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Valuation of soil ecosystem services of organic farming agroecosystem as an approach to natural resource management at Gasa, Bhutan

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ABSTRACT: Bhutan officially commenced organic farming (OF) since 2004 declaring Gasa as 100% organic district. OF is one of the proven approaches to improve soil quality. Therefore, the value of soil ecosystem services (ES) of organic agroecosystem were studied at Gasa, Bhutan. Study was carried out at Goenkhatoe and Goenkhamae gewog (village block) under Gasa district. The ES was assessed include nitrogen, phosphorus, potassium (NPK), soil formation, and soil moisture regulation and carbon sequestration. The two comparative studies on the state of ES were performed: (1) between the two study areas and (2) among the soils growing carrot, garlic, potato, and the forest. The economic value was determined using the cost avoided valuation method. The economic value was estimated from the total cultivated area of 296.36 acres (farms growing certified crops: carrot, garlic and potato). Results showed that soil quality was good enough requiring no external synthetic inputs to provide ample ES without compromising the crop yield. The soil ES of OF was found higher at Goenkhatoe than Goenkhamae. When comparing the ES of soils of OF and forest, the ES were not significantly different except for nitrogen and phosphorus. Moreover, farmers could avoid the cost of USD 21,124.03 for not having to buy NPK fertilizer, USD0.406 from soil formation, USD 824,939.11 from carbon capture and USD345,501 for not having to irrigate field. This study reveals OF has the potential to enhance soil ES by sustaining the good soil quality. Moreover, OF could reap huge economic benefits for not having to depend on external inputs. These findings would provide holistic knowledge about the potential of OF in soil ES provision for the decision makers and other farmers to make authentic decision. However, we recommend conducting similar studies at a regular basis since the result is subject to vary over time due to varied geophysical factors. An aggregate of such results over time would contribute to better decision making.

Keywords: bhutan, sustainability, certified crop, economic valuation, ecosystem service

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Introduction

Bhutan is situated in the eastern Himalaya with a total geographical area of 38,394 km^2 (National Statistics Bureau, 2017b). Bhutan is popular by its development philosophy, Gross National Happiness (GNH). GNH aligns country's progress as per the holistic vision, "Bhutan 2020: A vision for Peace, Prosperity and Happiness" (Planning Commission, 1999). Under this vision, agriculture is identified as one of the five jewels (hydropower, agriculture, tourism, cottage and small industries, and mining) (Dendup et al., 2017); 66% of the population depends for their livelihood on agriculture (National Statistics Bureau, 2017a). Moreover, the initial study on the value of ES from the crop land was USD1,831 in a year per hectare (Kubiszewski et al., 2013).

Discerning the priceless value of natural environment, Bhutan embraces conservation of natural resource conservation amidst the development of five jewels. The natural resources are the life sustaining stock and provides infinite economic value in the form of ecosystem services (Costanza et al., 1997). As a result, the country introduced "high value low volume green services and products" as a strategy to safeguard the detrimental impacts. The concept of organic farming (OF) was reiterated as one of the approaches to streamline this strategy (Gross National Happiness Commission, 2013).

Costanzo and Bàrberi (2014) stated that OF is the hybrid of natural ecosystem providing similar ES. It is the manufactured ecosystem regulating the flows of materials, energy and information from the natural ecosystem which has the potential to enhance the health of the soil organisms. Ultimately, healthy soil organisms boost the soil ecosystem services (Barrios, 2007). The most prominent services include supporting services: primary nutrient and soil formation; and regulating services: moisture regulation and carbon sequestration. Thus, OF stabilize the life on earth which is not realized in actual sense due to the lack of standard economic measures.

The plausible benefits of OF in environment triggered the Royal Government of Bhutan to adopt it. Therefore, Bhutan started 100% organic with Gasa district since 2004, where major cultivation is done in Goenkhatoe and Goenkhamae gewog (village-blocked). As of now three vegetables: carrot, garlic and potato are organically certified.

