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Soil Quality and Productivity in Organic Farming in Context of Nepal: A Review

[1]Biboss Maharjan ; [2]Dhurva Prasad Gauchan ; [3]Janardan Lamichanne
[1]Department of Biotechnology School of Science, Kathmandu University, Dhulikhel, Kavre, Nepal
E-mail: bibossmaharjan@gmail.com ; E-mail: ljanardan@ku.edu.np

ABSTRACT

Soil of organic farms has been found with more biological diversity and microbial activity than the conventional farming system. Majorly organic farming has enhanced the biological soil quality indicators: Microbial biomass carbon (MBC), Microbial biomass nitrogen (MBN), enzymatic activities and soil microbiological diversity. In most cases, increase of microbial biomass was greater than 50%. Likewise, environmental benefits of organic farming are more compare to conventional farm with natural ecological harmony. Although there still lacks a huge realm to be explored in the field of organic farming especially in the developing countries including Nepal. Legal framework with scientific Research relating to organic farming necessarily needs to be explored more in order to the ground development of organic farming in Nepal.

. KEYWORDS: Soil, Soil quality, Organic farming, Conventional farming

INTRODUCTION:

Around the dawn of 20th century organic farming emerged at different regions of the world (Aterya, 2015) and its growth, popularity and importance started from 1990 onwards majorly in European countries and US, immediately after expansion stage (1970-1990) (Shi-ming & Sauerborn, 2006) mainly because of increment of awareness among people about environment and food safety (Bowen, 2001). Further acceleration of organic farming's growth took after the recognition of sustainable agriculture by Food and Agriculture Organization (FAO); due to worldwide concern of chemical contamination in agriculture in "The world Food Summit Plan of Action (1999)".

Organic farming has four renowned principles: 'the principle of health', 'the principle of ecology', 'the principle of fairness' and 'the principle of care'. The IFOAM General Assembly in Italy, June 2008 defines organic agriculture as "a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved".

In comparison with chemical based intensive conventional farming, Organic farming have advantageous impacts on the various aspects of environment alike soil, water, biodiversity, human health (Lampkin, 1990; Gracia & de Magistris, 2008; Aldanondo-Ochoa & Almansa-Sáez, 2009) and majorly on agriculture soil with its huge impact on enrichment of the soil quality (Hansen *et al.*, 2001; Shannon *et al.*, 2002; Marinari *et al.*, 2006; Flohre *et al.*, 2010; Wani *et al.*, 2013). Therefore, this review primarily discusses various examples to illustrate the role of organic farming in enhancing the soil quality and important indicators to be included in defining the soil quality. In addition, review attempts in finding gap in studies relating to soils of organic farming and reasons behind it, for the further improvising and developing the organic farming in Nepal.

ROLE OF ORGANIC FARMING IN ENHANCING SOIL QUALITY:

Since the early 90's several studies had been carried out worldwide to determine the soil quality of organic farming system by making a comparisons with adjacent soil of conventional farming systems. Those studies have focused on different soil physical, chemical and biological processes and properties (Table 1).

Table 1: Majorly used soil quality indicators in organic farming in priority basis from 1 to 3

Soil Properties and Processes	Indicators Used
1. Biological Properties and Processes	Microbial Biomass Carbon
	Microbial biomass Nitrogen
	Enzyme activities
	Soil DNA Content
	PLFAs, CLSU, T-RFLP
2. Chemical Properties and Processes	Soil pH
	Soil Organic Matter content
	Total Nitrogen
	Available Phosphorus

	Available Potassium
	Cation Exchange Capacity
	Micro nutrients (Ca, Mg, Al, Mn, Zn, Br, Na, Fe)
3. Physical Properties and Processes	Soil Texture
	Bulk Density

Beside soil physical, chemical and biological indicators, soil of organic farms has been looked in terms of it productivity capacity by working on the yield difference between organic and conventional farms (Drinkwater *et al.*, 1995; Eltun *et al.*, 2002; Seufert *et al.*, 2012; Ponti *et al.*, 2013; Pimental *et al.*, 2015) and impact of organic farming on physical loss of soil on erosion (Siegrist *et al.*, 1998; Pacini *et al.*, 2003; Wood *et al.*, 2006; Wani *et al.*, 2013). However, in organic farming, for soil quality study, major effort has been given to soil biological properties and processes, because in conventional farm nutrients are directly derived from the chemical fertilizers used but in organic farming, nutrients are derived from the decomposed materials of various fractions of organic matter done by activity of soil microorganisms (Franzlubbers & Haney, 2006).

