteropneustes fossilis*	LA	LC
62	Clariidae	Magur	Walking catfish	*Clarias batrachus*	LA	LC
63	Gobiidae	Bele	Tank goby	*Glossogobius giuris*	MA	LC
64		Bele	Tiger goby	*Eugnathogobius oligactis*	LA	VU
65		Lomba chanda	Elongate glass-perchlet	*Chanda nama*	MA	LC
66		Gol chanda	Indian glass fish	*Parambassis ranga*	MA	LC
67		Lal chanda	Highfin glassy perchlet	*Parambasis lala*	LA	LC
68	Cichlidae	Tilapia	Mozambique tilapia	*Oreochromis mossambicus*	LA	LC
69	Balitoridae	Bilturi, balichata	Sand loach	*Acanthocobitis botia*	LA	LC
70	Belonidae	Kakila	Frashwater garfish	*Xenentodon cancila*	MA	LC
71	Hemiramphidae	Ekthota	Congaturi halfbeak	*Hyporamphus limbatus*	LA	LC
72	Sciaenidae	Kuli	Cuja croaker	*Macrospinosa cuja*	MA	NT
73	Anguillidae	Bamos	Indian mottled eel	*Anguilla bengalensis*	MA	VU
74	Sybranchidae	Kuchia	Gangetic mudeel	*Monopterus cuchia*	LA	VU
75	Tetraodontidae	Potka	Ocellated pufferfish	*Tetraodon cutcutia*	CA	LC

*CA = commonly available, MA = moderately available, LA = less available, RA = rarely available, *CR = critically endangered, EN = endangered, VU = vulnerable, NT = near threatened and LC = least concern.

From the record of the study Cyprinidae was the most leading family among the 25 families containing maximum fish species (20) which consists of 27% of the total ichthyofauna species. Bagridae (11%) was the second most leading family comprising 8 fish species followed by 5 species of Schilbeidae and Gobiidae (7%), 4 species of Channidae and Cobitidae (6%), 3 species of Mastacembelidae, Siluridae, Clupeidae and Palaemonidae (4%), 2 species of Osphronemidae and Notopteridae (3%), 1 species of each family were found under Anabantidae, Sisoridae, Nandidae, Heteropneustidae, Clariidae, Cichlidae, Balitoridae, Belonidae, Hemiramphidae, Sciaenidae, Anguillidae, Sybranchidae and Tetraodontidae (1%) (Figure 2).

Similar findings of Cyprinidae as a major family were also reported for many other rivers of Bangladesh with differences of number of species. For instance, Joadder *et al.* (2015) found Cyprinidae as dominant family with 23 species of fishes at the Padma River. Galib (2015) identified Cyprinidae family as dominant with 15 species at the river Brahmaputra. Islam *et al.* (2016) found Cyprinidae as highest contributing family with highest number (10) of species at the Jamuna River of Bangladesh. Chaki *et al.* (2014) documented Cyprinidae as the most dominating fish family consisting of 18 fish species in the Atrai River of Bangladesh. Mohsin *et al.* (2013) recorded Cyprinidae as the most dominant fish family containing of 22 species of fishes in the Padma River of Rajshahi district. However, dominant fish species of the Cyprinidae family was different in many rivers of Bangladesh which might be due to geographical and environmental differences of those rivers.

According to the present study, 7 fish species were rarely available in the study sites (Figure 3). The rarely available species are those fish species which passing a very critical condition that will be disappeared in near future. In percentage, MA species consists 43% of the total recorded fish species followed by LA (33%), CA (15%) and RA (9%) (Figure 4). Kamrujjaman and Nabi (2015) found 29 species (40.42%) of fishes as locally rare, only 3 species (6.25%) of fishes were very common and 16 species (33.33%) were common in the Bangshi River. Islam *et al.* (2015b) recorded 24 commonly available, 16 moderately available, 18 rarely available species of fishes from the wetlands of Sylhet district. Islam *et al.* (2015a) recorded as available (43.86%), less available (29.82%), rare (18.42%) and very rare (7.89%) species

of fishes at the Payra River of Bangladesh. Gain *et al.* (2015) recorded 50% of the fishes as available followed by 26% less available, 16% rare and 8% very rare in the Passur River of Bangladesh. Arefin *et al.* (2018) found 14 species as commonly available (23%), 28 species as moderately available (45%), and 20 species as rarely available (32%). The number and percentage of available fish species found in the present study is slightly different with the above studies which might be due to the differences of geographical location, study duration, and difference of availability of fishes in the study periods.