The ecological intensification which is one of the models of OF (Tittonell, 2014) is in practice at Gasa. According to Rolando et al. (2017) such a farming approach has the potential to foster regulating and supporting services of the soil.

Jónsson et al. (2017) stated that despite multiple benefits in regulating the natural resources, the value of soils are rarely appreciated due to the absence of direct economic value. Valuation should be done to heighten the public awareness and help foster government support for greater adoption of sustainable practice (Daryanto et al., 2019). Thus, study was conducted to value the soil ecosystem services in organic farming agroecosystem as an approach to natural resource management at Gasa, Bhutan.

Materials and Methods

Study area

Bhutan is a landlocked country with rugged terrain and fragile ecosystems lying in Southeast Asia. Altitude ranges from 100 to 7500 meters above sea level favoring six different agroecological zones (Policy and Planning Division, 2016). Only 7% of the total geographical area is cultivable and as of now only 2.93% is under cultivation (Royal Society for Protection of Nature, 2016).

Gasa district is in the northwest of Bhutan comprising four gewogs (village blocks): Laya, Lunana, Goenkhatoe and Goenkhamae. Laya and Lunana gewog lying in high altitude experience severe climatic condition limiting the diversification of crops (Gasa Dzongkhag Administration, 2017). Thus, peoples' livelihood depends on cordyceps and livestock.

The study was conducted at Goenkhatoe and Goenkhamae because climatic condition is favorable to produce different cultivars of crops. The organic farming was officially started since 2004. As of now, National Organic Program and Bhutan Agriculture and Food Regulation Authority had given organic certification to three vegetables: carrot, garlic and potato. Carrot is cultivated in the month of March and harvest by the end of June, garlic is cultivated in the month of early March and harvest by early June, and the potato is cultivated in February and harvested in the mid of June. The farmers practice mixed farming, crop rotation, keep farmland fallow during off seasons, and use farmyard manure for fertilizer. No chemical is used in the farm.

This study compared the value of ecosystem services between Goenkhatoe and Goenkhamae, and among the three certified crops and the forest. The comparison between two study area was done because of the variation in physical factors namely altitude and types of crops grown. Goenkhatoe lies at an altitude of 2300 to 2900 meter above sea level (masl) and Goenkhamae at an altitude of 1500 to 2500 masl. Due to which the paddy cultivation is not done in Gonkhatoe. The total cultivated area is 296.36 acres (293.91 acres at Goenkhatoe and 0.45 acres at Goenkhamae). The comparison among three certified crops and forest were made to study the value of ES from the soils growing each of the crops and forests.

