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Soil Properties and Soil Management Practices in Commercial Organic and Conventional Vegetable Farms in Kathmandu Valley

Gautam Shrestha
Himalayan College of Agricultural Sciences and Technology (HICAST), Kathmandu, Nepal
e-mail:shresthagautam@live.com

Abstract
Soil management practices determine the long term productivity of soil. A comparative study of commercial organic and conventional vegetable farming systems was carried out to find out impact of different farming systems on soil properties. This study was executed in Kathmandu valley (Kathmandu, Bhaktapur and Lalitpur districts) among 30 organic and 30 conventional commercial vegetable farmers. Semi-structured questionnaire survey and soil physical and chemical analysis were performed to gather the required information. Results showed that bulk soil pH was significantly higher in the organic field than in the conventional field. Soil organic matter and available soil potassium were significantly higher in amount in the organic farm than in the conventional farm. Total soil nitrogen content and available soil nitrogen content were significantly higher in amount in the conventional farm than in the organic farm. Conventional farmers were applied significantly higher amount of chicken manure and biozyme as compared to organic farmers. Organic farmers applied significantly higher amount of urban compost and bone meal as compared to conventional farmers. Farmers perceived productivity was increasing in trend in the organic farms whereas it was declining in the conventional farms.

Key words: soil fertility, organic agriculture, conventional agriculture

Introduction
Soil is the natural resource in the earth which is the source of food for living organisms. With the dawn of agricultural civilization, human learnt to use soil for food production. To increase the productivity, later human started to add organic manure in the soil. This type of agriculture is known as traditional agriculture. This type of farming is still in practice in the remote parts of Nepal (MoAC 2008). Invention of ammonia synthesis process in 1909 and consequent development of Haber Bosch process provided an option to add nitrogen nutrient in easily available form through chemical fertiliser. Later on, human discovered mineral deposits of other plant nutrients (e.g. phosphorus, potassium and sulphur) as well. Human started to append different chemical fertiliser to increase crop productivity. This type of farming is termed as conventional agriculture. In consequence of excessive use of chemical fertiliser and pesticide, we saw environmental pollution, biodiversity loss, human health problem (Eyhorn *et al.* 2002, Hall & Moffitt 2002). We learnt conventional agriculture is not a sustainable option for the healthy mother earth. Hence, going back to the origin, human has given a new name to an age old agriculture 'organic agriculture'. With more insight and sophistication, organic agriculture is expected to fulfil the food demand of human population in the future as well (Badgley *et al.* 2007).

Organic agriculture movement was initiated in industrialised countries - Britain, Germany, Japan and the US in 1930s and 40s (Lotter 2003). Within a century of initiation, organic agriculture had spread in many parts of the world. Many studies have been conducted comparing organic and conventional farming systems. Comparative studies began with yield comparison (Mader *et al.* 2002), economics (Offermann & Nieberg 2000) and soil parameters (Lotter 2003).

Comparing soil properties, Birkhofer *et al.* (2008) established significantly higher soil acidity in the organic wheat farms in comparison to conventional ones in Switzerland. In contrast, Deria *et al.* (2003) found no significant difference in soil acidity between organic and conventional wheat farms in Australia. Clark *et al.* (1998) and Liebig & Doran (1999) presented significantly higher total soil nitrogen in the organic farm than in the conventional farm. In contrast, Clark *et al.* (1999) showed nitrogen availability is limited in the organic farming system. Monokrousos *et al.* (2006) found significantly higher extractable soil phosphorus content in organic asparagus field in comparison to conventional field. In contrast, Romanyà & Rovira (2009) indicated significantly higher soil phosphorus content in conventional farm in comparison to organic farm. Andrist-Rangel *et al.* (2007) compared soil potassium content between conventional farm and organic farm from 1987 to 2004 in Sweden and found non-significant difference. Lotter (2003) indicated that organic farm can either have significantly higher or no significant difference in soil potassium content than in conventional farm. Cardelli *et al.* (2004) revealed significantly higher soil organic carbon content in organic farm in comparison to conventional farm with vegetable crops. They published results after four years of research in which they were applying only chemical fertiliser in conventional farm. In contrast, Chirinda *et al.* (2010) established non- significant difference in soil organic carbon content after 11 years of experiment among different farming systems.

