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Effect of Agricultural Land Use Changes on Soil Nutrient Use Efficiency in an Agricultural Area, Beijing, China

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Abstract: Agricultural land use and management practices may affect soil properties, which play a critical role in sustaining crop production. Since the late 1970s, several new agricultural land use types had been introduced in the rural areas of China. The purpose of this study is to evaluate the effect of these land use changes on the soil properties, nutrient absorption rate, and nutrient use economic efficiency ratio in an agricultural area of Beijing. Specifically, the cropland, the orchard and the vegetable field were examined. Results of this study suggest that land use and farming management practices significantly affect the content of soil organic carbon (SOC), total nitrogen (TN), total phosphorus (TP), and available phosphorus in the surface layer of 0–25 cm ($p < 0.05$) in the Yanqing Basin, northwestern Beijing. Soil nutrients in each agricultural land use type decrease rapidly with the increasing soil depth. Orchard and vegetable field tend to have higher soil nutrients than the cropland does. However, the soil nutrient-absorption rate (NAR) of the orchard and vegetable field is lower than that of the cropland, even though orchard and vegetable field may provide much higher economic benefit. While increasing SOC, TN, and TP in the orchard and vegetable field by intensive farming may be a valuable option to improve soil quality, potential increase in the risk of nutrient loss, or agricultural non-point source pollution can be a tradeoff if the intensive practices are not managed appropriately.

Keywords: agricultural land use; soil nutrient absorption rate (NAR); soil nutrient use economic efficiency ratio (NEER); soil property; environmental effect

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1 Introduction

Agricultural land use changes has become an increasing focus of research because of its significance in affecting soil fertility and related properties, i.e., soil bulk density, soil organic carbon (SOC), total nitrogen (TN), total phosphorus (TP), and ultimately the value of ecosystem services (Bauer *et al.*, 2002; Xu *et al.*, 2006; Wang *et al.*, 2009; Feng *et al.*, 2010). Soil nutrients play a crucial role in sustaining soil quality, crop production and environmental quality in general (Andrews *et al.*, 2004; Al-Kaisi *et al.*, 2005; Ross *et al.*, 2008; Ma *et al.*, 2009). How to restore SOC and establish a healthy agricultural system is an essential issue in enhancing soil quality, sustaining and improving food production, maintaining clean water, and reducing the increasing trend in atmospheric CO_2 (Lal, 2004; de Jong *et al.*, 2010; Grewal *et al.*, 2010). Soil nitrogen (N) and phosphorus (P), for example, are two indispensable nutrient inputs for sustaining agricultural outputs. However, increasing nutrient inputs may result in increasing risk of soil N and P losses, thus affecting ground water and surface water

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quality, and essentially the regional eco-security (O′Reagain *et al.*, 2005; Udawatta *et al.*, 2006). Given the complex relationship between economic benefit and environmental needs, it has become a challenging task to adopt balanced agricultural land use management to reduce soil degradation (Silburn *et al.*, 2007; Yu *et al.*, 2010).

Soil nutrients are closely related to agricultural land use types and their associated management practices (Duiker and Beegle, 2005; Kong *et al*., 2006; Reijneveld *et al*., 2009; Agbede, 2010; Wang *et al*., 2010). Appropriate land use management measures may improve the soil nutrient status. It was reported that the conversion of the cropland to pasture or forest has a great potential in increasing soil carbon (C) (Degryze *et al.*, 2004; Chen *et al*., 2007; Cantarello *et al*., 2011). Long-term rice cropping could cause significant increases in the contents of SOC, TN and TP in the plow layer. However, such long-term culture could also increase risk of N and P loss, resulting in adverse environmental impacts such as water eutrophication (Zhang and He, 2004; Zhang *et al*., 2007). Increasing crop diversity including perennial grasses can be effective in improving C and N sequestration, and similar effect can be achieved by reducing tillage intensity (Al-Kaisi *et al.*, 2005). Moorman *et al.* (2004) found that ridge-tillage system was more effective in retaining soil with a relatively higher level of SOC and TN than conventional tillage practices (Cambardella *et al.*, 2004). Farming management (e.g., irrigation, organic matter addition in term of manure or straw), either alone or in combination with chemical fertilizers, and rotation of upland crops with rice or wheat may contribute significantly to the increase of SOC storage (Su and Zhao, 2003; Pan *et al.*, 2005; Dawson *et al.*, 2008; Sainju *et al.*, 2008). Increasing SOC through high mineral fertilizer input is also a valuable option for sustainable agricultural production in the low SOC areas (Shi and Yu, 2003; Xu *et al.*, 2006). However, the intensive farming by using fertilizers and pesticide may deteriorate soil health, leading to poor productivity and adverse environmental effects (Wells *et al.*, 2000).