Soil Microorganisms, microbial biomass:

Soil microorganisms actively participate in nutrient cycling, transformation processes, soil aggregate formation as well as in plant pathology (Widmer *et al.*, 2006). Understanding and sharp knowledge of soil microorganisms are essential component in defining the soil quality (Widmer *et al.*, 2006; Gunapala & Scow, 1998). For the better understanding of soil microorganism's: analysis of microbial biomass carbon/nitrogen, soil respiration, enzyme activities and Phospholipids fatty acid has been profoundly used as soil quality indicators in comparing soil quality between organic and conventional farming system that indicates microbial population, activity and structure (Rice *et al.*, 1996; Dick *et al.*, 1996).

Soil microbial biomass influences the availability of amount of the carbon and other nutrients majorly N and P for plant growth and development (Jenkinson & Ladd, 1981; Marumoto *et al.*, 1982). Significantly higher microbial activity and biomass (described using six microbial variables) was found in the organic and low input farms than conventional farming system, conducted at the department of agronomy field facility in University of California from 1989 to 1993 where crop residues and manure were used as the carbon and nitrogen source for the tomato plant in organic and low input farming systems. Gunupala and Scow (1998) found that the amount of carbon entering the soil plays an important role in differentiating the microbial communities. Influence of environmental factor on microbial biomass was also examined in above mentioned research that gave a negative correlation between soil temperature and microbial biomass, and a positive correlation between soil moisture content and microbial biomass. In the same study area as of above(i.e. agronomy field facility in University of California) in 1996 a higher concentration of microbial biomass in moistened soil than air dry soil in organic and low input farm than conventional farming system was found (Lundquist *et al.,* 1999). In an extensive work, Hartmann *et al.*, 2015 reported greater concentrations of microbial biomass on average basis (37%) in organic farm system than conventional farm. Correspondingly, high percentage increment in concentrations of microbial biomass in organic farming system has also been reported in many other works (Mader *et al.,* 2002; Diepeningen *et al.,* 2006; Marinari *et al.,* 2006; Reganold *et al.,* 2010) in (Table 2).

Table 2: Average percentage increment of microbial biomass in soil of organic farms than conventional farming in three experiments (a) based on three time sampling, (b) based on three times sampling on different seasons and (c) based on total 13 number of samples

	Soil Depth (in cm)	**Percentage increment of MB in OF than Conventional farming (on Average basis) (in %)**	**References**
Moist Soil	Upper (0-3)	62.84[a]	Lundquist *et al.,* 1998
	Lower (3-15)	66.79[a]	
Dry Soil	Upper (0-3)	20.23 [a]	
	Lower (3-15)	58.04 [a]	
Microbial biomass carbon		38.63	Eltun *et al.,* 2002
Microbial biomass nitrogen		34.33	
MBC	Upper (5-20)	63.58[b]	Marinari *et al.,* 2006
	Lower (20-35)	54.09 [b]	
MBN	Upper (5-20)	125.56 [b]	
	Lower (20-35)	88.35 [b]	
Upper (0-10)		159.31[c]	Reganold *et al.,* 2010
Lower (20-30)		108.91 [c]	

Higher concentrations of microbial biomass due to application of different forms of organic amendments also evidently distinguished microbial communities in organic and conventional soils. Microbial community analysis was done with phospholipids ester linked fatty acids (PLFAs) where they found the ratio of mono unsaturated: saturated PLFAs increased with increasing organic inputs to the soils (conventional to organic), clearly distinguishing the microbial communities in the organic and conventional soils (Lundquist *et al.*, 1999). Related, Widmer *et al.*, 2006 in Switzerland with the analysis of soil DNA content, colony forming units (CFU) counts, community level substrate utilization (CLSU) patterns, terminal restriction fragment length polymorphism (T-RFLP) profiles of bacterial 16S rRNA genes and microbial biomass demonstrated higher soil DNA content in farm yard manure (FYM) receiving farming systems than farms without FYM, while both cluster analysis of the CLSU and T-RFLP clearly marked microbial community of two farming systems, which coincides with results of DOK (bio-Dynamic, bio-Organic, and "Konventtionell") field experiment in Switzerland indicating the type and quality of organic fertilizers determining the microbial diversity in soil (Hartmann *et al.*, 2015).

