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Comparison of the environmental indicators of phosphorus efficiency and the balance between saffron and wheat production systems in the Qaenat region, Iran

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ABSTRACT: Improving the resource use efficiency in agro- ecosystems is an important factor for reducing environmental pollution. To evaluate phosphorus (P) efficiency and balance indicators, a research was conducted in wheat and saffron production systems in the Qaenat region (South Khorasan Province, Iran) during 2011 and 2012, based on the method of the Organization for Economic Co-operation and Development (OECD). The required information about wheat and saffron cultivation was collected via questionnaires and the required coefficients were obtained from various literatures. The results showed that the phosphorus efficiency and balance indicators were significantly different between distinct districts only in the case of wheat crops. The highest P efficiencies of wheat and saffron farms were 7.21% and 2.93%, respectively. Additionally, P efficiency and balance indicators showed a significant difference between both crops in some districts, so that wheat had higher P efficiency than saffron, which was mainly because of the different amounts of animal manure applied to these crops. There was no significant difference between the different ages of saffron farms for P efficiency and balance. Furthermore, there was a significant negative correlation between P efficiency and balance indicators. It would appear that there are many opportunities for improving the efficiency of P and to prevent environmental pollution through the optimization of management decisions.

Keywords: Agri-Environmental Indicators, OECD, Phosphorus Fertilizer, Sustainability.

INTRODUCTION

An adequate supply of nutrients in soil is essential for good crop growth. From all the necessary nutrients plants need, some are required in large amounts, especially nitrogen, phosphorus and potassium, and usually are heavily used on agricultural land. It is therefore very important to maintain a healthy balance between nutrients applied to and nutrients removed from fields, to ensure optimal use of resources, and to limit pollution problems, particularly those associated with nitrogen and phosphate surpluses (OECD, 2007).

Phosphorus is an essential nutrient for crops and animal production, but when applied to agricultural land as chemical fertilizers and manure in excess, the removal by harvested crops and repeated applications can lead to an accumulation of phosphorus in surface soils (Elrashidi et al., 2005). Substantial evidence exists showing that higher phosphorus concentrations in soils can result in increased phosphorus losses to natural waters (Haygarth et al., 2005; Schulte et al., 2006; Skhiri and Dechmi, 2012). This is especially true in areas with intensive animal farming. Long-term P accumulation is not sustainable and can eventually lead to lake eutrophication (Schussler et al.,

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2007), an issue that can threaten the sustainability of agro- ecosystems.

In agriculture, sustainability includes a set of physical, biological, economic and social factors (Gonçalves-Gomes et al., 2009). Therefore, from an environmental viewpoint, a farming activity is sustainable if its polluting emissions and its use of natural resources can be tolerated and supported in the long-term by the natural environment. Thus, the first step in the overall assessment of agricultural sustainability is that the environmental impact of agriculture should be fully recognized. This impact can be analysed on a range of spatial scales, from the field to the national or even the supranational scales (OECD, 2001).

The impacts of agriculture on the environment are a major public concern. For this reason, calculating phosphorus balances has been identified as a preferred agri-environmental indicator by OECD member countries. The information provided by phosphorus balances is needed to analyse the interactions between agriculture and the environment, to monitor how environmental concerns are being integrated with agricultural policy and to evaluate the impact of changes in agricultural policy on the environment. It must be recognized, however, that any nutrient balance provides only an indirect indication of nutrient losses to surface waters (Oenema et al., 2003; Oborn et al., 2003). The soil-surface balance of phosphorus may range from negative values to more than +200 kg ha^{-1} $year^{-1}$, depending on the farming system and the way in which the farm is managed (Gronroos and Seppala, 2000; Hooda et al., 2001; Steinshamn et al., 2004).

Saffron (*Crocus sativus L.*) belongs to the Iridaceae family and it is mostly distributed in the Irano-Touranian region and West Asia where there is low annual rainfall, cold winters and hot summers (Sepaskhah and Kamgar-Haghighi, 2009). Saffron is known as one of the world's most expensive medicinal and agricultural products (Aghaei and Rezagholizadeh, 2011; Koocheki et al., 2011). It has a special place among Iran's export products (Azizi Zehan et al., 2006). Due to saffron's specific climatic conditions, the Razavi and South Khorasan provinces serve as the main cultivating areas in Iran of this valuable plant (Mollafilabi and Shoorideh, 2009).