Generally, the effect of agricultural land use change on soil nutrient use efficiency was conducted from two levels, macro-scale and micro-scale. In the macro scale, most researches were focused on qualitative assessment by using remote sensing data or models (Stevens and van Wesemaela, 2008; Song *et al*., 2009; Wang *et al*., 2009; Liu *et al*., 2010; van Delden *et al*., 2010). In the micro scale, most studies were carried out by using the experimental data at controlling states (Bauer *et al*., 2002; Ross *et al*., 2008; Xiao *et al*., 2008; Li *et al*., 2010; Luo *et al*., 2010; Ren *et al*., 2010), and the land use system was less considered. However, all the results are somehow deviated from the real world. To compare the effects of agricultural land use change on soil nutrient use efficiency and the potential risk by using on-site data is particularly helpful for the decision-makers.

In the last two decades, dramatic changes in the agricultural land use and the associated management practices have happened in the rural area of China (Liu *et al*., 2009). Some studies have evaluated the influence of the agricultural land use changes on soil nutrient properties (Degryze *et al*., 2004; Chen *et al*., 2007; Zhang *et al*., 2008). However, few of the studies were conducted to compare the soil nutrient use efficiency and potential environmental risk of soil nutrient loss. In this study, three agricultural land use types, e.g., orchard, vegetable field (vegetable), and cropland (corn) were examined to study the effects of agricultural land use changes on soil nutrient use efficiency. Our objectives are: 1) to explore the effects of agricultural land use changes on soil properties; 2) to compare the difference of the effects of agricultural land use on soil nutrient use efficiency based on human input; and 3) to provide recommendations for managing soil carbon storage, sustaining soil quality and crop production for the agricultural regions.

2 Study Area and Methodology

2.1 Study area

The study area is located in the Yanqing Basin, northwestern Beijing (40º16′–40º47′N, 115°44′–116°34′E), and it is within the semi-humid temperate climate zone (Fig. 1), covering about 450 km^2 with an elevation ranging from 480 m to 580 m above sea level. Soils in the study area are developed from alluvial deposits, classified as *Usochrepts* by United States Department of Agriculture (USDA) Soil Taxonomy, or *Eutric Cambisols/Gleyic Cambisols* by FAO/UNESCO. The mean annual temperature is 8.5℃, and the mean annual precipitation is 469 mm. The frost-free period is about 161 days in a year, and the primary agricultural land use types are cropland (corn, soybean), vegetable field (vegetable) and orchard.

