Impact of long-term intensive cropping under continuous tillage and unbalanced use of fertilizers on soil nutrient contents in a small holding village

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Long-term field studies are important to generate information on changes in soil, which help in understanding nutrients management strategies for sustainable crop production. The present study was carried out in Kafr El-Kadera village at El-Monofia governorate, Egypt located at Middle Delta. It started in 1981 and was repeated in 2008 to evaluate the effect of continuous cropping, tillage and unbalanced fertilizers use on soil properties. The village cultivates two irrigated crops/year. Fertilizers used are nitrogen (N) and phosphorus (P) only. No potassium (K) or micronutrients were used. Results showed that, electrical conductivity (EC) showed decrements, while organic matter (OM) and CaCO3 showed increases with time. The average values of P content increased with time in all sites. On the other hand, potassium and micronutrients (Fe, Mn, Zn and Cu) showed decreases with time.

Key words: Intensive cropping, nutrient depletion, alluvial soil, unbalanced fertilization, potassium, iron, manganese, zinc, copper.

INTRODUCTION

The physical properties of any soil are function of climate, vegetation, parent material topography and time. Changes in frequency and intensity of tillage practices alter soil properties, distribution of nutrients and soil organic matter in the soil profile. These changes become stable with time and could affect availability of nutrients for plant growth, crop production and soil productivity (Turan et al., 2009).

Guo et al. (2000) reported that phosphorus (P) was significantly different among sites with time. Results suggested that variation within agriculture practices could influence soil nutrient changes among locations. Variation in texture could result from differences in mineralogy of parent materials; in this case variation is likely to affect the amount and distribution of phosphorus independent of cultivation history. This result suggested that shifting
The objective of this study was to examine the long-term effects of intensive cropping system and N or NP applications alone on soil physical and chemical properties after 27 years of continuous cropping. It compared soil properties in 2008 with those of the same soils in 1981 (El-Fouly, 1989).

**MATERIALS AND METHODS**

Soil and crop nutritional surveys were conducted in 1981 (El-Fouly, 1989) and repeated in 2008 to study the effect of continuous intensive cropping and addition of N or NP fertilizers on changes of physical and chemical properties on alluvial silty clay loamy textured soil.

**Background of study site**

The study area is located at the Middle of Nile Delta at El-Monofia Governorate, Egypt. The study area covers 880 feddan (about 350 ha) divided into 16 locations. The location number, area and site names are presented in Table 1. Field crops occupy 88% of the area, while vegetable and citrus occupy 12%. All farmers at all sites grow field crops and follow cropping systems as follows. Maize is the main crop in summer and wheat and/or clover in winter. Between summer and winter, some farmers cultivate potatoes, pea and/or maize as forage crop, all crops are irrigated. Irrigation water in this village comes through small canals. Fertilizers used for each crops are given in Table 2. Most of the holdings are below 1 ha. The agriculture system is intensive and farmers are market oriented.

**Soil sampling**

Soil samples (0 to 30 cm) were collected in September before planting and before fertilization in 1981 and 2008. Soils alluvial textured was generally silty clay loam.

**Tillage and field practices**

Before sowing each crop, mold board plowing of the soil was performed to a depth of 30 cm then disking and planting. Farmers used traditional crop varieties till 1989. Since 1990, farmers have been using high yielding varieties of crops. After harvest, farmers plow the soil to a depth 30 cm and after tillage the following crop is sown. Farmers use high rates of nitrogen and phosphorus fertilizers on all field crops and did not use potassium fertilizers for any crop. The crops in the village did not suffer from any water shortage during the study period. Relatively good quality irrigation water was available all the year.