In the present survey gulsha (*Mystus cavasius*) was documented as the most abundant fish species among the 11 commonly available species. Boro baim (*Mastacembelus armatus*) was the second most abundant species followed by jatpunti (*Puntius sophore*), rani (*Botia dario*), gonia (*Labeo gonius*), kalibasu (*Labeo calbasu*), gura chingri (*Macrobrachium lamarrei*), boal (*Wallago attu*), fulchela (*Salmostama phulo*), potka (*Tetraodon cutcutia*), and taki (*Channa punctatus*). Similar findings were also found in various studies on several small rivers. Kamrujjaman and Nabi (2015) recorded the most dominated species kalo bujuri (*Mystus tengra*) and jatpunti (*Puntius sophore*) from the Bangshi River of Bangladesh. Imteazzaman and Galib (2013) documented jatpunti as the most abundant fish species in the Halti *beel* of Bangladesh. Hossain *et al.* (2009) recorded jatpunti, tit punti (*Puntius ticto*) followed by chanda (*Chanda nama* and *Parambassis ranga*), chapila (*Gudusia chapra*) and tengra (*Mystus vittatus*) as the most abundant fish species in the Chalan *beel* of Bangladesh.

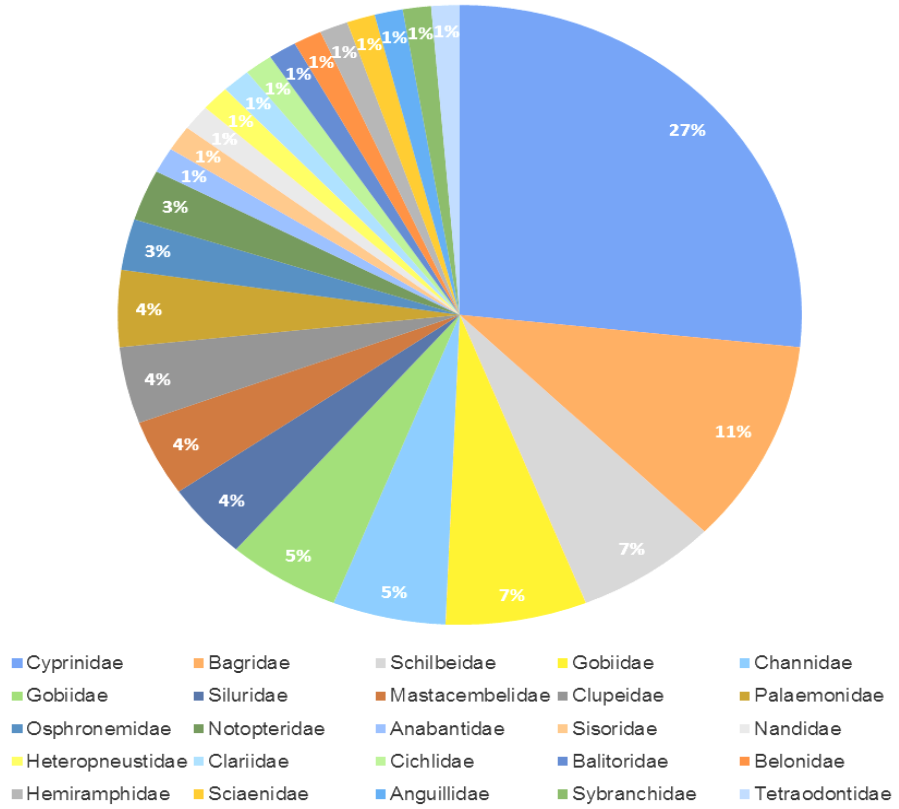

Figure 2. *Percentage of fish species diversity under different families recorded in the Juri River.*