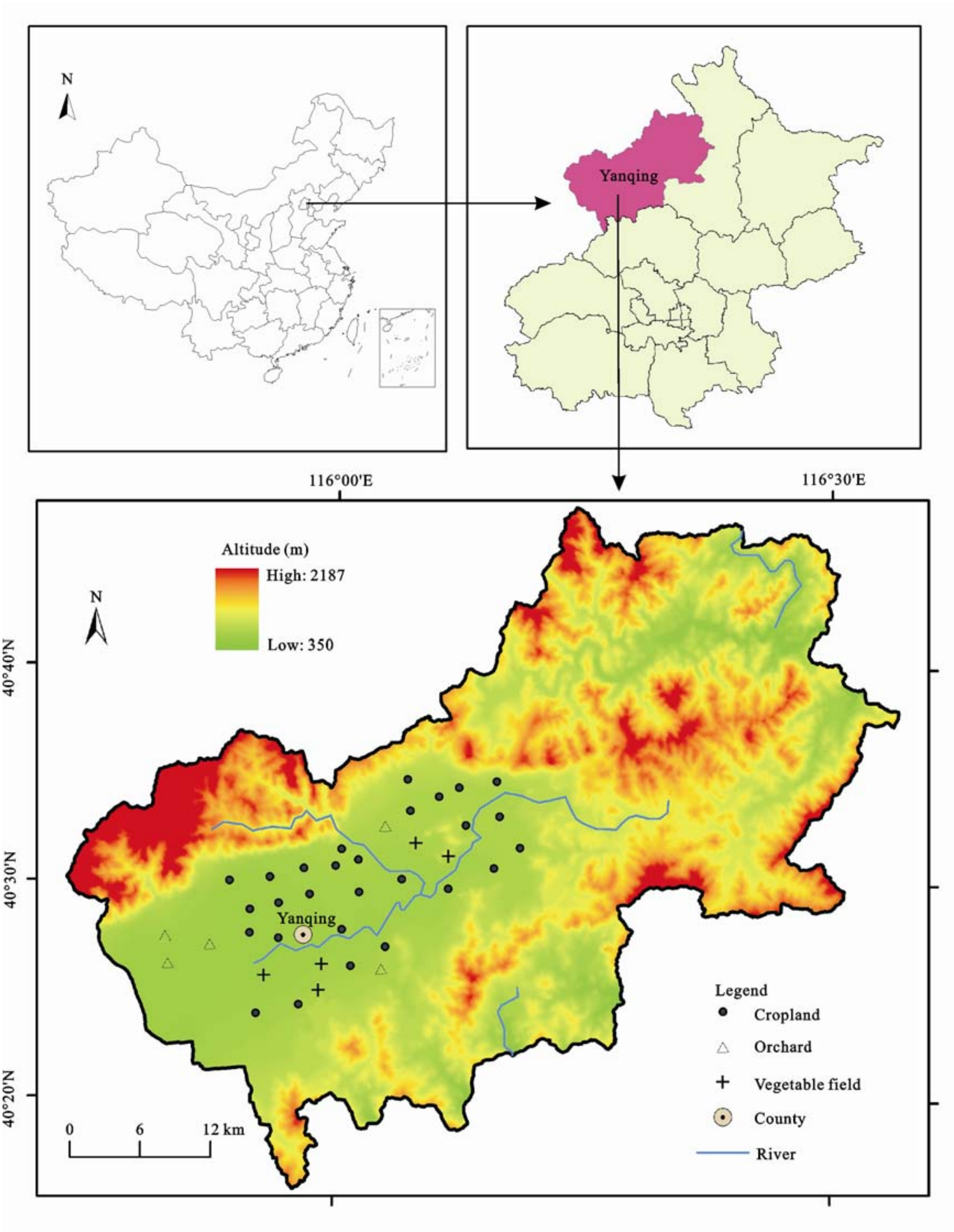

Fig. 1 Location of study area and sample sites

2.2 Sample sites selection

Agriculture in the study area has a long history of corn and soybean cultivation, and the land use types of vegetable field and orchard have been in rapid expansion since 1979. In this study, 38 sample sites were selected based on agricultural land use and topographic conditions (Fig. 1). Most vegetable field and orchard in the study area were converted from cropland in the early 1980s. To obtain the farming management practices, questionnaires were created and information of interest was surveyed for each land use type at each sampling site in the study area (Table 1).

Table 1 Agricultural land use types and management practices in Yanqing basin, Beijing, China

	Orchard	Vegetable field	Cropland (corn)
Composition	Apple tree (*Malus domestica* Borkh.), peach tree (*Prunus persica* L.) and apricot tree (*Prunus armenica* L.), cultivated over 10 years	Chinese cabbage (*Brassica rapa* L.), cabbage, broccoli, cauliflower and capsicum. Cropping twice a year, cultivation history over 10 years	Cropping once a year, long traditional cultivation, succession cropping or rotation with the other crops (wheat, soybean)
Fertilization	Surface application of poultry manure in October or April. Organic matter content: 900 kg/ha, TN: 120–180 kg/ha, TP: 40–80 kg/ha; Surface application of calcium superphosphate in flowering stage. TP: 40–100 kg/ha; Surface application of nitrogen fertilizer before harvest, several times, TN: 390 kg/ha	Surface application of poultry manure and ammonium phosphate in April and July. Organic matter content: 1790 kg/ha, TN: 227 kg/ha, TP: 123.9 kg/ha; Surface application of nitrogen fertilizer 2–3 times in each season, TN: 690 kg/ha	Little manure and limited amount of fertilizer application. TN: 150–264 kg/ha, TP: 65–83 kg/ha
Tillage	Moldboard plowing powered by tractor or manually in October or April after fertilizing to depth of 20–25 cm, manual hoeing in June and August	Moldboard plowing powered by tractor in October or April to depth of 20–25 cm; harrowing by tractor in April, manual hoeing in June and August. Manual ridge-tillage or bed, manual hoeing twice for each vegetable season	Moldboard plowing powered by tractor in October or April to depth of 20 cm, harrowing ridge-tillage and seeding by tractor in late April, manual hoeing twice in May and June
Irrigation	Flooding irrigation 4–6 times per year	Irrigation in cultivation bed; 4–10 times for each vegetable season	No irrigation
Residue treatment	Plant leaves buried in soil and pruning shoots taken away as fuel	Roots and part of leaves buried in soil or browsed by flocks and herds	Roots buried in soil and straws burnt in-situ; used as fuel or ground as livestock forage