Due to environmental pollution resulting from excess phosphorus in groundwater and other natural resources, which leads to imbalances in phosphorus balance, improving phosphorus efficiency is an important issue in agro-ecosystems. As saffron cultivation is considered a low-input agricultural system in Eastern Iran (Khorasan Province), the objectives of this research were: a) an environmental impact assessment of the use of phosphorus fertilizers in saffron production systems and comparison with wheat production systems (as a higher input crop); b) evaluate the phosphorus efficiency and balance indicators in the production systems of these two crops.

MATERIALS & METHODS

This research was conducted in the Qaenat region in the south of Khorasan Province, east of Iran (Fig. 1). Based on the number of farms, 50 wheat farms and 48 saffron farms (farms aged two, three, five and seven years) were randomly selected from three districts in the Qaenat region: central, Nimbolouk and Sede.

In order to collect data, questionnaires were prepared based on the research objectives and were filled out by the farmers of the selected farms. For each field, a soil sample was collected at harvest time to determine organic matter and salinity. Additionally, plant samples (shoots) collected from farms were analysed to determine phosphorus uptake by plants. The plant samples were first placed in an oven at 75°C for 48 h and were ground after drying.

Phosphorus was measured by spectrophotometer device using Olson's method (Olsen et al., 1954). Finally, the measured values, along with the required coefficients collected from various literatures, were used to calculate the phosphorus efficiency and balance indicators. These indicators were defined as follows.

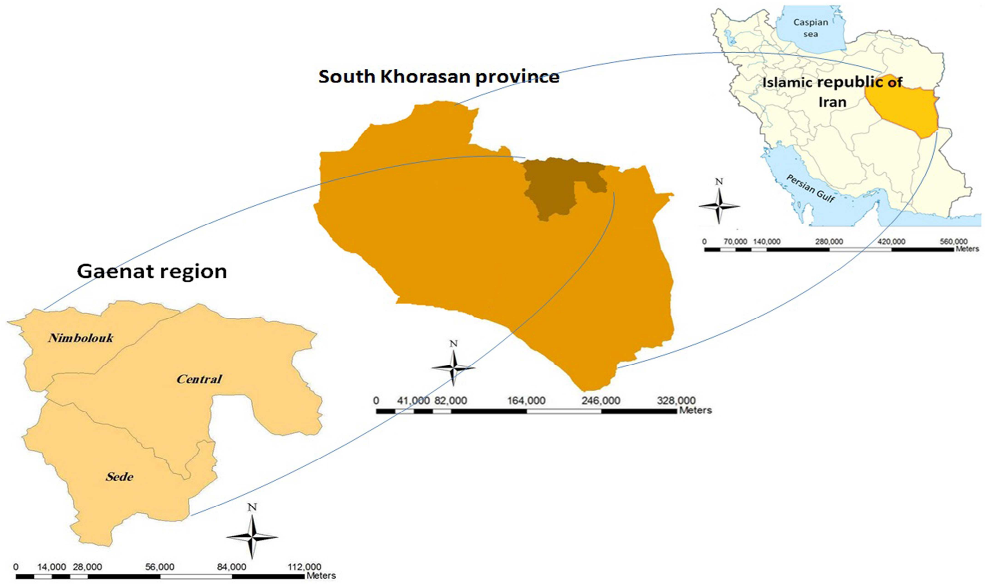

Fig. 1. Location of the study area in the Qaenat region in the south of Khorasan Province, east of Iran

Phosphorus balance indicators

Phosphorus balance indicates the difference between the total quantity of phosphorus entering and leaving the soil annually, based on the phosphorus cycle. Excess phosphorus may remain in the soil, leach into groundwater or run-off into surface water. The soil surface balance was calculated as total phosphorus inputs minus total phosphorus outputs and included the following parameters.

Inputs

1. Fertilizers: estimated input of P from chemical fertilizer [kg P] = the total amount of chemical fertilizer used per unit of arable land [t] × fertilizer coefficient [kg P t-1] (1).