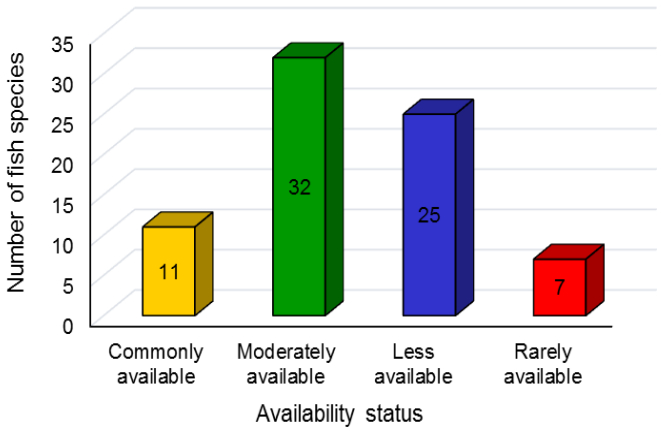

Figure 3. *Status of ichthyofaunal diversity in the study area.*

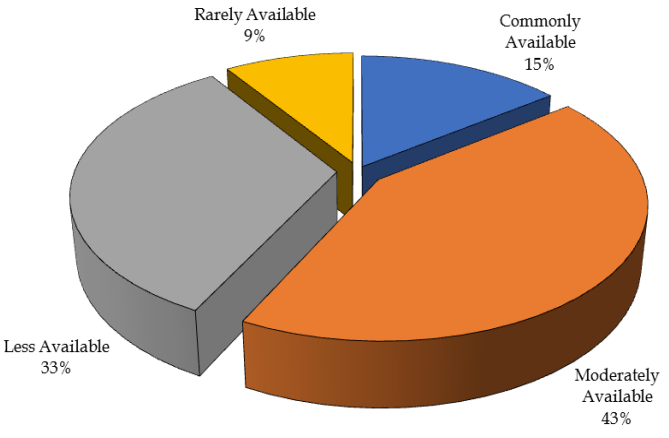

Figure 4. *Percentage of fish biodiversity in the study area.*

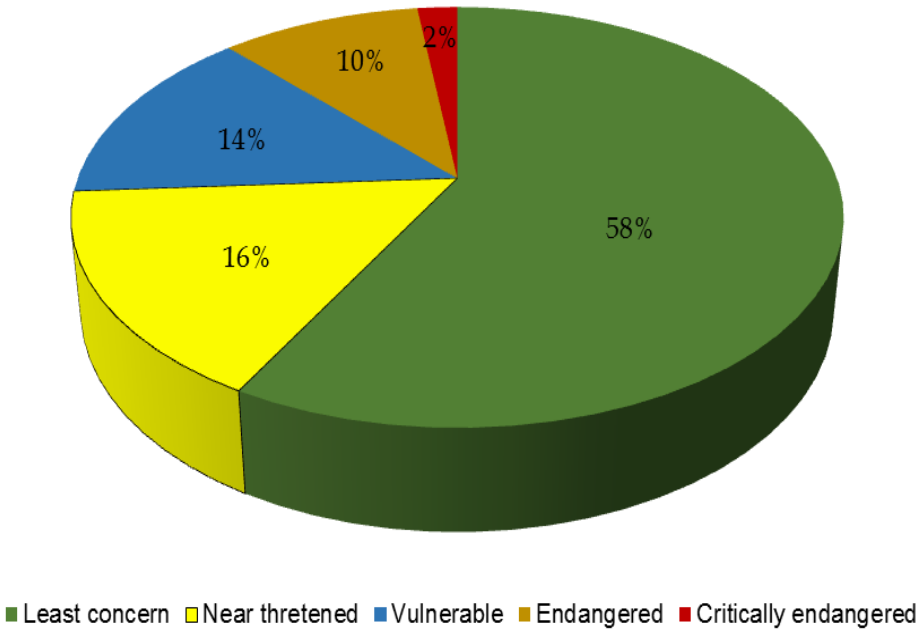

Figure 5. *Percentage of fish species according to IUCN status.*

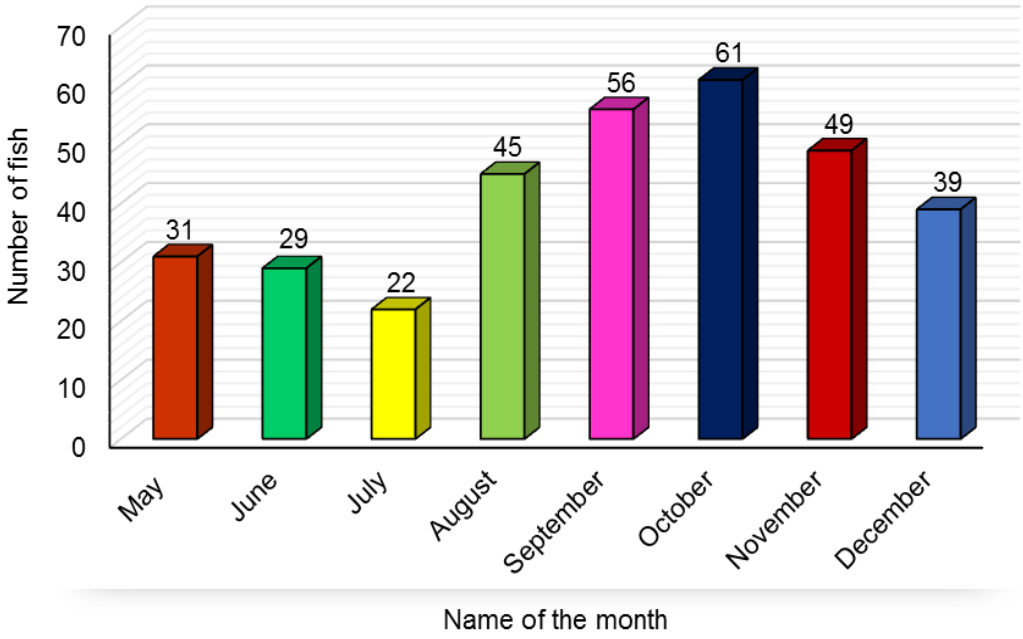

Figure 6. *Monthly variation of fish species availability.*

Biodiversity of threatened ichthyofauna species

Out of the recorded 75 fish species, 44 species LC, 12 species NT, 10 species VU, 8 species EN, and 1 species CR were recorded from the Juri River (IUCN, 2015). According to the present study vulnerable species were ayre (*Sperata aor*) and guizza ayre (*Sperata seenghala*) of Bagridae family, tit punti (*Puntius ticto*) of Cyprinidae family, boal (*Wallago attu*) of Siluridae family, foli (*Notopterus notopterus*) of Notopteridae family, gutum (*Lepidocephalichthys annandalei*) of Cobitidae family, chapila (*Gudusia chapra*) of Clupeidae family, bele (*Eugnathogobius oligactis*) of Gobiidae family, bamos (*Anguillla bengalensis*) of Anguillidae family, kuchia (*Monopterus cuchia*) of Sybranchidae family. Among the 8 EN species, kani pabda (*Ompok bimaculatus*) and modhu pabda (*Ompok pabda*) were identified under the family of Siluridae, gozar (*Channa marulius*) of Channidae family, boro baim (*Mastacembelus armatus*) of Mastacembelidae family, rita (*Rita rita*) of Bagridae family, chital (*Notopterus chitala*) of Notopteridae family, rani (*Botia dario*) of Cobitidae family, and gharua (*Clupisoma garua*) of Schilbeidae family.

A single CR species is baghair *(Bagarius bagarius)* under the family of Sisoridae. The CR are those fish species which passing a very critical condition that will be disappeared in near future. During the study period 2 species were recorded as extinct which were available one or two decades ago. These 2 species named- mohashol (*Tor tor*), and nandina (*Labeo nandina*) were documented frequently as extinct. Conversely, it was informed that the CR fish species would be extinct in near future.