Physical and chemical parameters of soil: Different soil physic-chemical indicators showed the mixed results (Table 3) in comparing to soil quality of organic and conventional farming system. Alike use of majorly organic matter in soil leads to decrease in bulk density of soil in organic farming system than conventional one (Reganold *et al.,* 1993; Drinkwater *et al.*, 1995; BulluckIII *et al.*, 2002), whereas soil pH not significantly different among farming systems (Mader *et al.,* 2002; Diepeningen *et al.*, 2006; Marinari *et al.*, 2006). Furthermore, soil macro and micro nutrients also showed the diverse results. Increase in soil nutrients: calcium (Ca), magnesium (Mg), aluminum (Al), manganese (Mn) by 2-3 times in field plots of Virginia and Maryland, USA where organic manure(cotton-gin trash, cattle manure, hey manure and yard manure) were used as soil fertilizers compare to field plots where chemical fertilizers were used (BulluckIII *et al.*, 2002). Higher amount of calcium and magnesium in organic farms than conventional farms using manures and cover crops are also reported in Clark *et al.*, (1998) and Mader *et al.*, (2002). High cation exchange capacity (CEC), total soil nitrogen in organic farm are reported in Reganold *et al.*, (1993), Marinari *et al.*, (2006) and Reganold *et al.*, (2010) but phosphorus (P) and potassium (K) are reported lower in organic than conventional farm in Reganold *et al.*, (1993) and Mader *et al.*, (2002). Similarly, higher amount of ammonium, nitrate and total nitrogen were observed in organic farming system (with poultry and green manure use as fertilizers) compared to conventional farming system, but nitrate and ammonium concentration was least at time of November 2001. It might be due to problem of leaching at time of autumn rainfall (Marinari *et al.*, 2006) which was also indicated by lower level of Nitrate in organic as well as conventional farm in Netherlands (Dipeningen *et al.*, 2006). Beside the leaching or other environmental problems, soil physical and chemical parameters are majorly influenced by types of amendments used and type of production system followed on agriculture field (Bulluck *et al.*, 2002).

Table 3: Comparison table of major soil indicators of organic and conventional farming system

Organic Farming system		Conventional Farming system
Very High	Microbial biomass	Low
High	Microbial activity	Low
High	Biological diversity	Low
Low	Bulk density	Slightly high
High	Calcium, Magnesium, Aluminum	Low
High	Total soil nitrogen	Low
Slightly High	Cation exchange capacity	Low
Low	Phosphorus, Potassium	High
Very High	Soil organic matter	Low
Similar	Soil pH	Similar
Low	Productivity	High

Soil amendments not only influence soil physical and chemical properties but also the soil organic matter content. Soil organic matter is a complex matter (Brady & Weil, 2014) which includes dead plants parts, animals and microbial waste products in various stage of decomposition (Brady, 1995) primarily containing carbon as major element. In order to maintain the soil fertility in organic farms, we must consider the quality and quantity of soil organic matter (Bending *et al.*, 1998; Bosatta & Agren, 1999).

A study carried out in Switzerland for 21 long years to determine the soil organic matter and biological soil quality indicators in organic farming and conventional farming revealed that soil organic matter was greatly influenced by the type of manure being implied (Fließbach *et al.,* 2007). A study done in four different regions in England found out the higher concentration of soil organic matter in agriculture fields, but comparing the soil organic matter content of conventional farm and organic farm there was not much of significant difference, implying to the management practices that needs to be approached in different farming practice to enhance soil organic matter (Gosling & Shepherd, 2005). Similar results were shown in a research done in United States about soil organic matter in organic farming system (Marriot & Wander, 2006).

Soil Productivity in Organic Farming:

While we are discussing about soil quality in organic farming, study on yield capacity of soil along with physic-chemical and biological considerations should also be done (Eltun *et al.,* 2002) because future of organic farming depends on whether it is competitive economically to conventional farming or not (Ponti *et al.,* 2002). Work done by Eltun *et al.,* (2002) in Norway has reported the reduction of yield of cereals crops followed with potatoes and forage crops in organic farming system. Study found reduction of yield in integrated and organic farm than conventional farm, reason being insufficient nutrient supply to plants. Although, the reduction in yield, economic return was more in organic farming than conventional farming system, as Norwegian government provide subsidy to organic farming and in addition to that organic products do get the premier price. Coinciding to above result, review work of Pimentel *et al.,* (2015) presented some examples of yield reduction in organic farm than conventional farm. Like reduction of 30-50% organically grown wheat and cereals (Mader *et al.,* 2002) crops in European field, 38% reduction of yield of wheat in New Zealand (Nguyen & Haynes, 1995), 7 % reduction of yield of sweet corn in organic farm than in conventional system in New Jersey (Brumfield *et al.,* 2000) but the high net economic return due to premium price in market as previously mentioned in organic farming than conventional farming.