The conversion factor (P coefficient) was considered based on the prevalent form of applied phosphorus fertilizer in the region (triple superphosphate) (Peivandi et al., 2009).

2. Livestock manure: estimated input of P from livestock manure [kg P] = the total amount of livestock manure used per unit of arable land [t] × manure coefficient [kg P t^{-1}] (2).

It should be noted that in this study, according to the questionnaire information, cattle manure was the most commonly used manure in the farming units of this region. Therefore, a cattle coefficient was used to calculate the amount of P per tonne of used manure (Knott, 1997).

3. Atmospheric deposition of phosphorus compounds: atmospheric deposition [kg P]= utilized agricultural area [ha] × P deposition rate [kg P ha^{-1}] (3).

There was no available data regarding P deposition rate in Iran; therefore, we inevitably used the phosphorus atmospheric deposition coefficient representative of Greece (OECD, 2001) in this study, because of the country's similarities to the Iranian climate, compared to other member countries of the OECD.

4. Other inputs (seeds and planting material, etc.): the P input from the seed cultivated (kg) = the amount of seed cultivated (t) × the amount of P in the seed [kg P t^{-1}] (4).

Given that most of seeds from the sampled farms represented the Roshan cultivar, the percentage of phosphorus in wheat seed was taken from Shahr Aeini et al. (2011). The percentage of phosphorus in the corms of saffron farms of all ages was measured directly in the laboratory.

Outputs

When crops are harvested or grass is grazed, some of the phosphorus contained in the plant is removed along with the harvested crop. Therefore, the total annual amount of phosphorus removed from the soil in terms of phosphorus balance is equal to the amount of phosphorus removed by the harvested crop. Thus, we have:

Amount of P removed in harvested crop [kg P] = crop production [t] × P coefficient for crop [kg P t^{-1}] (5).

In this study, according to the determined P percentage in the harvested crop samples (shoots) from each farm, the rate of coefficients were calculated and used to estimate the output of phosphorus from the soil.

Finally, phosphorus balance indicator per hectare was calculated as follows:

Balance of phosphorus per hectare [kg ha^{-1}] = phosphorus balance indicator [kg]/total cultivated area [ha] (6).

Phosphorus efficiency indicator

This indicator was measured as the percentage of total P uptake (output) to the total available P (input).

Phosphorus efficiency indicator [%] = (total P outputs [kg]/Total P inputs [kg]**)** ***** 100. (7)

All the calculations and statistical analyses were performed using Excel and SPSS (v. 16).

RESULTS & DISCUSSION

Phosphorus balance indicator

The obtained conversion coefficient used for calculating the indicators of phosphorus efficiency and balance is shown in Table 1. Phosphorus in saffron shoots was determined to be between 0.10% and 0.12%. It was estimated that for every tonne of saffron hay harvested, about 2 kg P would be removed from the soil if saffron leaves were harvested along with the flowers (Kafi et al., 2006). The determined value for P contained in wheat shoots was lower than expected (Table 1). The low P percentage in wheat shoots may have been due to a deficiency of organic matter and the available P in the soil of this region. The critical P level for wheat depended on factors such as the amount of soil clay, soil organic matter, iron oxides, climate and crop management. The critical levels of P in soils of Iran has been reported to be 10.5, while the available P in roughly 48.3% of all Iranian wheat farms has been projected as being below critical level (Olfati et al., 2000). On the other hand, a large amount of consumption P fertilizer is non-soluble after entering the soil. Indeed, part of this fertilizer is converted to non-soluble calcium and magnesium compounds in calcareous soil, where it is outside the reach of plants.