In percentage, among the five categories (IUCN, 2015) of available 75 fish species, LC species consists 58%, NT species consists 16%, VU species consists 14%, EN species consists 10%, and CR consists 2% (Figure 5). Here, 19 fish species (26% of the total recorded species) were recorded as threatened species. Joadder *et al.* (2015) recorded 28 species of fishes as threatened by IUCN at the river Padma and categorized as VU (13%), EN (18%), and CE (8%). Kamrujjaman and Nabi (2015) documented 52.08% threatened species in the Bangshi River of Bangladesh in which VU, EN and CE were 20%, 36% and 44%, respectively. Rahman *et al.* (2015) revealed that 32.14% of fish species were threatened in the Talma River of northern part of Bangladesh, and documented 12.5% as VU, 16.07% as EN and 3.57% as CE species among the total threatened fish species. Chaki *et al.* (2014) identified 30 locally threatened species among which VU 13.51%, EN 18.92%, and CE 8.11% were recorded at the Atrai River of Bangladesh. Galib *et al.* (2013) found 41.27% species threatened including 15.87% VU, 15.87% EN and 9.52% CE fish species at the river Choto Jamuna of Bangladesh. Mohsin *et al.* (2013) considered 26 species threatened by IUCN Bangladesh including VU (13.04%), EN (13.04%) and CE (8.70%) of the total fish species from the Padma River at Rajshahi district. The threatened fish species with their various percentages of categories of different small and big rivers of Bangladesh slightly too largely differed from the present study due to various manmade and natural factors.

During the survey with the respondents of the present study, two species of fishes namely mohashol and nandina were not found in the study area which were available before 10-20 years. Chakraborty and Mirza (2010) studied and recorded six important commercial aquatic species, mohashol, nandina, olive barb and reptiles as extinct species from the Someswari River during 2001-2005. The excess fishing pressure, different geographical locations, water flow, and suitability of feeding, breeding and nursing grounds of different waterbodies cause different calculation and identification of threatened fish species from the Juri River.

Monthly variation in fish availability

During this study maximum number of species (61) were found in October followed by September (56), August (45), November (49), December (39), May (31), June (29), and lowest numbers of species (22) in July. However, in the study area the amount of fish caught was abundant during September to November (Figure 6). The availability and abundance of the fish as observed during the period of study were closely related to seasonal variations and fishes were found to be more available in the Juri River immediately after rainy season. With exceptions of a few occasions, fishes were available round the year. However, all species could not be easily caught by the used fishing gears due to the extent of water flow and depth variation in the river basin. Khan *et al.* (2018) recorded maximum number of fish species from Kolavanga *beel* during the month of August (35) followed by September (29) and October (25).

Ahmed (1997) observed that seasonal fluctuation in the fish species is a normal phenomenon and concluded that some species were found throughout the year. Haque (2013) recorded 31 species of fish in Baikka *beel*. The maximum number of species in both wetlands was found during the month of August. It was reported by all the respondents that the availability of fishes has been declining due to various manmade and natural reasons.

Conclusion

The Juri River is naturally an aquatic resourceful river in the north-eastern part of Bangladesh. Since, it is an interconnecting body of water between two important waterbodies of Sylhet region (Hakaluki *haor* and the Kushiyara River) its ecosystem plays a dynamic role in supporting the ichthyofaunal diversity. It was perceived from the fishers and visiting fish markets around the study area that about 42% species of fishes were less available and rarely available which might be disappeared from the study area in near future. From the statement of the respondent's habitat degradation, climate change, and human activities are found to be responsible for ichthyofaunal diversity loss in the Juri River. It can be concluded that proper management measures should be taken including community participation to conserve the overall aquatic ecosystem and enhance fish production in the Juri River of Sylhet district in Bangladesh.

Conflict of interest

The authors declare there are no conflicts of interest.

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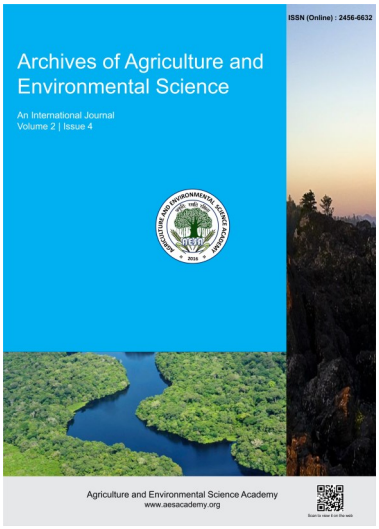

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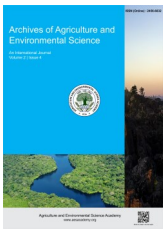

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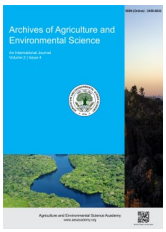

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