Environmental Concerns in Organic Farming

Development of organic farming started mainly aiming to produce food in more environmentally friendly manner (Udin, 2014) by avoiding use of chemical pesticides and fertilizers (Leifeld, 2012). Environmental concern of organic farming has mainly dealt with soil erosion problems, nitrogen run off, leaching, energy and water uses in agriculture (Eltun *et al.,* 2002; Pacini *et al.,* 2003; Wood *et al.,* 2006). Regarding soil erosion, the problem was found to be associated with soil type and crop rotation in conventional farm and organic farm respectively of same slope landscape. That is, in conventional farm soil erosion was found to be 1.9 t/ha in clayey soil whereas it was 3.5 t/ha in sandy soil and for organic farming system erosion was 16.57 t/ha where there was rotation of barley and broad and it was 5.5 t/ha where the rotation was maize silage, barley, broad bean, maize and grassland (Pacini *et al.*, 2003) similarly mixed cropping systems with perennial grasses cover was found to better protection against soil erosion (Figure 1) (Eltun *et al.*, 2002). In addition, problem of nitrogen leaching or runoff is also more prone in conventional farming system than with organic practiced (Figure 2) (Eltun *et al.*, 2002; Wood *et al.*, 2006). The problem of nitrogen leaching was linked with regional pedo climatic conditions, different farm types and related crop rotations. Looking from the energy perspective view, organic farm was found to be more efficient overall energy requirement although the direct energy requirement of organic farming was high (Wood *et al.*, 2006).