Table 1. The obtained conversion coefficient used for calculating phosphorus efficiency and balance indicators

Parameter	Coefficient (Unit)	Reference
Wheat seed P	0.45 %	Shahr Aeini et al. (2011)
Saffron corm P	0.02 - 0.09 %	Calculated
Phosphorus fertilizer P	48%	Peivandi et al. (2009)
Manure P	0. 4%	Knott (1997)
Wheat shoot P	0.04 - 0. 1 %	Calculated
Saffron shoot P	0.10- 0.12 %	Calculated
Atmospheric deposition of phosphorus compounds	0.2 kg P ha^{-1}	OECD (2003)

According to the study' calculations, the phosphorus balance of wheat showed significant differences between districts (Table 2)**.** Sede and Nimbolouk, at 83.313 and 45.805 kg ha^{-1} had the highest and lowest P balance, respectively (Fig. 2). Ekholm et al. (2005) stated that P losses to surface waters may differ drastically due to the diversity of agricultural production systems practiced under contrasting environmental conditions. In a study of nutrient balance in Italy, Bassanino et al. (2011) reported average phosphorus balance for five macro land units (main crops included winter wheat, maize, rice and leys and meadows): 12, 18, 39, 22 and 5 kg ha^{-1}.

Since a lower value of this indicator indicates less environmental pollution, Nimbolouk illustrated the better situation with less contamination risk (Fig. 2). The wheat farms in Nimbolouk had the minimum input and maximum output per hectare, leading to a smaller difference between the P input and output, thus reducing the P balance (Table 3)**.** In this region, much of the wheat cultivation is conducted by farming corporations**.** Compared to the indigenous knowledge of subsistence farmers, the monitoring of the production process by company experts can contribute to the efficient use of fertilizers and achieving a higher yield. This means that the difference between P inputs and outputs can be reduced. The maximum P input was found for wheat farms in Sede and showed significant differences from the other two districts. This was due to higher P fertilizer application in this district. However, the P output through wheat shoots showed no significant difference for the values of the two other districts. This overuse of P fertilizer in Sede is a direct result of the low soil fertility in this region, but is not a sustainable approach for overcoming soil nutrient deficiency. However, it is predicted that readily available sources of P fertilizers are running low worldwide (Sepehr et al., 2009) and that increasing fossil fuels prices can lead to the increase of the price of fertilizers, and consequently, the increased cost of production. On the other hand, due to the indiscriminate use of P fertilizers, environmental problems such as eutrophication can occur. Therefore, long-term strategies must be developed that will eventually result in a balance of inputs and outputs, or even an imbalance (inputs < outputs) that will eventually lead to declining P storage. Accomplishing this requires reducing P inputs or increasing deliberate exports (Schussler et al., 2007). Reductions in P inputs can occur by improving the efficiency of animal feed, which can also potentially yield large financial savings (Wu et al., 2001). Bundy (1998) showed that improved cropping practices increases crop P exports from wisconsin cropland and reduced the rate of accumulation of soil P from 1975 to 1995**.**

For saffron, there was no significant difference between districts with regard to P balance indicators (Table 2), due to the P inputs and outputs not showing any significant differences between the saffron farms of the different districts. However, P balance was lower in the saffron farms of the central district than in the other two (Fig. 2).

Table 2. Results of one-way variance analysis of phosphorus balance indicators between districts for each of the crops

	S.O.V	Sum of Squares	df	Mean Square	F	Sig.
Wheat	Between Groups	19782.2	2	9891.12	5.803	0.005
	Within Groups	80113.4	47	1704.54		
	Total	99895.7	49			
Saffron	Between Groups	18920.7	2	9460.34	0.917	0.407
	Within Groups	464189	45	10315.3		
	Total	483110	47			

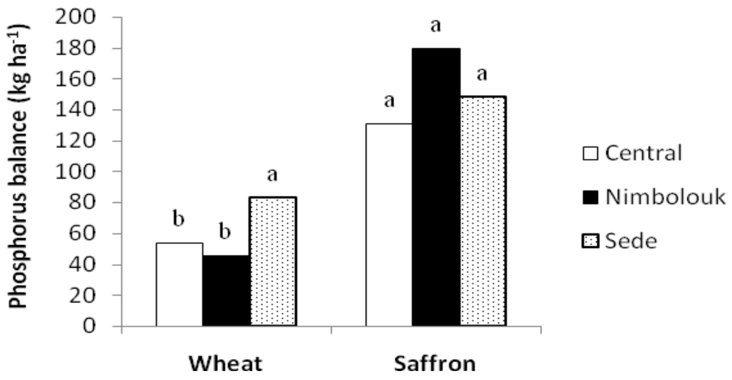

Fig. 2. Mean comparison of phosphorus balance indicators between Qaenat districts for wheat and saffron. Means with the same letters had no significant difference at 5% probability level, based on Duncan's test.