2.3 Sample collection and analysis

2.3.1 Soil sample

The soil samples were collected from 2005 to 2006 prior to the tillage/seeding season in April and post-harvest in October by using soil auger, and the sampling depths were 0–10 cm, 10–25 cm, 25–40 cm, 40–70 cm and 70–100 cm. For each sample, soil from 5 points within a 50 m radius area was taken, and put together to make a mixed sample for soil nutrient analysis. The analyzing results of October in 2005 and 2006 were used to calculate the annual balance of soil nutrient of different agricultural land use types.

The soil core method was used to measure soil bulk density in the field by the oven-dried soil mass and the sample volume (SPCAEC, 1996). Soil samples for chemical analysis were air-dried, ground and sieved (0.28 mm) before laboratory examination. Soil organic carbon (SOC) was determined by rapid dichromate oxidation of dried ground samples and the results were multiplied by 1.1 to adjust for the difference from the dry combustion method (Tiessen and Moir, 1993); soil total nitrogen (TN) was analyzed by the semi-micro Kjeldahl method (McGill and Figueiredo, 1993). Soil total phosphorus (TP) was measured by concentrated sulfuric acid and perchloric acid digestion, and the available phosphorus was determined by bicarbonate extraction using the acidic molybdate-ascorbic acid (AMAA) method (SPCAEC, 1996).

2.3.2 Plant sample

In the harvest season, plant samples were collected at each site. Total fresh biomass was weighed in the laboratory by using electronic meter (0.01 g), and dry biomass weight was measured after the plant sample was dried to a constant weight at 90℃. TN and TP were measured by using the same instruments for the soil nutrient analysis after the samples were ground and treated using distilled water and then sulphuric acid. The detailed procedure are referred the literature of Bao (2000).

2.4 Soil nutrient use efficiency

In this study, the soil nutrient use efficiency was examined and expressed in two parameters, the soil nutrient absorption rate (NAR) and soil nutrient use economic efficiency ratio (NEER). The NAR is a ratio of the amount of soil nutrients absorbed by plant to the annual amount of soil nutrients lost from the soil system. The NEER measures the crop productivity, which is represented by the ratio of the total economic value (annual yield × the unit price) to the annual net soil nutrient loss. In general, annual soil nutrient balance in an agricultural land use system can be described by the following equation:

$$N_{\text{out}} = \Delta N + F + N_{\text{B}} + N_{\text{air}} + N_{\text{els}} \quad (1)$$

where, N_{out} is the annual net loss of soil nutrients from the soil system; ΔN is the annual soil nutrient change in the soil system (kg/ha); F is the annual soil nutrient input by fertilizer/manure application (kg/ha); N_B is the nutrient input by the plant residue return (kg/ha); N_{air} is the input of soil nutrient by air deposit; N_{els} is the input of soil nutrients from other sources (kg/ha), e.g., nutrient input due to seedling, irrigation, rainfall, *etc*.

In this study, the N_B is not considered given the plant residue was only minimally returned to the soil. Since the contribution from N_{els} was also expected to be small comparing to other inputs, it was therefore ignored in this study. Soil nutrients due to air deposit (N_{air}) were reported to be in the range of 82.8–83.3 (kg/ha)/yr in northern China (He *et al.*, 2007; Zhang *et al*., 2008). The nitrogen from air deposit is closely related to volatilization of chemical fertilizers and manures which is not considered in this study (Xie *et al.*, 2009). It was therefore assumed that the gain (N_{air}) from air deposit would be trivial by assuming $N_{air} = 0$ as the volatilization was not accounted for in the nutrient loss calculation.

The NAR indicates the amount of nutrient absorbed by the plants for growing, and it can be calculated by comparing the amount of nutrient in plants to the total soil nutrient loss (N_{out}). The NEER measures the benefits of the agricultural land use in term of nutrient inputs. Given the above soil nutrient balance, the NAR and NEER can be calculated by the following equations:

$$\text{NAR} = \frac{N_y}{N_{out}} \times 100\% \tag{2}$$

$$\text{NEER} = \frac{Y \times P_c}{N_{out}} \tag{3}$$

where, N_y is the total amount of nutrient absorbed by the plant (kg/ha); Y is the net crop seed yield or fruit yield (kg/ha); P_c is the unit price of agricultural products.