Figure 1: Annual soil losses (kg/ha) in different cropping system in Norway

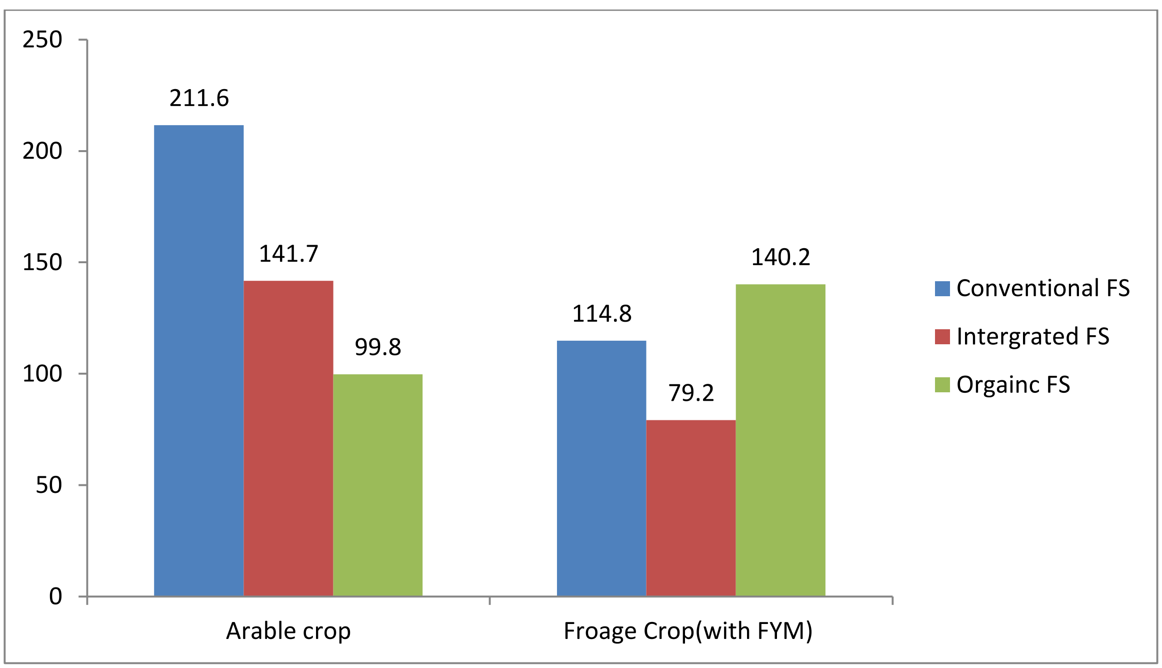
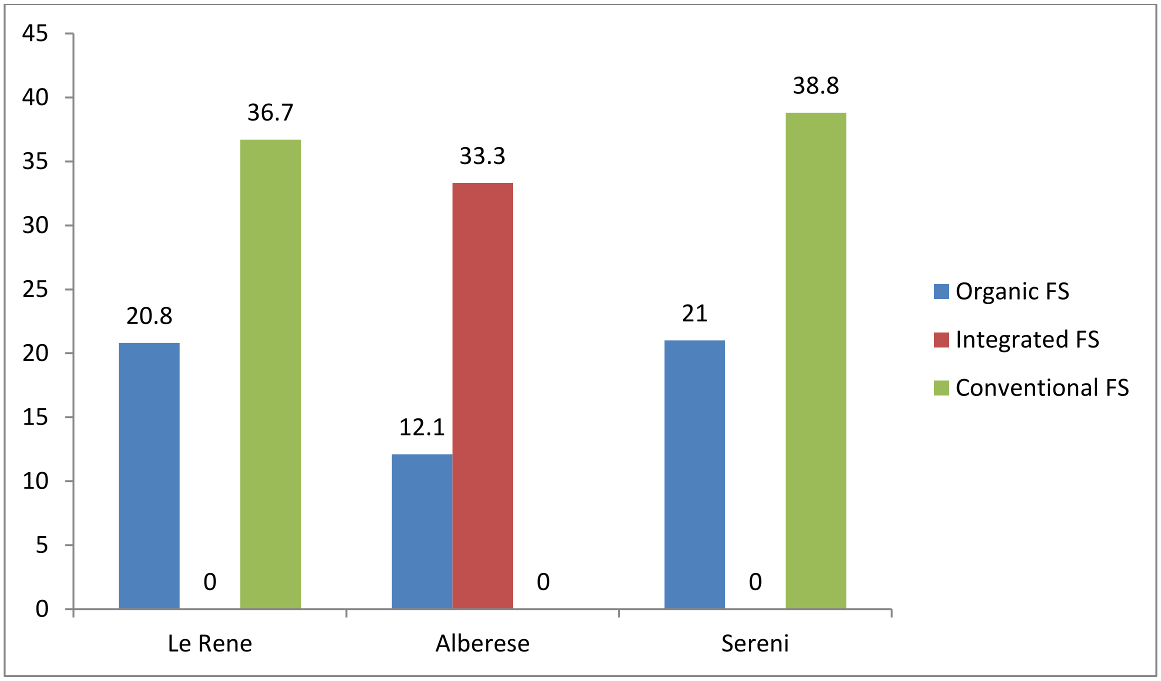


Figure 2: Nitrogen Losses (kg/ha) in different fields of Italy



SOIL QUALITY STUDIES IN NEPAL AND GAPS IN ORGANIC FARMING:

For the determining discreet effect of organic farming in soil environment, comprehensive review of majority studies encountered provided information about work conducted in developed world; which has been lacking in developing world, including Nepal.

Over the years, considerable research has been conducted in Nepal in the field of soil science (Desbiez *et al.*, 2004); research has focused on various aspects of soil as well as agriculture relating to soil (Figure 3) but there is still no existence of study dealing with soil biological quality (Bajracharya *et al.*, 2007) while Begum *et al.*, 2011 has done some work on assessing soil quality using biological indicators that is Micro arthropod communities assessment. Those studies have revealed some crucial outcomes (Table 4) which must as soon be addressed for the sustainable soil management.

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Figure 3: Pictorial representation of different soil studies that has been carried out in Nepal

STUDY RELATED TO SOIL IN NEPAL

SOIL	REFRENCES
→ Quality assessment using micro arthropod communities	Begum *et al.*, 2011
→ Quality affected by different land use systems	Begum *et al.*, 2009 Chauhan *et al.*, 2014 Bhattari *et al.*, 2014
→ Quality affected by different slope aspects	Begum *et al.*, 2010
→ Fertility status in different land use systems	Regmi and Zoebisch, 2004 Shrestha, 2009
→ Carbon stocks in soil aggregate in different land use system	Shrestha *et al.*, 2004 Shrestha *et al.*, 2007 Upadhyay *et al.*, 2005 Dahal *et al.*, 2014 Poudel at al. 2014
→ Erosion and nutrient losses	Shrestha, 1997 Aterya *et al.*, 2002 Gardner and Gerrard, 2003 Dahal *et al.*, 2006 Tiwari *et al.*, 2009
→ Fertility management by organic inputs and farmers indigenous knowledge	Desbiez *et al.*, 2004 Chaudahary *et al.*, 2006 Dahal and Bajracharya, 2013

Table 4: Impact on soil due to more chemical intensive farming in various regions of Nepal.