Table 3. Mean comparison of the parameters of phosphorus efficiency and balance for saffron and wheat farms for the different Qaenat districts

Crop	District	P input (kg ha^{-1})					Yield (ton ha^{-1})	Shoot P (%)	P output (kg ha^{-1})
		Seed/Corm	Fertilizer	Animal manure	Atmospheric deposition	Total input			
Wheat	Central	1.138^{a}	54.153^{ab}	0^{a}	0.2^{a}	55.491^{b}	3.79^{b}	0.0438^{a}	1.661^{b}
	Nimbolouk	0.990^{a}	48^{b}	0^{a}	0.2^{a}	49.190^{b}	7.36^{a}	0.0462^{a}	3.385^{a}
	Sede	0.847^{a}	84.761^{a}	0^{a}	0.2^{a}	85.635^{a}	4.74^{b}	0.0495^{a}	2.322^{ab}
Saffron	Central	0.627^{a}	41.400^{a}	90.548^{a}	0.2^{a}	132.575^{b}	1.60^{a}	0.1161^{a}	1.858^{a}
	Nimbolouk	0.894^{a}	88.212^{a}	92.099^{a}	0.2^{a}	181.407^{a}	1.63^{a}	0.1161^{a}	1.893^{a}
	Sede	0.831^{a}	101.400^{a}	47.935^{b}	0.2^{a}	150.363^{ab}	1.58^{a}	0.1168^{a}	1.846^{a}

Means in each column and for each crop followed by similar letter(S) are not significantly different at 5% probability level using Duncan's Multiple Range Test.

There was significant difference in terms of P efficiency indicators in the wheat crops between districts, but not for saffron (Table 4). Nimbolouk, with an average of 7.21%, showed higher efficiency than the other two districts. The central and Sede districts accounted for the lowest amounts in terms of P efficiency indicators, with averages of 3.49 and 3.04%, respectively (Fig. 3). The higher P efficiency in Nimbolouk was the result of minimum P input and maximum P output (Table 3).

Table 4. Results of one-way variance analysis of phosphorus efficiency indicators between districts for each of the crops

Crop	S.O.V	Sum of Squares	df	Mean Square	F	Sig.
Wheat	Between Groups	175.262	2	87.63	9.70	0.000
	Within Groups	424.413	47	9.03		
	Total	599.675	49			
Saffron	Between Groups	475.120	2	237.6	301.1	0.282
	Within Groups	77.215	45	795.5		
	Total	253.228	47			

Fig. 3. Mean comparison of phosphorus efficiency indicators between Qaenat's districts for wheat and saffron. Means with the same letters had no significant difference at 5% probability level, based on Duncan's test

T-test results showed significant differences between these two crops in the central and Nimbolouk districts with respect to P efficiency and balance (Table 5). Phosphorus balance in saffron crops was higher than for wheat and conversely, wheat production systems had a greater P efficiency than saffron-producing systems. Thus, it appears that saffron-based systems cause more environmental pollution than wheat-based systems. This was mainly due to higher P inputs in saffron farms, while the amount of P output was almost similar for both crops (Table 3). However, one should again consider that the main reason for the differences in P balance between these two types of crops was the inequality of their P inputs. For saffron, as a valuable perennial crop, large amounts of animal manure are traditionally applied on farms, which gradually releases its nutrients to supply food to plants in later years; however, no animal manure is used in wheat farms (Table 3), as this type of fertilizer is expensive and scarce in this region, and can intensify weed problems. Additionally, they decompose slowly and can have a major effect on wheat lodging for several years after their application. Animal manure was consumed at an average of 22.63, 25.52 and 16.26 tonnes per hectare in the central, Nimbolouk and Sede districts, respectively. Compared to balance averages for a number of farms, P surpluses between individual farms of the same farm type may vary, as shown by Reiner et al. (1996). P surpluses on arable farms were in the range between -14 and 4 kg ha^{-1} per year, while on mixed farms with predominantly cattle livestock, P surpluses were between 14 and 165 kg ha^{-1} per year. In a study by Keller and Schulin (2003), the obtained P surplus was 1.1 kg ha^{-1} per year for arable crops on arable farms, and 8.0 kg ha^{-1} per year for arable crops on dairy farms.