**Table 1. Location number, name and area/feddan.**

| Number | Site name | Feddan   | ha  |
|--------|-----------|----------|-----|
| 1      | El-Bahary | 41       | 17.2|
| 2      | El-Tarbeah| 35       | 14.7|
| 3      | El-Ramroma| 80       | 33.6|
| 4      | El-Berka  | 30       | 12.6|
| 5      | El-Meadia | 30       | 12.6|
| 6      | El-Areada | 36       | 15.1|
| 7      | El-Fed El-Kabear | 33 | 13.9|
| 8      | El-Fed El-Sageer | 45 | 18.9|
| 9      | Kebalia   | 90       | 37.8|
| 10     | El-Tarabeah| 75      | 31.5|
| 11     | El-Remia  | 90       | 37.8|
| 12     | El-Omeda  | 50       | 21.0|
| 13     | El-Metab  | 70       | 29.4|
| 14     | El-Elow   | 65       | 27.3|
| 15     | El-Taboot | 70       | 29.4|
| 16     | El-Gofara | 45       | 18.9|
| Total  |           | 885      | 371.7|

1 Feddan=4200 m².

cultivators may have the more fertile sites originally and have only moved into a less fertile one.

Diaz-Zorita and Grove (2002) noted that available phosphorus increased due to regular application of phosphatic fertilizer. Obviously, continuous use of N alone leads to sever depletion of other nutrient with corresponding decrease in grain yield. Without application of K, soil K eventually drop below the critical level (Zheng, 1999). Similar findings were reported by Elangovan (1984) who reported that K content in 100% NP was lower than that of 100% N alone and unfertilized soils due to the relatively higher crop yields and high removal of K. High K removal in the absence of K soils due to the relatively higher crop yields and high removal of K. High K removal in the absence of K addition has resulted in drastic reduction of total K as well as available K under NP alone (Samra and Anand, 2008).

Due to the relatively higher crop yields and high removal of K, the K values were significantly decreased by time. Deficiency of Zn, Fe and Cu are the common feature of these soils. Being arid to semi arid area, about 75% of the cultivated area is irrigated while the rest is rain-fed. The micronutrients availability in soils is a function of the rate of replenishment from soil solids to soil solution. In all soils, replenishment of micronutrients takes place from earth minerals present in the pedosphere or lithosphere. The pedospheric variations due to parent material, topography, climate etc. lead to spatial variation of micronutrients in soils (Katyal and Sharma, 1991).

The distribution of micronutrients may differ among the profiles developed on different parent materials and landforms. With the introduction of high yielding varieties, the removal of nutrients, including micronutrients from the soils, is very large. Continuous use of nitrogenous and phosphatic fertilizers in the intensive cropping system with less use of organic manures results in quick depletion of micronutrients from soils (Dhane and Shukla, 1995).

Previous studies showed depletions in micronutrients (El-Fouly et al., 2010a) and magnesium (El-Fouly et al., 2010b), under different cropping systems and in different soils.

The crops in the village did not suffer from any water shortage. Farmers use high rates of nitrogen and phosphorus fertilizers on all field crops and did not use potassium fertilizers for any crop. The crops in the village did not suffer from any water shortage during the study period. Relatively good quality irrigation water was available all the year.
Table 2. Average organic manure and fertilizers used.

|                  | 1981-1995 | System 1 | System 2 |
|------------------|-----------|----------|----------|
| Summer (June-Oct.) |           |          |          |
| Organic manure   | 50 m³/ha  | 50 m³/ha |          |
| N- (Urea or ammonium nitrate) | 125-250 kg/ha | 125-250 kg/ha | 125-250 kg/ha |
| P- (single superphosphate) | 75-125 kg/ha | 75-125 kg/ha |
| Winter (Nov-May)  |           |          |          |
| Organic manure   | 50 m³/ha  |          | -        |
| N- (Urea or ammonium nitrate) | 125-250 kg/ha | 40 kg/ha |
| P- (single superphosphate) | 75-125 kg/ha | 75-125 kg/ha |
| After 1995        | Summer (June-Oct.) | Maize | Maize |
| Organic manure/ha | 75-100m³ | 75-100 m³ |
| N- (Urea or ammonium nitrate/ha) | 180-300 kg/ha | 180-300 kg/ha |
| P- (single super phosphate) | 38-55 kg/ha | 38-55 kg/ha |
| Winter (Nov-May)  | Wheat     | Clover   |
| Organic manure   | 100 m³/ha | 85-100 m³/ha |
| N- (Urea/ammonium nitrate) | 180-250 kg/ha | 125-250 kg/ha |
| P- (Single super phosphate) | 38 kg/ha | 40-60 kg/ha |