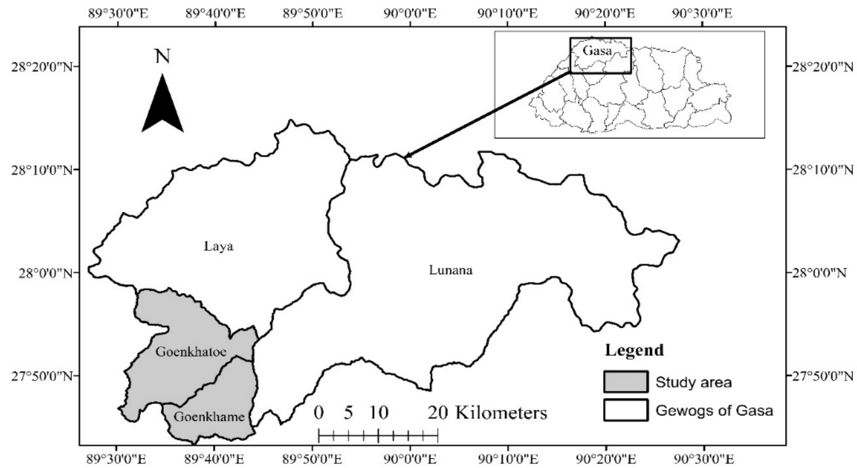

Fig. 1. Map showing the study area

Selection of ecosystem services

An exhaustive list of ecosystem services (ES) was prepared and grouped under each category of services based on Millennium Ecosystem Assessment (2005). Then the ES were selected (**Table 1**) based on the availability of the substitutable services (synthetic inputs) used in conventional agriculture in Bhutan. The carbon sequestration was determined to assess the contribution of OF on Bhutan's pledge of remaining carbon neutral. García-Palacios et al. (2018) stated that OF is found more effective in carbon sequestration than CF.

Soil sampling

Soil samples were collected during the month of June 2018 and the sampling site was selected based on the judgement sampling technique (Pennock et al., 1993). The judgement was based on the field on which certified crops were grown (carrot, potato and garlic) and for potato field, samples were collected from the field on which potato was not harvested and excluded the harvested field. However, carrot was not harvest and garlic was harvested during the time of sample collection. Soil samples from the filed growing garlic was collected after harvest, potato just before harvest and carrot before three weeks to harvest. Soil samples from the forest was collected based on the similarity in the slope and agriculture field.

The total of 30 composite soil samples (10 each from fields growing carrot, garlic and potato) were randomly collected. Soil samples from the forest nearby agriculture field was also collected to compare the state of ES from OF in relation to forests. The samples were collected using soil augur at 0 to 20 cm depth. This was done as per Zanner and Graham (2005)'s statement that pedologic processes influence is stronger at this range due to sunlight and precipitation reach.

Laboratory analysis

Soil sample analysis was conducted at the laboratory of College of Natural Resources (CNR) in Bhutan. The soil samples were air-dried at ambient temperature for 15 days. Then homogenized using mortar and pestle and sieved through 2 mm mesh. Sieved soil was stored in sealed plastic bag until analysis.

1.1. *Analysis of soil ecosystem services*

Each of the ES were analyzed for the state of soil ES provision and the economic value from the identified services in two study areas and the different certified crops grown. The Independent *t* test and Mann Whitney test were conducted for parametric and nonparametric data respectively to compare the state of ES between Goenkhtoe and Goenkhamae. Analysis of Variance and Kruskal Wallis test were conducted for parametric and nonparametric data respectively to compare the ES of the field growing carrot, garlic, potato and forest.

Approximation of economic value was done using the avoided cost method. The value was estimated per unit area and multiplied by the total cultivated area of the study sites that is 296.36 acres.

Table 1 Ecosystem services (variables) and methods used for analysis

Variables	Method	Valuation method
Nitrogen	Kjeldahl method (Horwitz and Latimer, 1996)	
Phosphorus	Spectrophotometric molybdovanadate method (Horwitz and Latimer, 1996)	
Potassium	Flame photometric method (Horwitz and Latimer, 1996)	Cost avoided/ Avoidance expenditure Christie et al. (2007); (Tietenberg and Lewis, 2012)
Soil formation	Earthworm density (Sandhu et al., 2008)	
Organic carbon	Dry combustion method (Santi et al., 2006)	
Soil respiration	Titration method (Anderson, 1982)	
Moisture content	Dry combustion Method (Craze, 1990)	

Avoidance cost method is the indirect method to approximate the forfeit of the actual cost by opting for better alternatives (Tietenberg and Lewis, 2012). This study employed the approximation of the economic value of OF as the better alternative of CF.

Primary nutrient (NPK) analysis

Nitrogen was determined using Kjeldahl method; phosphorus by bray extracting solution using spectrophotometric; and potassium was determined using flame photometric.