There are few studies on soil physical properties comparing conventional and organic farm. In the study conducted by Zeiger & Fohrer (2009), soil moisture content in the organic farm was relatively higher in comparison to conventional farm. Liebig & Doran (1999) revealed significantly lower soil bulk density in organic farm in comparison to conventional farm. In contrast, Schjønning *et al.* (2002) and Chirinda *et al.* (2010) showed non- significant effect of contrasting farming systems in the soil bulk density.

Concerning commercial agriculture, government of Nepal has started promoting commercial organic and conventional farming since 10th five year national development plan (2002 – 2007). The continued government support can be noticed in the Nepal Agricultural Policy, 2004 and Agricultural Development Strategy (ADS) (ADB 7762-NEP 2013) as well.

Many studies have been published comparing different cropping systems. However, studies on vegetable based systems comparing soil nutrient status in farmers' field are lacking. This study aims to give a small impetus on the real world scenario i.e. commercial vegetable fields of the suburbs in Kathmandu valley than experiment field situation.

Methodology

Study area

Kathmandu valley consists of three districts namely Kathmandu, Lalitpur and Bhaktapur. These districts are densely populated (Zurick & Rose 2009) areas in Nepal. Vegetable production is an age old traditional farming practice near the water resources in Kathmandu valley. Kathmandu valley is one of the areas with the highest vegetable productivity per unit area in Nepal (ABPSD 2012). Moreover, increasing population and demand for fresh vegetables have increased the area of commercial vegetable farming in the periurban areas in the valley. Furthermore, health conscious consumers dwelling in the city area are demanding for the organic vegetables; to supply the demand organic vegetable production area is also expanding (Bhandari 2006). The periurban commercial vegetable growing farmers in Kathmandu valley were selected for the study.

Questionnaire survey

Thirty farmers each growing vegetables following organic and conventional management methods were selected for the study. Questionnaire was prepared in Nepali language and pre-tested and amended before the survey. Farmers from Bhaktapur (15), Kathmandu (25) and Lalitpur (20) districts were interviewed using semi-structured questionnaire to gather information about soil management aspects of the farm. Questionnaire survey and soil samples collection were done from May 15 to June 15, 2013. Farmers applied fertiliser in the field recently in February, 2013.

Soil sample collection and analysis

Soil samples were taken from the soil depth of 0 to 20 cm. Both bulk and rhizospheric soil samples were collected from each farmer's field. For rhizospheric soil sample, soil from plant rhizosphere region was considered. For bulk soil sample, soil which was further away from the plant stand was taken. Soil samples for soil pH and available soil nitrogen determination were stored in the refrigerator.

For the determination of physical and chemical properties of soil, about 500 g of soil was air dried and sieved with 2 mm sieve and stored in the air tight plastic bags. Particle size analysis was done by Bouyoucos method with hydrometer, bulk density using measuring cylinder and particle density using pycnometer. Soil pH was measured using 0.01 M $CaCl_2$ (calcium chloride) solution with the glass electrode pH meter. Soil organic matter content was determined by Walkley Black method using 0.1667 M $K_2Cr_2O_7$ (potassium dichromate) solution. Available soil potassium content was determined with flame photometer using 1.0 N $CH_3CHOONH_4$ (ammonium acetate) extractant. Available soil phosphorus content was determined by modified Olsen's method with spectrophotometer using 0.5 M $NaHCO_3$ (sodium bicarbonate) extractant. Available soil nitrogen content was determined with steam distillation method using 1.0 N KCl (potassium chloride) extractant and MgO – Devarda's alloy. Total soil nitrogen content was determined by Kjeldahl digestion and distillation method using digestion mixture (Na_2SO_4 and $CuSO_4$). The details of the procedures followed are given in FRSRD (1980) and Shrestha (2012).

Results and Discussion

General characteristics

Duration of farming varied among farmers from just a year to 15 years of experience in commercial farming. One of the organic farmers was doing organic farming for 20 years. Organic farmers were involved in farming for more duration (five years) in comparison to conventional farmers (three years) (Table 1).

Table 1. General characteristics of commercial organic and conventional farms in Kathmandu valley

Parameters	Organic farm	Conventional farm	Level of significance*
Number of crops in a year	5.91 ±0.56	4.80 ±0.49	ns
Area of farm (Ropani)	10.5 ±1.81	17.69 ±4.09	ns
Years of farming	4.73 ±0.87	2.9 ±0.51	0.038

* Level of significance of difference between two farming systems tested with independent samples T test, ns = non-significant difference; 1 Ropani = 500 m^2

Crops

Data were taken on at the most ten crops from each respondent. Results showed that about 10% organic farmers grew ten crops in the field in a year whereas only 6% conventional farmers were growing ten crops with commercial purpose. Tomato was the main crop in both organic and conventional commercial vegetable farms in Kathmandu valley (Figure 1).