2.5 Statistical analysis

SPSS®11.0 (SPSS Inc.) was used for the statistical analysis. Preliminary analysis was first conducted and indicated that the soil data were normally distributed. Therefore, parametric statistics of ANOVA analysis were used to test the significance among the agricultural land use types at $p < 0.05$. If the effects of agricultural land use types are significant, mean separations were achieved by using a protected least significant difference (LSD) test at $p < 0.05$.

3 Results

3.1 Soil organic carbon change

The SOC contents at the same depth were higher in orchard and vegetable field than in cropland (Table 2). The difference among different agricultural land use types in the SOC contents occur primarily in the soil of surface layer (0–25 cm). The SOC contents vary from 4.16 g/kg to 10.00 g/kg for the orchard in the soil layers of 0—100 cm, 3.80 g/kg to 9.67 g/kg in the vegetable-cultivated field, and 3.14 g/kg to 8.33 g/kg in the cropland. The results of statistical tests indicate that the SOC is enriched significantly ($p < 0.05$) in surface layer (0–10 cm) soil of the orchard.

It was found that the soil nutrient contents decrease sharply with the increasing soil depth in each of agricultural land use types (Table 2). In general, SOC varies from 7.63 to 10.00 g/kg in the 0–25 cm layer and enriched especially in the soil of surface layer. Both orchard and vegetable field have higher SOC in the whole soil profiles than cropland.

3.2 Total nitrogen change

The TN contents in the vegetable field are the highest and those in the cropland are the lowest (Table 2). In the depths of 0–25 cm, the TN contents range from 0.79 g/kg to 1.12 g/kg in the soils of the vegetable field and orchard, and that in the cropland varies from 0.76 g/kg to 0.87 g/kg. For the depths of 25–40 cm, however, there were no significant differences ($p < 0.05$) between the agricultural land use types.

Similar to the SOC, the TN contents decrease consistently with increasing soil depth (Table 2). For orchard, the TN content in the depth of 0–10 cm is significantly higher than those in the other layers from 25 cm to 100 cm. For all three agricultural land use types, the TN contents in the depth of 0–25 cm are significantly higher than those in the layer of 70–100 cm ($p < 0.05$). In the vegetable field, the TN contents are significantly higher in the depth of 0–25 cm than those in other layers from 25 cm to 100 cm. For the cropland, there are no significant variations ($p < 0.05$) for the TN contents from the 0 cm to 25 cm, but the TN is noticeably lower in the deeper soil layers (25–100 cm).

3.3 Total phosphorus and available phosphorus change

The soil TP contents range from 0.71 g/kg to 1.00 g/kg, following the order of vegetable field > orchard > cropland in the soil depths from 0 to 25 cm (Table 2). There are no significant differences between orchard and vegetable field. However, for the soil depths of 0–25 cm, the TP contents in vegetable field are significantly higher than that in the cropland. For the deeper soil layers (40–70 cm), the TP is significantly higher in orchard than that in the other two agricultural land use types ($p < 0.05$).

Following the same pattern as observed for the SOC and TN, the TP contents in each agricultural land use type decrease generally with soil depths increase, in particularly in the soil profile of 0–40 cm (Table 2). Correspondingly, the TP contents in the depths of 25–100 cm range from 0.51 to 0.70 g/kg in these land use types.

The available phosphorus in vegetable field is the highest (Table 3), corresponding well to the highest P fertilizer inputs and frequent irrigation (Table 1). In the depths from 0 to 40 cm, the available phosphorus contents in vegetable field range from 22.03 mg/kg to 66.10 mg/kg which is about 2.5–6.5 times higher than those in the other two agricultural land use types (Table 3). It is presumed that high available phosphorus contents are prone to potential risk of P loss and non-point source pollution.

3.4 Soil nutrient absorption rate and soil nutrient use economic efficiency ratio

Data of the agricultural land use economic outputs, plant nutrient update, and input of fertilizers are shown in Table 4. For different agricultural land use types, the calculated values of nutrient absorption rate (NAR) and nutrient use economic efficiency ratio (NEER) are listed in Table 5. For both N and P, the NAR values in cropland and vegetable field are higher than that in the orchard, and the order is cropland > vegetable field > orchard. Compared with P, the absorption rate of N is a relatively higher in the three agricultural land use types.