Laboratory analysis

The soil samples were collected and air-dried, ground, sieved to pass through 2 mm sieve and analyzed. Soil samples were analyzed for texture with a hydrometer (Bouyoucos, 1954), for pH and electric conductivity (EC) using water extract (1 soil : 2.5 water) method (Jackson, 1973). For total calcium carbonate (CaCO₃%), calcimeter method was used as described by Alison and Moodle (1965). Organic matter (O.M%) content was determined according to Walkley and Black (1934) using potassium dichromate (Chapman and Pratt, 1978). Phosphorus was extracted using sodium bicarbonate (Olsen et al., 1954). Potassium (K⁺) was extracted using ammonium acetate. Micronutrients were determined by atomic absorption spectrometer after extraction according to Lindsay and Norvell (1978). Same procedures were used in both years.

RESULTS AND DISCUSSION

Soil pH

In general, pH varied from 8.2 to 8.7 in both 1981 and 2008, at a depth of 0 to 30 cm (Table 3). Lopez et al. (2003) and Lopez and Pardo (2009) reported that soil pH can vary considerably from one spot in the field to another. It also varies with depth. Different geographic regions, as already mentioned, may have different pHs because of the five soil forming factors: (1) parent material, (2) climate, (3) living organisms, (4) topography, and (5) time.

Soil electrical conductivity (EC)

The electrical conductivity of the surface soil of all sites ranged between 0.19 to 0.54 and from 0.13 to 0.46 dSm⁻¹, respectively in 1981 and 2008 (Tables 3). In general, EC showed decrement in 2008 compared with 1981. This might be due to over irrigation of the soil and low use of chemical fertilizers. Similar results were obtained by Turan et al. (2009) who reported that EC dropped with time increase, also Manojlovic et al. (2008) found similar results.

Soil OM (%)

Soil organic matter content across sites was low to medium, ranging from 1 to 1.4% in top soil in 1981 and between 1.3 to 2.6% in 2008 (Table 4). Soil OM showed increment in 2008 than what was found in 1981. This increase could be attributed to the continuous supply with organic manure is each cultivation season. Zheng (1999) reported that soil receiving no fertilizer or farm yard manure (FYM) showed no consistent changes in organic matter at 0 to 20 cm depth, while application of FYM once in every cycle increased OM content by 0.29% in 12 years. NP application increased OM content by 0.30% in 12 years. Combination of FYM + NP increased organic matter content by 0.42% in 12 years. The soil OM was increased gradually with the cultivation time.
Xiaorong et al. (2006) reported that soil organic matter was higher in cropped and fertilized soil after 18 years. Other factors may also influence the degree of change in organic matter.
Table 5. Soil phosphorus and potassium (mg/100 g soil) in surface soil layer in 1981 and 2008.

| Site | P 1981 (%) | 2008 (%) | K 1981 (%) | 2008 (%) |
|------|------------|----------|------------|----------|
| 1    | 1.2        | 3.4±0.4  | 57.8       | 55.3±4.2 |
| 2    | 1.3        | 4.0±1.0  | 47.7       | 24.5±16.2|
| 3    | 0.6        | 3.7±0.34 | 81.1       | 42.6±5.6 |
| 4    | 1.0        | 3.5±0.4  | 70.7       | 47.6±7.9 |
| 5    | 0.9        | 2.9±0.6  | 63.0       | 46.9±4.1 |
| 6    | 1.0        | 3.9±0.2  | 80.8       | 55.5±3.4 |
| 7    | 1.0        | 3.0±0.6  | 63.0       | 53.9±5.2 |
| 8    | 0.7        | 3.96±0.6 | 67.0       | 53.5±5.1 |
| 9    | 1.4        | 3.6±0.32 | 48.6       | 54.4±8.1 |
| 10   | 1.3        | 3.7±0.9  | 57.3       | 23.3±14.3|
| 11   | 1.0        | 3.82±0.2 | 57.0       | 54.3±4.0 |
| 12   | 0.7        | 2.7±0.3  | 58.7       | 54.6±5.6 |
| 13   | 0.8        | 2.9±0.22 | 57.6       | 36.6±4.3 |
| 14   | 0.9        | 3.5±0.4  | 49.3       | 47.6±7.9 |
| 15   | 0.7        | 3.4±0.4  | 57.5       | 55.3±4.0 |
| 16   | 0.8        | 3.2±0.54 | 51.5       | 55.3±4.0 |