The economic value was calculated based on the approximation of not having to use synthetic inputs in growing carrot, garlic and potato. The information on the cost of each fertilizer used for the production of identified vegetable was collected from the Policy and Planning Division (2016). The fertilizer recommendation for growing each crop was based on National Soil Services Center (2009). The total monetary value was calculated using the equation 2:

Cost of production per year = area of crop production in acres x cost of fertilizer per kg x recommended quantity of fertilizer (kg/acre) x frequency of application,………(1)

Where the total area of production was taken 296.36 acres that is the total cultivated dryland in Goenkhatoe and Goenkhamae.

Soil formation

The total of 10 composite soil samples were collected each from (certified crops) the soil volume of 25 cm^3 and the earthworm population was counted. Soil formation and its economic value was studied based on the method adopted in Sandhu et al. (2008). Authors based their method from Fraser et al. (1996) in which the mean biomass of an earthworm is 0.2 g; and had also used Pimentel et al. (1995)'s assumption that in a year 1 tonne of earthworms form 1 tonne of soil $hectare^{-1}$.

For economic value, the avoided cost of purchasing topsoil was considered. The cost of topsoil in Bhutan was estimated at USD 1 kg^{-1} (approximate cost based on farmers view).

Carbon sequestration

The carbon sequestered in the soil was determined using the equation from Pearson et al. (2007):

$SOC = \delta \times d \times \%C,$ ……………………(2)

Where SOC = soil organic carbon stock per unit area [kg m^{-2}]
δ = soil bulk density [gcm^{-3}]
d = the depth at which the sample was taken [cm]
$\% C$ = organic carbon content

The economic value was estimated based Clean Development Mechanism considering trading of carbon offset at USD 20 per ton of carbon. This is the shadow carbon price at which carbon trading could be done.

Soil moisture content

Soil moisture content was determined to analyze the required soil moisture content for growing each of the three crops.

Economic analysis was done based on cost of crop water requirement for each of the crops. It was estimated based on the length of growing period of each of the crop (i.e carrot 150 days, garlic 180 days and potato 130 days). The estimate water requirement for each of the crops were calculated from the cost of irrigation for water replacement. The cost was estimated at the rate of USD 0.1 day^{-1}.

Results

Organic farming practices

Carrot

The farmers started the interest in carrot since 2010 anticipating the huge commercial potential. Carrot is cultivated in the month of March that is by likely at the end of frost and harvested by the end of June. By the end of June to January, they supply to hoteliers at Thimphu, the capital city of Bhutan. It was learned that they plant carrot by making bed of with desired sizes (no standard bed size). After they are ready with the bed and soil preparation, seed is broadcasted, and add compost and cover crops such as artemisia to protect the seed. Moreover, such practice also helps boost soil fertility.

For fertilizer, farmers use farmyard manure and chopped artemisia. They use approximately 25 baskets (i.e. 1 basket is equivalent to about 10 kg) of farmyard manure per acre before the cultivation. At the certain stage, smaller quantity is used. They use juice extracted from walnut tree leaves and garlic for pest repellent and weeding is done manually.

Garlic

Garlic production is also on increase with increasing demand. The commercial level cultivation started since 2009 and ever since it is one of the highest incomes earning cash crops at Gasa. Farmers grow garlic from early March to Early June and start supply from June to September.

The soil is prepared by ploughing (or digging for smaller scale) and adding farmyard manure. Similar to carrot and potato, they use almost similar quantity of farmyard manure that is 25 baskets (i.e. 1 basket is equivalent to about 10 kg) of farmyard manure per acre. Weeding is done manually in all crops since no machinery is available. No heavy machine is used for growing crops.

Potato

The potato was found growing more in quantity than garlic and carrot. They grow potato from end of February to June and supply from July to November. It is one of the ever-growing crops that every household grows.

The use of farmyard manure is commonly used fertilizer in all crops including potato during soil preparation and some small quantity in between the growing period. The potato tubers are plated about 6 to 8 inches deep and make horizontal bed to check soil erosion. The insect's repellent, weeding and other management practices are done the same as carrot and garlic. After the harvest of the potato, they let the shoot (stem and leaves) rot on the farm to add nutrient to the soil.