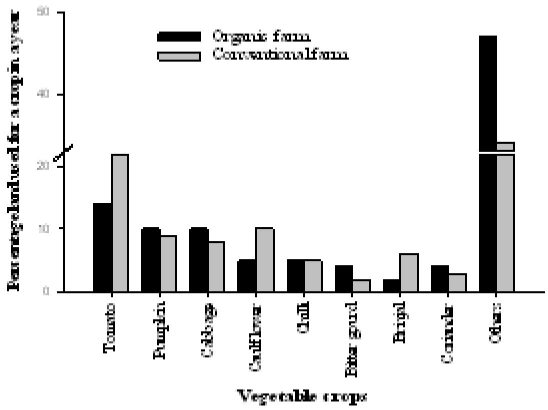

Fig. 1. Choice and diversity of vegetable crops in commercial organic and conventional farms (percentage coverage out of total area) in Kathmandu valley

Soil properties

Many organic farmers were growing vegetables in the coarse textured soil in comparison to conventional farmers (Table 2).

Table 2. Soil texture in commercial organic and conventional farms (percentage of soil samples out of 30 each) in Kathmandu valley

Soil texture	Organic farm (percentage)	Conventional farm (percentage)
Coarse	33.3	10.0
Medium	50.0	63.3
Fine	16.7	26.7

Organic vegetable farm had significantly higher bulk soil pH in comparison to conventional vegetable farm (Table 3). Available soil nitrogen content in the conventional vegetable farm was almost double in comparison to the organic farm. Total soil nitrogen content in the conventional vegetable farm was significantly higher in comparison to the organic farm. Available soil potassium content was significantly higher in the organically managed soil than in the conventionally managed soil (Table 3).

Table 3. Soil physical and chemical properties in commercial organic and conventional farms (mean ± standard error, out of 30 soil samples) in Kathmandu valley

Parameters	Organic farm	Conventional farm	Level of significance*
Soil physical properties			
Moisture content (percentage)	29.70 ± 1.44	30.52 ± 1.28	ns
Bulk density(g cm^{-3})	1.09 ± 0.02	1.08 ± 0.02	ns
Particle density (g cm^{-3})	2.09 ± 0.04	2.11 ± 0.02	ns
Soil chemical properties			
Rhizospheric soil pH	5.66 ± 0.11	5.54 ± 0.07	ns
Bulk soil pH	5.49 ± 0.09	5.29 ± 0.06	0.035
Organic matter (percentage)	7.24 ± 0.51	6.08 ± 0.28	0.016
Available nitrogen (ppm)	44.92 ± 18.21	85.68 ± 14.06	0.045
Total nitrogen (percentage)	0.22 ± 0.01	0.27 ± 0.01	0.006
Available phosphorus (P_2O_5 kg ha^{-1})	1241.36 ± 230.77	874.91 ± 96.31	ns
Available potassium (K_2O kg ha^{-1})	705.89 ± 111.17	513.11 ± 54.94	0.041

* Level of significance of difference between two farming systems tested with independent samples T test, ns = non-significant difference.

Fertiliser use

Chemical fertiliser was applied only in the commercial conventional vegetable farms (Table 4). Conventional farmers were applying 8 kg nitrogen, 5.5 kg phosphorus and 5 kg potassium per ropani using chemical fertiliser in a year.

Chicken manure was applied significantly higher in amount by conventional vegetable grower than the organic farmer. In contrast, urban compost and bone meal application was significantly higher in amount by organic farmer in comparison to conventional farme (Table 4).

About 75% conventional vegetable farmer have applied lime in the field whereas only 35% of organic farmer have applied it once in the past (Table 4).

Table 4. Fertiliser use in commercial organic and conventional farms ((mean ± standard error, out of 30 each) in Kathmandu valley

Fertiliser (kg $ropani^{-1}$ $year^{-1}$)	Organic farm	Conventional farm	Level of significance*
Chemical fertiliser			
Urea (46% N)		12.62 ± 1.14	
Diammonium phosphate (18% N, 46% P)		11.90 ± 0.99	
Muriate of potassium (60% K)		8.02 ± 0.78	
Organic manures			
Chicken manure	593.84 ± 59.53	999.36 ± 152.12	0.020
Farmyard manure	2228.54 ± 195.40	1964.62 ± 241.62	ns
Urban compost	410.26 ± 141.66	74.00 ± 8.45	0.011
Mustard cake	38.38 ± 5.38	32.79 ± 3.13	ns
Bone meal	47.46 ± 3.46	17.09 ± 3.48	0.000
Compost mix	1746.08 ± 381.962	2293.81 ± 1040.42	ns
Biozyme	1.00 ± 0.00	2.27 ± 0.38	0.000
Application of lime (% farmers)	75.50 ± 24.78	35.37 ± 11.35	

* Level of significance of difference between two farming systems tested with independent samples T test, ns = non-significant difference.