The NARs in vegetable field and orchard are lower than that in the cropland, and the NEERs show the op-

Table 2 Comparison on effects of agricultural land use and management practices on soil properties with increasing soil depth

Soil property	Land use type	Sample sites	Soil profile depth (cm)				
			0–10	10–25	25–40	40–70	70–100
Soil bulk density (g/cm^3)	Orchard	5	1.36 (0.17) a A	1.38 (0.03) a A	1.42 (0.04) a A	1.44 (0.01) a A	1.39 (0.04) a A
	Vegetable field	5	1.36 (0.12) a A	1.36 (0.03) a A	1.39 (0.03) a A	1.39 (0.04) a A	1.41 (0.03) a A
	Cropland	28	1.38 (0.06) a A	1.38 (0.02) a B	1.41 (0.02) a B	1.40 (0.02) a B	1.42 (0.03) a B
SOC (g/kg)	Orchard	5	10.00 (1.15) a A	8.16 (1.27) a B	5.21 (1.03) a BC	5.33 (1.04) a BC	4.16 (0.86) a C
	Vegetable field	5	9.67 (0.66) ab A	9.16 (0.70) a A	6.42 (0.47) a B	4.73 (0.80) a BC	3.80 (0.40) a C
	Cropland	28	8.33(0.31) bc A	7.63 (0.48) ab A	5.13 (0.43) a B	4.03 (0.49) a BC	3.14 (0.68) a C
TN (g/kg)	Orchard	5	1.07 (0.13) ab A	0.79 (0.12) ab AB	0.57 (0.10) a BC	0.53 (0.08) ab BC	0.38 (0.07) ab C
	Vegetable field	5	1.12 (0.08) a A	0.97 (0.09) a A	0.66 (0.06) a B	0.55 (0.03) ab BC	0.45 (0.05) ab C
	Cropland	28	0.87 (0.10) c A	0.76 (0.04) b A	0.56 (0.04) a B	0.44 (0.05) b BC	0.33 (0.04) b C
TP (g/kg)	Orchard	5	0.84 (0.03) ab A	0.78 (0.02) ab AB	0.66 (0.05) a BC	0.70 (0.03) a ABC	0.60 (0.09) a C
	Vegetable field	5	1.00 (0.10) a A	0.87 (0.08) a A	0.60 (0.05) a B	0.51 (0.04) b B	0.52 (0.03) a B
	Cropland	28	0.77 (0.03) bc A	0.71 (0.04) bc A	0.56 (0.03) ab B	0.52 (0.04) b B	0.56 (0.05) a B

Notes: Uppercase letters after the values represent the significant differences (at the 0.05 level with different letters) among soil depths, and the lowercase letters represent the significant differences (at the 0.05 level with different letters) among land use types; Data in parentheses are standard error

Table 3 Comparison of effects of agricultural land use and management practices on soil available phosphorus contents (mg/kg)

Agricultural land use type	Sample size	Soil profile depth (cm)		
		0–10	10–25	25–40
Orchard	5	18.83 (9.21) b A	4.14 (1.17) b A	4.31 (0.79) b A
Vegetable field	5	66.10 (6.20) a A	45.62 (14.34) a AB	22.03 (7.90) a B
Cropland	28	20.77 (7.01) b A	6.48 (1.45) b B	4.92 (1.06) b B

Notes: Uppercase letters after the values represent the significant differences (at the 0.05 level with different letters) among soil depths, and lowercase letters represent the significant differences (at the 0.05 level with different letters) among land use types; Data in parentheses are standard error

Table 4 Characteristics of different agricultural products in study area

	Orchard (apple)	Vegetable field (cabbage)	Cropland (corn)
Economic yield (kg/ha)	34000–43000	30000–45000	5800–7700
Price index (yuan/kg)	1.8	0.8	1.4
Economic benefits (kg/ha)	67500	30000	9450
Water content (%)	87.10	94.00	23.66
N content in plant (g/kg)	5.27	39.97	16.39
P content in plant (g/kg)	0.74	3.96	2.46
N absorbed by plant (kg/ha)	25.50	89.93	84.46
P absorbed by plant (kg/ha)	3.58	8.91	12.68
N input by human in 2005 (kg/ha)	519.5	917.0	207.3
P input by human in 2005 (kg/ha)	127.5	123.9	74.1

Table 5 Comparison of soil nutrient use efficiency among agricultural land use types

Index	Soil nutrient	Orchard (apple)	Vegetable field (cabbage)	Cropland (corn)
NAR (%)	N	4.94 A	24.94 A	41.05 A
	P	2.84 A	8.01 A	17.45 A
NEER	N	130.78 C	83.20 A	45.93 A
	P	532.64 C	269.94 AC	130.09 A

Note: The same letter after the value indicates no significant differences at the 0.05 level among different land use types

posite results, i.e., the higher NEER values are found in the vegetable field and orchard (Table 5). For the NEER of both N and P, the order is orchard > vegetable field > cropland. The contrast in the change patterns of the two parameters (e.g. soil NAR and soil NEER) among different land use types provides an interesting perspective that vegetable and orchard may offer better economic profits than cropland. However, their profitability was achieved at the cost of low soil nutrient use efficiency.