Primary nutrients (NPK)

Results showed significant difference in NPK between the soils of Goenkhatoe and Goenkhamae (Error! Not a valid bookmark self-reference.). Mann Whitney test showed N was greater for Goenkhatoe (Mdn=0.10) than Goenkhamae (Mdn=0.08), U = 24.50, p = .001; and also, K was greater in the soils of Goenkhatoe (Mdn=320) than Goenkhamae (Mdn=131.50), U = 52.00, p = 0.044. Independent t test showed P was higher in the soil of Goenkhatoe (150.43 ± 28.35) than Goenkhamae (100.98 ± 10.07); $t(28)$=4.793, p=.000.

Table 2 Comparison of primary nutrients in two study areas

Study site	Nitrogen (N)[a]	Phosphorus (P)[b]	Potassium (K)[a]
	%	mg kg^{-1}	mg kg^{-1}
Goenkhatoe	0.10	150.43	320.00
Goenkhamae	0.08	100.98	131.50
	U = 24.50	t = 4.793	*U = 52.00*
p	.001	.000	.044

[a]= Mann Whitney test (value expressed as median), [b]=Independent t test (value expressed as mean)

When comparing soils growing certified crops and the soils of forest, there was significant difference in the N and P. N was highest in the soil growing carrot (0.11%) followed by garlic (0.10%) and potato (0.09%) (Error! Not a valid bookmark self-reference.). The LSD (Least Significant Difference) showed significant difference between the soils of forest to the soils of field crops. N was highest in the soils of forest (0.54%).

Table 3 Primary nutrients of soils growing certified crops and the soils of forest

	N[a]	P[b]	K[a]	Post hoc test for N				Post hoc test for P			
	%	mg kg^{-1}	mg kg^{-1}	1	2	3	4	1	2	3	4
1) Carrot	0.11	132.10	263.70		n	n	**		*	n	*
2) Potato	0.09	114.35	303.68	n		n	**	*		**	**
3) Garlic	0.10	163.75	447.65	n	n		**	n	**		n
4) Forest	0.54	188.80	152.75	**	**	**		**	**	n	
	F=7.891	H=7.045	F=2.211								
p	.020	.050	.062								

**=significant (p<.001), *=significant (p<.05), n=not significant, [a]=one-way ANOVA (value expressed as mean), [b]=Kruskal Wallis test (value expressed as median)

Since soils need no synthetic inputs, farmers could avoid the cost of synthetic fertilizer of USD 21124.03 from the total area of 296.36 acres per season in growing carrot, garlic and potato. They could save from potato, carrot and garlic of USD 5437, USD 4022 and USD 10665 respectively (**Table 4**). If farming system was conventional, then farmers had to spend USD 21124.03.

Table 4 Cost avoided from the production of carrot, garlic and potato by growing organic

Fertilizer used	Cost as of 2017 (USD kg^{-1})	Fertilizer recommendation (kg acre^{-1})			Cost of production (USD per 296.36 acres)		
		Potato	Carrot	Garlic	Potato	Carrot	Garlic
Urea for N	0.26	24	8	20	1843	614	1536
Suphala for NPK	0.49	16	4	30	2317	579.	4343
Muriate of potash for K	0.54	8	24	30	1276	3828	4786
Total					5437	5022	10665

The soil organic matter and soil respiration were analysed to assess their impact on nutrient content of the soil. It was found that soil organic matter and soil respiration were higher in the soils of Goenkhatoe than Goenkhamae.

Table 5 Soil organic matter and soil respiration of two study areas

	Soil organic matter	Soil respiration
Goenkhatoe	1.96	4.32
Goenkhamae	1.84	3.56

Soil formation

On average, the earthworm density at Goenkhatoe and Goenkhamae was 17 earthworms per cm^3. The minimum at Goenkhatoe was 4 and maximum was 28. At Goenkhatoe, there was uniform distribution at minimum of 12 to maximum of 21 earthworms per cm^3. However, there was no significant difference in the earthworm density between the two study areas as well as among the three certified crops and the forest (**Table 6**).