Irrigation

Organic farmers were using mainly flood method of irrigation (50.0%) whereas hose method was the main method (50.0%) of irrigation among conventional farmers. Non-conventional irrigation methods such as drip irrigation and sprinkler irrigation were more common in the conventional farms in comparison to the organic farms (Table 5).

Table 5. Irrigation methods in commercial organic and conventional farms (percentage respondents out of 30 each, multiple response) in Kathmandu valley

Irrigation method	Organic farm (percentage)	Conventional farm (percentage)
Flood irrigation	53.3	30.0
Drip irrigation	13.3	13.3
Sprinkler irrigation	6.7	36.7
Hose method	26.7	50.0

Farmers' indigenous knowledge

A chi-squared test for goodness of fit using farmers' perception of soil texture as expected value and results of soil textural analysis as observed value was performed. The observed chi-squared value for two degrees of freedom and p-value of 0.005 was 10.79 whereas tabulated value was only 10.60. Hence, we can say that the farmers' perception about the soil texture was in agreement with the mechanical analysis (Figure 2).

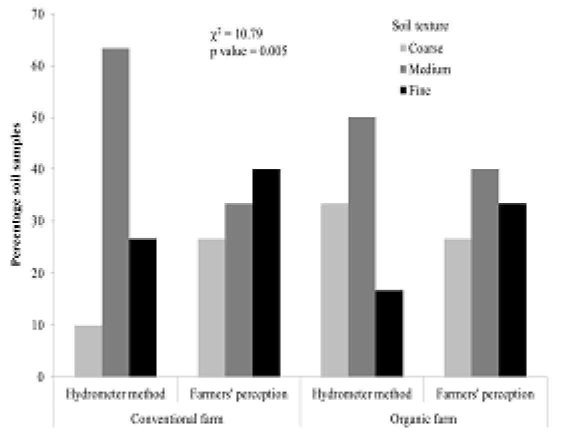

Fig. 2. Parity test on farmers' perception of soil texture and results of mechanical analysis (percentage of 30 soil samples each) in Kathmandu valley

Farmers were well aware of the soil productivity status in their fields (Figure 3). For them, nutrient content in the soil as medium status has turned out to be less productive soil. Similarly, soil with high nutrient status as satisfactory and soil with very high nutrient status as productive soil. Chi-squared test for goodness of fit showed that the observed chi-squared value for two degrees of freedom and p-value of 0.002 was higher (i.e. 12.50) in comparison to the tabulated value (i.e. 12.43).

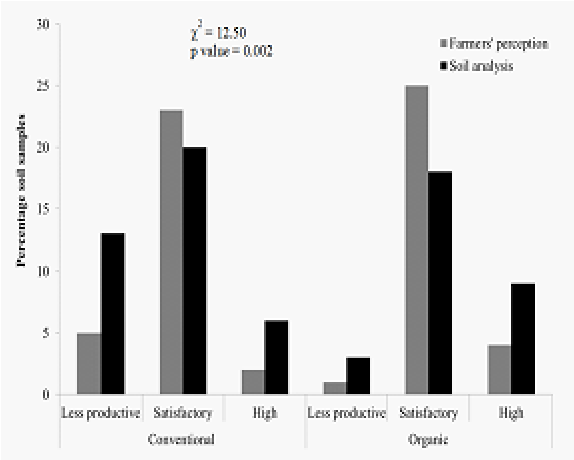

Fig. 3. Parity test on farmers' perception on soil productivity and soil analysis results (percentage of 30 soil samples each) in Kathmandu valley

As water is the critical factor for growing a crop, water availability was the main factor to select a piece of land for vegetable production. In addition to that, about 20% commercial farmers also made inquiry about soil fertility before choosing a field for vegetable production (Table 6).