4 Discussion

4.1 Effects of agricultural land use and management on soil nutrient change

Land use conversion from traditional cropland (corn, soybean, or wheat) to orchard or vegetable field has taken place widely in China over the last three decades, especially in the suburb areas of metropolises. The national land use for orchard, for example, expanded from 2.02×10^6 to 10.04×10^6 ha from 1982 to 2006 (FAOSTAT, 2007). In the study area, the orchard land had increased from 2151 ha to 4633 ha, and vegetable field from 1176 ha to 4952 ha in the period of 1982–2007. Industrialized operations have also taken place on the new land uses. Some vegetable field is now managed by companies and some are developed as tourism agriculture-sites. Driven by maximizing economic profit, farmers prefer intensive farming by using fertilizers, tillage, and irrigation systems as a more cost-effective way to increase land production (Table 1). This trend is also reflected in the national mega trend where the consumption of chemical fertilizers increased from 1.66×10^{10} kg to 4.77×10^{10} kg, and the irrigated arable land increased from 4.46×10^7 ha to 5.50×10^7 ha from 1982 to 2006 in China (FAOSTAT, 2007). These intensive farming practices have already resulted in a noticeable increase in soil nutrient contents under orchard and vegetable production (Xu *et al.*, 2006).

Soils under different agricultural land use types may differ remarkably in the SOC, TN and TP, *etc*. This corresponds well to the different input of manure and chemical fertilizers preferred by different land use types. The amounts of manure applications are much higher in orchard and vegetable field, with about 900 (kg/ha)/yr for orchard and 1790 (kg/ha)/yr for vegetable field, respectively. In contrast, very little is used in the traditional cropland. It indicates that the contents and the chemical properties of the SOC will depend on the amounts and types of organic matter input in these different land use types (Wells *et al.*, 2000; Wu *et al.*, 2004).

The high soil TN and TP in orchard and vegetable field are resulted from high N and P inputs into these systems. In general, the inputs of TN in the orchard and vegetable field are 2–4 times higher than that in the cropland. Correspondingly, the inputs of TP are 1.5–2 times higher. The high available phosphorus in vegetable field may be attributed to the large amounts of chemical P fertilizer applications and frequent irrigation (Wells *et al.*, 2000). In many cases, the saturation of the soil with nitrogen or phosphorus, has led to nitrates losses to shallow groundwater (Zalidis *et al.*, 2002). In intensive horticultural systems, interaction between high fertilizer inputs and frequent irrigation schemes may enhance nitrate leaching and non-point source pollution in the surface and ground water.

Soil nutrient stratification in the profile (i.e., nutrients decrease significantly downward the soil profile) supports the soil surface layer as the primary enrichment zone. Soil nutrient enrichment in the surface layer may be caused by fertilizing (Shepherd and Withers, 1999), tillage (Duiker and Beegle, 2005), irrigation (Zhang and He, 2004), and plant cycling (Jobbagy and Jackson, 2001). Such nutrient enrichment is much stronger in the orchard and vegetable field than in the cropland due to the intensive tillage, fertilization and irrigation in the upper soil layers (Ellert and Gregorich, 1996; Degryze *et al.*, 2004).

4.2 Effect of agricultural land use on soil nutrient use

Land use managements may produce considerable influence on soil nutrient absorption and nutrient use efficiency. As shown in Table 5, the NAR and NEER changed significantly among the three agricultural land use types. Good soil quality must produce good crop yield and maintains better environmental quality (Sharma *et al.*, 2005). Intensive agriculture such as orchard and vegetable productions has become popular due to better economic outputs for the local farmers. However, intensive agriculture is known to emit more nutrients, particularly N and P to the environment, which may result in serious water quality impairment (Gillingham and Thorrold, 2000; Monaghan and Smith, 2004; Ma *et al.*, 2009).