Animal manure contains more organic materials compared to chemical fertilizers and are considered a relatively rich source of nutrients, especially nitrogen, phosphorus and potassium. The problem occurring is that when manures are applied at a rate to meet the N requirement of crops, the amount of P and K added is generally in excess of plant requirements (Mikkelsen and Hartz, 2007). As animal manure makes its contained elements gradually available to plants (Eghbal et al., 2004), over time, P can build up to concentrations that can pose environmental risks, i.e., runoff from P-enriched fields can cause eutrophication of surface water bodies, stimulating the growth of undesirable organisms. The long-term use of P- and K-enriched manures to provide the major source of N must therefore be monitored to avoid these problems (Mikkelsen and Hartz, 2007).

A higher P input in the saffron farms was observed. However, P balance for saffron farms in Sede showed no significant differences to that of wheat farms (Table 5). Additionally, it must be noted that P output through corms, which are usually removed from the soil at the end of a six- to seven-year production period and used for next planting, was not anticipated in the calculations.

Table 5. Mean comparison of phosphorus efficiency and balance indicators between two crops in each district, based on a t-test

Indicator	District	crop		T stat	Sig.
		Wheat	Saffron		
Phosphorus balance ($kg\ ha^{-1}$)	Central	53.83	130.917	6.206^{**}	0.000
	Nimbolouk	45.805	179.514	3.215^{**}	0.004
	Sede	83.313	148.52	1.518^{ns}	0.076
Phosphorus efficiency (%)	Central	3.495	1.731	-2.525^{*}	0.012
	Nimbolouk	7.209	2.431	-3.415^{**}	0.001
	Sede	3.042	2.915	-0.137^{ns}	0.446

* and ** means significant at 5 and 1% probability levels, respectively; ns is non-significant

It has been proven that the positive impacts of organic fertilizers on the improvement of the chemical properties of soil and the better supply of nutrients decrease over time (Rasouli and Maftoon, 2010), and that repeated applications are required. In one study, it was found that the influence of manure on plant growth and yield was about 60% in the first year, and reduced to 45%, 30% and 25% in the three subsequent years. Although about 90% of fertilizer nutrients are consumed in the first year, a maximum of 10% remains in the soil for the following year's plants (Eghbal et al., 2004). However, it should be noted that sources of organic matter is limited in Iran and the nutrients they contain are not balanced. For example, generally, the available N and P are low in organic matter while potassium levels are high. Therefore, most soils need supplementary N or P alimentation in the form of chemical fertilizers (Rasouli and Maftoon, 2010). It can be concluded that if we ignore manure as a source of P input and if we take into account corm P output, saffron production systems will have a higher P efficiency than wheat systems.

The phosphorus efficiency indicator showed no significant difference between the two crops in the Sede district (Table 5). The less use of animal manure on the saffron farms of Sede was due to its restricted availability; this has led to the relatively greater reliance of farmers on chemical fertilizers in this district (Table 3), so that the difference between P inputs in wheat and saffron farms was 64.73 kg ha^{-1} in Sede, compared to 77.08 and 132.22 kg ha^{-1} in central and Nimbolouk, respectively, while P outputs for both crops in Sede were not significantly different from the other two districts. This indicates that the supplied P through animal manure exceeded plant requirements in the central and Nimbolouk districts and that increased consumption has not given rise to its absorption by saffron (Table 3), exposing it as a leaching risk. It has been claimed that animal manure gives rise to efficient P uptake by plants (Chaudhry et al., 1999). Sabahi et al. (2008) showed that the available P in an organic system was significantly higher than in a chemical system, with a significant positive correlation between the percentage of soil organic carbon and extractable P. The increase in soil organic carbon improved P availability in the following ways: i) increasing the solubility of non-soluble calcium phosphates by organic acids, produced through the decomposition and carbonic acid from breathing CO_2; ii) replacing phosphate ions instead of humus ions attracted iron and aluminium oxides; iii) inhibition of humus coatings on iron and aluminium oxides connected the phosphate ions and oxides mentioned above, and thus reduced phosphorus fixation by these oxides; iv) creating dissolved organic compounds called chelate aluminium and the reduction of non-soluble aluminium phosphate (Koocheki and Khalghani, 1998). However, it should be noted that increased P availability in soil will not necessarily lead to increased absorption and removal of nutrients from soil by crops, especially in the case of saffron, which has a low demand for nutrients and a lower biological yield than other crops, such as wheat.