Study showed the mean earthworm population of 16.80, 15.80, 17.40 and 7.33 per cm^3 from the soils growing carrot, potato, garlic and the soils from forest respectively (**Table 6**). Using the methods described in Soil formation section (under Materials and Methods), on average 17 earthworms formed 0.0034 kg of soil in each 25 cm^3 and 0.406 kg in 296.36 acres.

Table 6 Earthworm population and soil formed in two study areas and the soils growing three different crops and the forest

		Earthworm density (Count cm^{-3})	Soil formed (kg $acre^{-1}$)
Study area	Goenkhatoe	16.65	0.40
	Goenkhamae	16.71	0.40
	t	0.032	0.063
	p	0.975	0.950
Crops and forest	Carrot	16.8	0.40
	Forest	7.33	0.38
	Garlic	17.4	0.42
	Potato	15.8	0.18
	F	0.001	0.004
	p	0.975	0.950

The earthworm has helped natural soil formation due to which farmers of Goenkhatoe and Goenkhamae could avoid the total estimated cost of USD 0.406 from total agriculture land of 296.36 acres.

Carbon sequestration

There was a significant difference in the carbon stock at Goenkhatoe (M=18.43, SD=2.67) kg $m^{-2}$and Goenkhamae (M=16.07, SD=2.63) kg m^{-2} at t(31)=2.181, p=0.037. However, there was no significant difference among the soils growing three certified crops and the forest.

The total cost accrued from carbon stock was USD 824,939.11 from the total area of 296.36 acres. USD 440,684.89 was from the average carbon capture of 18.43 kg m^{-2} in Goenkhatoe and USD 384,254.22 from the carbon capture of 16.07 kg m^{-2} in Goenkhamae.

Soil moisture regulation

There was no significant difference in the soil moisture content between Goenkhatoe and Goenkhamae. The mean moisture content was 9.78 % and 9.41% for Goenkhatoe and Goenkhamae respectively. Similarly, there was no significant difference in the soil moisture content of three certified crops and the forest.

The farmers could save average value of USD 345,501 from 296.36 acres of land. The cost avoided from carrot, garlic and potato was USD 131,298, USD12,7547 and USD86,657 respectively. This is because farmers need not irrigate which otherwise would incur approximately USD 0.1 per day (farmers view).

Discussion

Organic farming practice in the two study areas

The farming practices dominates the age-long traditional practices and where possible integrates the modern methods such as preparation of bedding. They practices mixed cropping and crop rotation which are considered rejuvenating strategies by Department of Agriculture (2006); Tashi and Wangchuk (2016b). According to Dinis et al. (2015), the mixed cropping, crop rotation and keeping the land fallow are environmentally friendly and sustainable approaches.

It was found that farmers grow diversity of crops. As per the statistics of Department of Agriculture, diversity in crops has been increasing. Barrios et al. (2018) stated that more diversity boost soil properties thus enhancing ES. Diversifying the crops and not using heavy machineries reduce soil compaction and sustain the health of the soil.

Another good practice was in-situ green manuring which include legumes adds diversity to the crop. Moreover, Thomas and Shantaram (1984) stated that legumes have the ability to supplement nutrients. Parker et al. (2013) also stated that the practice of companion cropping, is also a good approach in farming.

The existing farming system supports Kristiansen (2006) and Adesope et al. (2012) who stated that OF is the original and mainstream agriculture which is given more recognition with the discovery of harmful impacts of the CF. Moreover, National Framework for Organic Farming in Bhutan as described in Department of Agriculture (2007) reveals the potentiality of the system to nurture the health of the ecosystems embracing fairness and care for the current and future generations and the environment.