Mean 1.0 3.4 60.5 48.2
Range 0.6-1.4 2.7-4.0 47.7- 81.1 23.3 - 55.5

Soil CaCO₃ (%)

Table 4 shows that means of CaCO₃% were different among locations in 1981 and 2008. CaCO₃% ranged between 0.98 and 1.80 in 1981 and between 1.0 and 1.9 in 2008 at surface soil layer. On the other hand, William (2006) found that after 18 years, soils CaCO₃ contents decreased with time.

Phosphorus (mg/100 g soil)

The results presented in Table 5 show that the surface soil P concentration ranged from 0.6 to 1.4 in 1981, and from 2.7 to 4.0 in 2008. The average values of P content increased with time among sites. These results suggest that variation within agriculture practices can influence soil nutrient content. The increase can be attributed to the continuous use of P fertilizers.

Hung et al. (2001) found that long-term P application in the form of single superphosphate caused significant increments. Increases in soil P only in the 0- to 10-cm depth suggest that residual P fertilizer has accumulated mainly in the soil surface. Setia et al. (2009) reported that available P in the control plot decreased whereas in plots with added P, available P increased significantly after 11 and 22 years.

Guo et al. (2000), and Diaz and Grove (2008) found that the increase in P which accumulated at all locations in 2008 may be attributed to the repeated application of the N+P. McCollum (1991) documented that annual addition of 45 kg P/ha for 20 or 40 years to continuous smooth brome (Bromis inermis) on a silt loam soil resulted in increasing soil P concentration (150 to 250 mg P/kg soil) as compared to unfertilized. The concentration of phosphorus in soil is influenced by some other factors. A study conducted by Chen et al. (2003) concluded that the recycling of P was mainly driven by plant P demand and sustained by root and leaf litter inputs. Besides, seasonal changes in environmental conditions such as rainfall, soil moisture and temperature are also involved in the P availability. Microbial biomass also plays an important role in P availability.

Potassium (mg/100 g soil)

Data in Table 5 show that mean values of K varied between 47.7 to 81.1 in 1981 and from 23.3 to 55.5 in 2008 surface soil layer. The decrease in soil K after 27 years of intensive cropping may be due to the continuous use of N or N+P fertilizer without any K addition in the soil at any cycle. Obviously, continuous use of N or P alone leads to severe depletion of other nutrients. The decreases in total K content were due to crop removal in the absence of external source of K supply through fertilizers and manure.

Ishaq et al. (2002) reported that the decrease was due
to the relatively higher crop yields and high removal of K. High K removal in the absence of K addition has resulted in drastic reduction of total K as well as available K under only NP addition (Harry et al., 2000).

Available Fe

Mean values of Fe content varied from 7.8 to 22.1 among sites in 1981 and from 4.3 to 16.9 at depth of 0 to 30 cm in 2008 (Table 6). In general, mean values of Fe content decreased in 2008 in comparison with 1981. The decline in Fe status with continuous cropping occurred because of Fe removal by the successive crops from the native soil reserve. Khan et al. (2002) reported that continuous application of increasing level of N significantly depleted the available Fe content in the soil. These results agreed with the findings of Nayyar et al. (2001), Li et al. (2007), Machado et al. (2007) and Santiago et al. (2008).

Available Mn

Table 6 indicates that there were drastic differences among locations in Mn content in 1981 and 2008. In general, Mn contents at all locations showed decrement in 2008 compared with 1981. Mn content ranged between 12.2 to 44.4 in 1981 and between 1.92 to 7.8 in 2008 (Table 6). Khan et al. (2002) reported that intensive fertilization and cropping for a long time have brought remarkable decreases in available Mn in soil. The decrease in Mn content due to continuous cropping can be ascribed to Mn removal by successive crops without any addition from the external source. Cropping sequence year after year have created a favorable environment for strains of Mn oxidizing bacteria or fungi leading to faster depletion. Malhi et al. (1998), Cox et al. (2003) and Carter (2005) found that Mn was negatively correlated with pH and sand, whereas a positive correlation existed with EC, OM, CaCO3 and clay. From this association, it can be inferred that addition of organic matter encourages the availability of Mn and as the soil become coarser, Mn deficiency become a problem (Setia and Sharma, 2004).