In general, the results of this study suggested that P efficiency was low in both saffron and wheat production systems in the Qaenat region, mainly due to their low P uptake. Calcium carbonate in the soils of semiarid regions tied up soil P, rendering the added P only sparingly available for plant uptake (Syers et al., 2008). The phosphorus fixation capacity of the soils varies according to their physical, chemical and biological characteristics, climate and agronomic management. Generally, plants could not absorb more than 80% of added P via fertilizers; the remaining P remains fixated in the soil or may leak out of arable lands, polluting the environment and surface waters. Although the concentration of P in soils vary from 400 to 1000 mg kg^{-1} (Han, 2006), plants absorb only a small amount of it (in ppm), depending on soil alkalinity, as different phosphate ions are determined by their solubility order, which are univalent anion $H_2PO_4^{1-}$, divalent anion HPO_4^{2-} and trivalent anion PO_4^{3-}, respectively (Rodriguez et al., 2006; Han, 2006).

The results of one-way ANOVA of phosphorus efficiency and balance indicators showed no significant difference between the different ages of saffron farms (Table 6). There was no significant difference in total P input between the different ages of saffron farms (Table 7). This means that almost the same amounts of fertilizer were used on farms of different ages (2, 3, 5 and 7 years) within the studied areas. However, P output showed significant differences between the various ages of saffron farms, so that the five-year-old farms accounted for the greatest P output (Table 7). It has previously been reported that the maximum yield usually obtains in the five-year aged farms (Kafi et al., 2006).

Table 6. Results of one-way analysis of variance of phosphorus efficiency and balance indicators between saffron farms of different ages

Indicator	S.O.V	Sum of Squares	df	Mean Square	F	Sig.
Phosphorus balance	Between Groups	9.19169	3	98.6389	0.606	0.615
	Within Groups	463940	44	1.10544		
	Total	483110	47			
Phosphorus efficiency	Between Groups	553.18	3	184.6	1.297	0.287
	Within Groups	699.209	44	765.4		
	Total	253.228	47			

Table 7. Mean comparison of phosphorus inputs and outputs between saffron farms of different ages

Farm age (year)	**Animal manure P** (kg ha^{-1})	**phosphorus fertilizer P** (kg ha^{-1})	**Yield** (kg ha^{-1})	**P input** (kg ha^{-1})	**P output** (kg ha^{-1})
2	83.528^{a}	67^{a}	1559.307^{b}	151.700^{a}	1.829^{b}
3	101.336^{a}	78.444^{a}	1599.770^{b}	180.398^{a}	1.858^{b}
5	72.576^{a}	65.212^{a}	1675.729^{a}	138.361^{a}	1.888^{a}
7	63.691^{a}	61.755^{a}	1601.139^{b}	126.863^{a}	1.876^{b}

Means in each column followed by similar letter(s) are not significantly different at 5% probability level, based on Duncan's Multiple Range Test.

Correlation of variables

For wheat farms, there was a significant positive correlation between phosphorus balance and soil salinity, and a negative correlation concerning the age of farmers and cultivation area. There was a significant negative correlation between phosphorus efficiency and the age of farmers, and a significant positive correlation with the area under cultivation and farmers' education (Table 8). There was no significant correlation for saffron farms (Table 8). These results emphasized the role of education and the experience of farmers, as well as mechanization (implemented on large farms) on better- and sustainable management of farms. It appears that older farmers with high levels of indigenous knowledge had a lower tendency toward development and improvement, and were more inclined to continue using traditional methods of crop management, whereas younger and more educated farmers, who were closely connected to information and extension services, were always looking to improve their knowledge and skills. These findings support the results of Chamba (2004) concerning the significant negative correlation between farmer age and yield, and the findings of Norouzi (2005) concerning the positive impact of the technical knowledge and skills of wheat farmers in the field of water management and crop yield.