Table 6. Reasons for choosing a particular piece of land for vegetable production among commercial organic and conventional farmers (percentage respondents out of 30 each) in Kathmandu valley

Reason	Organic farmers (percentage)	Conventional farmers (percentage)
Water availability	53.3	52.7
Fertile land	20.0	17.3

From the Table 7, it was a general observation by organic farmers that organic farming gives higher yield in the year continuum. In contrast, about 25%

conventional farmers observed requirement of higher amount of inputs to gain equal outputs as in the previous years.

Table 7. Trend of productivity as perceived by commercial organic and conventional farmers (percentage respondents out of 30 each) in Kathmandu valley

Productivity status	Organic farmers (percentage)	Conventional farmers (percentage)
Need higher amount of inputs than before	10.0	26.7
Equal productivity as before with equal amount of inputs	33.3	30.0
Higher productivity than before with equal amount of inputs	56.7	43.3

Problems

Conventional farmers were more concerned about soil fertility in comparison to the organic farmers (Figure 4). Nevertheless, soil fertility maintenance was not as serious problem as water management. More than 40% commercial vegetable growers were concerned for the water management.

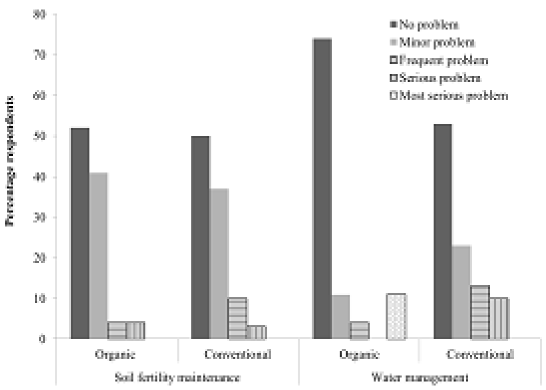

Fig.4. Relevance of soil fertility and water management problem in commercial organic and conventional farms (percentage respondents out of 30 each) in Kathmandu valley

Advice

About 50% of the respondents were asking for advice on soil fertility, fertiliser and irrigation management to the different advisory bodies (Fig. 5). Advice seeking habit was not different between organic and conventional vegetable farmers. Many commercial vegetable growing farmers were in contact with agricultural consultants (Figure 5).

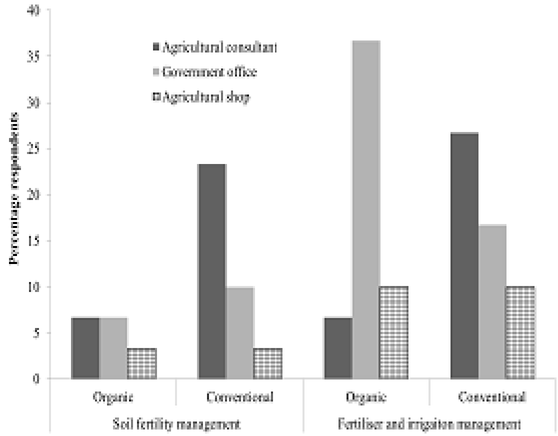

Fig.5. Resort for advice and information among commerical organic and conventional vegetable farmers (percentage respondents out of 30 each) in Kathmandu valley

Crops

Although, leguminous vegetable crops were cultivated by the commercial farmers, these crops did not find significant place in the commercial farms (Fig. 1). It was maybe due to either lack of knowledge (Shrestha *et al.* 2008) about contribution of legumes in soil nitrogen enrichment (Prasad & Power 1997) or lack of organic consumers' demand for organic fresh leguminous vegetables.

Bastakoti (2011) used the modelling approach to calculate the possibility of supplying nitrogen and phosphorus through legume integration in the organic farm in the context of Chitwan district, Nepal. Calculations revealed with minimum 30% legume integration in the organic farm, nitrogen and phosphorus surplus can be decreased to minimum. Moreover, Badgley *et al.* (2007) revealed possibility of supplying all the required plant nitrogen from legumes.

Soil properties

On par with Schjønning *et al.* (2002) and Chirinda *et al.* (2010), we found non-significant difference in soil bulk density between organic and conventional farm

(Table 3). Our results were in contrast with Liebig & Doran (1999), it was maybe because they applied only chemical fertiliser in the conventional plots. In the current study, conventional farmers were also applying comparable amount of organic manure in the farm to those by organic farmers (Table 4). Schjønning *et al.* (2002) and Chirinda *et al.* (2010) applied only pig slurry in organic farm which did not contribute significant biomass in the soil to increase the bulk density.