Available Zn

Table 7 indicates that all locations showed decreases in soil Zn content in 2008 compared with 1981. Mean values of Zn ranged between 0.87 and 2.6 and from 0.4 and 2.2 in surface soil of 0 to 30 cm depth through 1981 and 2008, respectively. With the introduction of high yielding varieties, the removal of nutrients, including micronutrients from the soils are very large. Continuous use of nitrogenous and phosphatic fertilizers in the intensive cropping system, with low use of organic manures, resulted in quick depletion of micronutrients from soils.
Table 7. Soil zinc and copper contents (ppm) in surface soil layer in 1981 and 2008.

| Site | Zn 1981 (%) | Cu 1981 (%) | Zn 2008 (%) | Cu 2008 (%) |
|------|-------------|-------------|-------------|-------------|
| 1    | 2.03        | 2.73        | 0.5±0.1     | 0.4±0.04    |
| 2    | 1.45        | 5.40        | 1.7±0.6     | 0.9±0.6     |
| 3    | 1.34        | 4.43        | 2.2±0.7     | 1.4±0.53    |
| 4    | 2.02        | 4.38        | 1.5±1.13    | 1.2±0.98    |
| 5    | 0.87        | 3.99        | 1.8±0.2     | 1.7±0.5     |
| 6    | 1.60        | 3.40        | 0.4±0.1     | 0.4±0.1     |
| 7    | 2.02        | 3.62        | 0.5±0.12    | 0.5±0.1     |
| 8    | 1.99        | 4.48        | 0.4±0.12    | 0.4±0.1     |
| 9    | 1.44        | 3.01        | 0.5±0.14    | 0.4±0.1     |
| 10   | 1.63        | 3.32        | 1.7±0.9     | 1.1±0.6     |
| 11   | 1.42        | 3.62        | 1.4±0.12    | 0.5±0.1     |
| 12   | 2.02        | 4.89        | 0.5±0.11    | 0.3± 0.1    |
| 13   | 2.60        | 4.35        | 0.5±0.1     | 0.4±0.1     |
| 14   | 1.05        | 4.84        | 0.5±0.1     | 0.4± 0.1    |
| 15   | 0.97        | 6.34        | 1.5±2.4     | 2.0±0.6     |
| 16   | 1.20        | 5.36        | 0.5±0.1     | 0.4±0.1     |

Mean 1.6  4.3
Range 0.87 - 2.60 0.4-2.2 2.73 - 6.34 0.3 - 2.0

The accumulation of Zn in surface soil layers might be due to: (i) the addition through plant residues left over by the soils which have also been reported by Katyal and Sharma (1991), Setia and Sharma (2004) and Verma et al. (2005). Similar results were obtained by Khan et al. (2002), Wright et al. (2007) and Ewa et al. (2009), where available micronutrient contents decreased with time.

Available Cu

Mean values of Cu content (ppm) in soil were differed among locations in 1981 and 2008 (Table 7). All locations showed decreases in Cu content in 2008 compared with 1981. The Cu content in 1981 varied from 2.73 to 6.34 and from 0.3 to 2.0 in 2008. Fertilizer addition caused a considerable decline in available Cu status irrespective of the level of application. Different treatments, continuous use of N alone resulted in a significant decline in the Cu content. Nayyar et al. (2001) also reported a decline in Cu content with increasing level of N, P and K in a long-term experiment after 22 cycles.

Conclusion

Long term cultivation of alluvial silty clay loamy soils of small holding under continuous tillage surface irrigation and unbalanced fertilizers use led to negative changes in nutrient contents in the soil. Balanced use of fertilizers, based on yield estimation, soil testing and plant analysis is recommended. Otherwise, continuous depletion of nutrients from the soil will continue, leading to yield decreases and low soil fertility.

Conflict of interest

The authors have not declared any conflict of interest.

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