This dual effect of intensive agriculture is better explained by the two parameters, NEER and NAR, used in this study. If the economic benefit (NEER) is considered only, orchard and vegetable production has much more benefit than the cropland does. However, a different conclusion may be derived if the higher NAR is the primary concern. Obviously, it is hard to determine the best management practices and regulation for sustainable agriculture if both economic and environmental effects are taken into account. The results of this study suggest that the orchard and vegetable field as the most popular land use shift from cropland may provide higher economic benefit, but at the same time this land use shift may pose higher risk of nutrient loss to potentially environmental impairment. For the long-term sustainability of both agriculture and the environment, systematic best management practices and balanced land use policies must be developed to provide an optimal solution aimed at both improving the soil nutrient use efficiency and reducing the adverse environmental effect.

4.3 Land use management and sustainable agricultural land use

Agriculture in China has changed dramatically since 1978. As the first step of the reform, the commune system was dissolved and land use rights were reassigned to individual farmer families, i.e., the 'Household Responsibility System'. Ever since the reform, agriculture can be characterized by household farming with small plots. The extensively divided agricultural land has made it difficult to apply a uniform management model to sustaining both agricultural production and environmental quality. Agriculture in recent years has become more intensive with large use of heavy machinery, fertilizers, agrochemicals, and large scale irrigation systems, and farming has been focused more on commodity products, such as orchard and vegetable (Zhang *et al.*, 2007). Consequently, soil nutrient use efficiency and environmental protection become less considered by local farmers in order to maximize economic outputs.

As driven primarily by the economic goal, the local farmers were keen to develop more orchard and vegetable field because of their higher economic incomes. Orchard may be a promising agricultural land use measured by soil erosion control and SOC improvement. However, its low soil NAR is a trade-off and has to be addressed. The vegetable field land use requires higher fertilizer application and irrigation water than the cropland system. As a result, vegetable production may result in higher TN, TP and available phosphorus in soil, thus posing higher risk of soil nutrient loss to the environment. Best management practices for reducing the potential non-point source pollution from vegetable field and orchard should be urgently implemented in the traditional agricultural areas.

There are different fertilization practices for traditional crop cultivation. The application of manure and fertilizer may increase SOC sinks (Wu *et al.*, 2004; Xu *et al.*, 2006), sustain soil quality, and sequester carbon. In the study area, corn roots are often returned to the field, but little of the straws. Straws are mostly used as fuel, and some are burned in-situ, and some of them are used as forage for livestock and finally returned to the field. The corn-straw-return-field practice is strongly recommended to increase soil quality and carbon stock. As for the orchard and vegetable field, manure applications should be encouraged, while chemical fertilizers should be used restrictively to reduce the risk of potential non-point source pollution. At the same time, the intense tillage in vegetable field should be reduced by adopting more conservation tillage practices (Cambardella *et al.*, 2004; Al-Kaisi *et al.*, 2005)

5 Conclusions

In this study, the effects of agricultural land use types on soil properties, nutrient absorption rate, and nutrient use economic efficiency ratio were examined by using field sampling and survey data. Results of this study indicate that the SOC, TN, TP and available phosphorus in different agricultural land use types are affected significantly by the different farming practices dominant in each system. Soil nutrient enrichment (SOC, TN and TP) is clearly observed in the studied agricultural land use types but to a different degree, with the most enrichment in soils under orchard and vegetable production. The effects of agricultural land use types on soil nutrients occur primarily in the surface layers of 0–25 cm, and in the soil layers 25–100 cm there are no significant differences. Soil nutrients of each land use type decrease sharply with the increasing soil depth, particularly in the soil layer of 0–40 cm. The SOC, TN and TP are higher in the soils of orchard and vegetable field, but lower in the soil of cropland. The soil available phosphorus contents in vegetable field are the highest among the studied agricultural land use types.

Orchard and vegetable field may benefit soil nutrient enrichment but at the cost of increased risk of soil nutrient loss and non-point source pollution. Vegetable field has the highest potential to release N and P to water bodies. While intensive agricultural land use types with more fertilizer inputs and frequent irrigation events may improve soil nutrient supply to achieve higher economic outputs, there remains elevated concern of increased risk to non-point source pollution if best management practices are not readily implemented. Conservation tillage, manure application, and corn-straw-return-field practices are all effective means to prevent or minimize the adverse environmental impact. We have to notice that some parameters used in this study are mainly based on the field survey to the farmers to calculate the NAR and NEER, which might result in a lower value than the real state. However, the general conclusions drawn from this study are believable. We hope more precise data would be used to improve the assessment results in future study.

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