Primary nutrients (NPK)

The result showed that SOM plays vital role in nutrient enrichment especially in total N replenishment. Total N was higher in Goenkhatoe than Goenkhamae and SOM content in Goenkhatoe (mean=1.96) was higher than Goenkhamae (mean=1.84).

The total N and K was higher in the soils of Goenkhatoe where SOM content was higher than the soils of Goenkhamae. The results support He et al. (2016) that SOM plays vital role in nutrient enrichment. Moreover, there was a positive correlation between SOM and soil respiration, $r = 0.370$, $n = 33$, $p = 0.034$. This result aligns the findings of Moinet et al. (2016) that soil respiration determines the protection of SOM.

The total N was higher in the soils of the forest than the soils growing certified crops. Moreover, N in the soils growing carrot was higher than the soils growing garlic which according to Thompson and Kelly (1985) should be vice versa. Authors stated that carrot and potato have the high NPK removal potential than the garlic whereby a yield of 10 tons of carrots remove about 100 pounds of K, 18 pounds of P and 32 pounds of N. A good potato crop in California removed about 150 pounds of N, 35 pounds of P_2O_2 and 250 pounds of K_2O. The conflicting result could be because the soil sample from the carrot was collected before the harvest and samples from the field growing garlic was harvested just after the harvest. Carmo et al. (2017) stated that harvest of crop biomass removes the NPK.

The existing NPK replenishing practice such as crop rotation with leguminous crops, keeping the land fallow during off-seasons, planting shrubs around the fields, adding biomass in the form of leaf litters and farmyard manure should be sustained. Carmo et al. (2017) stated that such practices have the potential to replenish NPK in a natural way.

Whatsoever, this study revealed that the NPK in the study area was adequate for the crops without compromising the yield. Wangmo and Iwai (2018) reported that the organic crop yield in the study area is in increasing trend. This result contrasts the report of National Soil Services Center (2009) that the soils in Bhutan in general are deficient in NPK. The adequate NPK from this study indicates that OF has the potential to retain the soil nutrients without having to apply the synthetic inputs. Indeed, a number of studies showed that OF has the potential to improve soil nutrient reaping huge economic benefits (Das et al., 2017; Naumova-Mihajlovska, 2017; Novikova et al., 2017; Tashi and Wangchuk, 2016a).

Moreover, farmers could reap huge economic benefits by avoiding the costs of buying synthetic inputs which otherwise could have incurred for CF. This study supports Carls et al. (2018), Sandhu et al. (2008) and Sandhu et al. (2010) that OF is not only environmentally sound but also economically beneficial than the CF.

Soil formation

Study showed that the earthworms have helped produce nutrient rich soil. The soils containing highest number of mean earthworms showed high nutrient content. According to Pfiffner (2014), earthworms are the architects of the fertile soil. Earthworms play vital role not only in soil formation but also in maintaining fertility of the soil (Garibaldi et al., 2018; Sandhu et al., 2010). Earthworm activities bring up sub-surface soil between 10 and 500 tons ha^{-1} $year^{-1}$, providing nutrients in the plant root zone and aiding the formation of approximately 1 ton $hectare^{-1}$ in a year of topsoil (Pimentel et al., 1995).

According to Iwai et al. (2008) farming without using chemicals had higher earthworm cast than those using chemicals. Thus, continued practice of OF would accrue more benefits. Sandhu et al. (2010) states that more the earthworm population better the soil formation. And better soil formation halts from relying on external inputs.

OF contains higher earthworm population due to lesser disturbance than the conventional system (Morvan et al., 2018)erosion and crusting in a silty. This means proper management is inevitable to sustain the nutrient rich soil. Sandhu et al. (2010) reported that one detrimental caused to earthworm population reduction is the intensive arable farming whether OF or CF. Also, earthworms are found more responsive to OM. Costanzo and Bàrberi (2014) stated that OF have similar functions as natural ecosystem. Such practice would help nourish the health of the earthworm. OF in Bhutan does provide conducive environment for earthworm nourishment.