Agriculture Practices	Impact on Soil/Environment	References
Chemical based intensive agriculture	Increased acidity of the soil	Raut *et al.*, 2012
	Low soil fertility	Dahal *et al.*, 2007 Raut *et al.*, 2010
	Ground/surface water pollution	
	Air pollution	
	Soil fertility decline in mid-hills Nepal	Shrestha 2009
	Soil OM decline in Terai belt of Nepal	Chaudhary *et al.*, 2006
	Low level of soil macro nutrients	Regmi and Zoebisch, 2004
	Soil Pollution	Palikhe, 2006

For the future sustainable soil management, these problems must be addressed in concerning the agriculture productivity for today's population. Organic agriculture could be the better option for tackling these problems, in which the limited study has been carried out in Nepal. Nevertheless, few works on soil fertility management through the inputs of organic amendments in agriculture field has been carried out (Bhattari *et al.*, 2006; Chaudhary *et al.*, 2006; Shrestha 2009; Pandey *et al.*, 2014), but a systematic and extensive study focusing on soil of organic farming has not yet been done in Nepal. Reasons behind it are stuck with the problem of organic farming in Nepal at policy level and lack of skill manpower and technology.

PROBLEMS AND POTENTIAL OF ORGANIC FARMING IN NEPAL

Traditionally, Nepalese farmers have been practicing the organic farming, and it's a culture and tradition of Nepalese people (Bhattari *et al.*, 2006) but with the rise of "Green Revolution" chemicals and pesticides were intensively used in agriculture worldwide and Nepal with no exception, and after the initiation of chemical pesticides (DDT and BHC) in 1995 for the control malarial disease focusing on public health, the use of pesticides got ever increased in Nepal (Sushma, *et al.*, 2015). With this concern, Government of Nepal, introduced the term "Organic Farming" in order to reduce use of chemical pesticides in the 10^{th} five year plan (2002-2007) (Atreya, 2015). Within 20 years starting from 1995, Government of

Nepal has developed 11 set of rules (Plans, Policies, Strategy, Guidelines) relating with the agriculture. But, still there is ambiguous vision of policy and guideline markers on organic farming. Ambiguity is prevailed in these sets of rules, for examples, "Agriculture Perspective Plan 1995" and "Nepal fertilizer policy 2002" are entirely against norms of organic farming whereas some polices (National Agriculture policy, 2004; Agribusiness Policy, 2006) are mainly focusing towards 'economy' and 'export market', rather than true principles of organic farming. Still, National Standards of Organic Agriculture Production and Processing, 2007 has set some guidelines for development of organic agriculture in Nepal, but still lack true vision on organic agriculture.

Beside government's lack of true vision on organic agriculture, there is a huge potential of transforming our traditional agriculture into organic agriculture, as the 26% of total agriculture land (800000 ha) of Nepal, is still free from the synthetic fertilizers and pesticides (Aterya, 2015) as well as urban market for organic products is also increasing (Bhatta *et al.*, 2008a). Furthermore, agriculture has becoming a less attractive profession to younger generation, so an approach of involving the younger generation into organic agriculture surely built a new bridge between young entrepreneurs and agriculture (Dahal, 2011).

CONCLUSION:

Presently, there is a huge potential and opportunities in organic farming in Nepal. But, the questions here are the various problems related to organic agriculture in Nepal both from policy level and farmer's level. Therefore, there is necessity of conducting the ground level research both from the governmental level and institutional level in soil science, plant nutrient management, plant pathology, pest management, social sectors, market feasibility and public preferences of organic farming in Nepal. Among which, soil science and plant nutrient management has to be given more concern and priority since it is the basis for agriculture. Grassroots level research on different aspects of soil sciences, with the facilitation from governmental organizations, universities, INGOs and NGOs should be initiated, in order to develop a new platform for the further development of the organic farming.

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