In contrast to Zeiger & Fohrer (2009), we found non-significant difference in the soil moisture content (Table 3). It was due to the rainy season during the soil sample collection period.

Organic vegetable farms had significantly higher bulk soil pH in comparison to conventional vegetable farms (Table 3). It was maybe due to no use of acidifying ammonium based nitrogen fertiliser in the organic farm (Table 4) (Brady & Weil 2012). In addition, significantly higher amount of bone meal used by organic farmers in comparison to conventional vegetable growers also contributed to calcium in the soil.

Agreeing with Cardelli *et al.* (2004), soil organic matter content was significantly higher in amount in organic farm than in conventional farm (Table 3). Regular application of higher amount of organic manure in the organic fields than conventional fields (Table 4) increased soil organic matter content. In contrast to Shrestha (2013), who showed decreased organic manure application by the subsistence vegetable farmers, commercial farmers were applying recommended dose of organic manure in the vegetable farms.

Available soil nitrogen content in the conventional vegetable farms was almost double in comparison to the organic farms (Table 3). It was maybe due to application of ammonium based nitrogen fertiliser in the conventional farms (Table 4). Reconfirming Burger & Jackson (2003), available form of nitrogen was maybe immobilised by more micro-organisms present in the organic farm than in the conventional farm. The cause for fewer micro-organisms in conventional farm was maybe application of toxic pesticides and chemical fertiliser (Elmholt & Labouriau 2005).

Total soil nitrogen content was significantly higher in the conventional vegetable field in comparison to the organic field (Table 3). Significantly higher amount of chicken manure application in the conventional vegetable farms than in organic farms has contributed in this difference (Table 4). It was maybe because chicken manure contains relatively higher percentage of nitrogen than other manures (Shrestha 2014). Our results reconciled Clark *et al.* (1998) and Liebig & Doran (1999) in which they revealed significantly higher total soil nitrogen content in organic farm than in conventional farm. In this study, it was maybe the duration of the farming which was on an average five and three year only in the organic and conventional farming respectively (Table 1).

On par with Clark *et al.* (1998), available soil potassium content was significantly higher in amount in the organically managed field than in conventionally managed field (Table 3). In this study, it was maybe due to the application of higher amount of urban compost containing higher amount of potassium (Karki 2003) in the organic farm (Table 4).

Fertiliser use

Commercial conventional vegetable farmers in Kathmandu valley were applying standard recommended dose of chemical fertiliser (Table 4) for vegetable production (ABPSD 2012). The amount of chemical fertiliser added was not as high as is in practice in the other countries like China. Chen *et al.* (2004) disclosed very high amount of macro-nutrients i.e. 800 kg nitrogen, 200 kg phosphorus and 200 kg potassium per hectare being applied for a vegetable crop mainly in the form of chemical fertiliser in Beijing region. Excessive application of chemical fertiliser creates a risk of soil degradation and causes environmental pollution (Tilman *et al.* 2002) which seems to be far less in commercial conventional vegetable farms in Nepal.

Farmers' knowledge

In general, farmers used only three types of soil texture i.e. coarse, medium and fine textural class (Table 1, Figure 2). Coarse textured soil included sandy loam; medium textured soil included loam, silt and silt loam and fine textured soil included clay, sandy clay loam, silt clay loam and clay in this study. Other soil textural classes were not determined during textural analysis.

Confirming Desbiez *et al.* (2004), though soil fertility status was medium in condition, farmers categorised those soil as less productive soil (Figure 3). It was maybe because for farmers, crop yield was the main yardstick to categorise soil productivity (Lima *et al.* 2011).

Reformulating Matthews & Pilbeam (2005), our results revealed that farmers were able to perceive the changes in the soil productivity. Confirming Lotter (2003) who showed increasing crop productivity in long term, in this study organic farmers perceived increasing trend of soil productivity (Table 7). Conventional farmers complained about requirement of higher amount of inputs than in the past years to get the same level of production from the field (Table 7). It was maybe due to destruction of the soil structure, loss of soil biota, and accumulation of toxic compounds in the soil in the conventional farm soil (Eyhorn *et al.* 2002, Hall & Moffitt 2002, MoAC 2008).

Organic farming is a good option for sustainable soil management. Conventional farmers in Nepal were applying very small doses of chemical fertilisers in comparison to those in the countries like China. Moreover, application of comparable amount of organic manure in the conventional farm as in the organic farm has maintained soil fertility. For maintaining soil nitrogen, growing of leguminous crops can be a sustainable option.

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