Small farms had low phosphorus efficiency and most belonged to smallholders. A large number of these scattered small fields have taken to adopting new technologies, mechanization and systematic cultivation in order to deal with obstacles and problems. Additionally, many people cultivate saffron in small plots as a secondary occupation. Given that a large part of the local income is dependent on agriculture and rural communities, and crop cultivation is an important component of revenue in the rural communities, it can be expected that with an increase in farm size, as well as addressing families' economic difficulties, farmers will be likely to implement sustainable farming practices.

The higher P efficiency and lower P balance indicators were associated with an increase in soil salinity on wheat farms (Table 8). With excessive fertilizer application, excessive salt and nitrate concentrations may accumulate and soil quality may deteriorate faster (Ju et al., 2007). A significant negative correlation between P efficiency and balance indicators (Table 8) indicated that the lower the phosphorus balance indicator, the less difference existed between P input and output, leading to an improvement in the P efficiency indicator. Additionally, as previously stated, areas with low P balance had higher P efficiency. In general, based on the observed correlations (Table 8), it can therefore be suggested that the socioeconomic situation and the status of farmers affected the indicators, which in turn influenced soil characteristics and environmental health.

Table 8. Correlation between the indicators of P efficiency and balance, socioeconomic factors and soil conditions for wheat and saffron farms (Spearman correlation test)

Variable	P balance	P efficiency	Farmer age	Education	Cultivation area	Soil salinity	Soil organic matter
Wheat							
Phosphorus balance	1						
Phosphorus efficiency	-0.38**	1					
Farmer age	0.37**	-0.33*	1				
Education	-0.32*	0.66**	-0.61**	1			
Area under cultivation	-0.28*	0.65**	-0.12	0.10	1		
Soil salinity	0.39**	-0.15	0.16	-0.34*	-0.16	1	
Soil organic matter	0.08	0.13	-0.22	0.06	-0.11	-0.25	1
Saffron							
Phosphorus balance	1						
Phosphorus efficiency	-0.65**	1					
Farmer age	-0.18	0.14	1				
Education	-0.10	0.25	-0.31*	1			
Area under cultivation	-0.16	0.09	0.14	0.06	1		
Soil salinity	0.09	-0.04	0.02	0.19	0.22	1	
Soil organic matter	-0.05	-0.09	0.07	-0.12	-0.27	-0.2	1

* = P < 0.05 ,** = P < 0.01

CONCLUSION

In terms of P cycle, there were significant differences between the two wheat and saffron cropping systems, with some remarkable differences between adjacent districts caused by crop management approaches. For wheat crops, P efficiency and balance indicators were not similar among the different studied districts, mainly due to differences in phosphorus inputs to soil, i.e., non-identically applied P fertilizer between districts. It appears that in these areas, phosphorus fertilizer use is not consistent with soil P deficiency or crop requirements. Thus, a part of sustainable agricultural development policies in this region should focus on optimizing fertilizer use, along with efforts to enhance the knowledge of farmers and further research on the interaction of soil, climate and plant-resource-use efficiency.

Regardless of animal manure, saffron farms had a higher P efficiency than wheat. The problem is non-optimized manure application in saffron farms. Large amounts of animal manure are applied annually on these farms, primarily to amend poor soils with very low organic matter content. The nutrients contained in this applied manure are usually higher than what the crop demands, exposing crops to leaching. More research is needed to enhance soil organic matter in saffron fields from alternative sources, such as companion crops or green manure and to optimize animal manure application based on the specific needs of crops to avoid environmental risks. The increasing use of chemical fertilizers has created irreparable damage to the environment, public health and economies that must be measured against the risks of excessive manure application.

In general, saffron fields appeared to be more sustainable than wheat fields. Saffron farms were generally extensively managed and compared to intensively-managed wheat farms, were characterized by lower soil disturbance, lower agro-chemical inputs, lower irrigation and higher income per area. Therefore, provided with improved management, saffron production systems, in addition to producing healthier products, can yield less environmental pollution so that these systems can be considered good candidates for being reverted to organic farming systems.

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