Having maintained the healthy earthworm has helped farmers reap economic benefits by not having to buy topsoil and external soil nutrients. The similar study in New Zealand by Sandhu et al. (2005) found that the mean values for organic fields was USD 6.06 ha^{-1} yr^{-1} and for non-organics was USD4.56 ha^{-1} yr^{-1}.

Carbon sequestration

Study found that the carbon sequestration was relatively higher in the agroecosystem than the forest. Also, the value was higher compared to the study done on forest by Suberi et al. (2018). Carbon accumulated by garlic (19.05 kg/m^2) was highest and lowest was for the soils of forest (17.48 kg/m^2). The possible reason could be as stated in Pfiffner (2014) that earthworm helps enhance carbon sequestration potential where earthworm density was higher in the soils growing garlic. Carbon sequestration helps increase SOC density, improve depth distribution of soil organic carbon (SOC) and carbon is protected from microbial processes (Lal, 2004, 2018). SOC in turn improves stability of soil structure, ensure enough aeration and water infiltration. Farming practices such as residue management, minimum tillage or conservation agriculture increases the carbon sequestration of the soil (Sandhu, 2007; Sandhu et al., 2010; Sandhu et al., 2008).

Since OF has the potential to sequester C and reduce greenhouse gas than conventional one as stated by Meng et al. (2017), farmers could save the cost incurred to install IGCC plant. OF enhances top SOC stocks in croplands compared with conventional farming, which can contribute to sequester C (García-Palacios et al., 2018)2018. This is the clear evidence that OF has high C capture potential than conventional one which means OF yield more economic benefits than the conventional one.

Soil moisture regulation

Carrot, garlic and potato in the study area grows on rainfed and no irrigation throughout the season. In the process, the yield was not compromised (Wangmo and Iwai, 2018). Thus, this study support Sandhu et al. (2007); Sandhu et al. (2008) and Sandhu et al. (2010) that OF proved to maintain higher levels of soil moisture than CF.

As a vital component of the hydrologic cycle, soil moisture dynamics can be altered by various factors, including climate (e.g., precipitation, temperature, wind, etc.), soil (e.g., soil texture, organic matter, porosity, aggregation, bulk density, etc.), topography and land use/land cover characteristics (Jia et al., 2017). Jia et al. (2017) stated some tree species like *C. korshinskii* lead to declining soil moisture. Thus, introduction of new plant species needs to be studied not only in terms of yield and adaptability by such impact as well.

The farmers could reap huge economic benefits for not having to irrigate their farm. Morvan et al. (2018)erosion and crusting in a silty stated that the available water content for OF and CF was 1.46 mm cm^{-1} and 1.23 mm cm^{-1} of soil respectively. They stated that their finding was in consistent with that of Hathaway-Jenkins (2011), who found that for different soil textures, higher maximum water holding capacity in organically managed compared to conventionally managed soils. These findings revealed that OF is the viable option for reducing the use of water ultimately cutting the economic cost.

Conclusions

We found that the OF agroecosystem in the study area had farming system in place that rejuvenate varied natural resources in the soil. This has provided varied soil ES which ultimately provided better economic benefits than CF. The well maintained OF agroecosystem could nourish soil, thus, the cost incurred for buying external inputs was avoided. This finding has supported numbers of other studies who stated that OF can be a better alternative to CF. The positive results from this study complies with the

Royal Government's endeavor to 100% organic. This initial study on this subject highlight the important soil ES in OF. These findings would provide knowledge about the potential of OF in soil ES provision for the decision makers and other farmers to make authentic decision.

However, the scope of this study is limited to the services identified, the crops selected and are specific to the study site. Also, the results are based on the samples collected during the month of June. Future studies exploring other ecosystem services such as biological pest control and pollination by analyzing service in different crop growing stages should be carried out for additional scrutiny.

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