Estimation of national and regional phosphorous budgets for agriculture in Turkey

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Abstract

This paper presents national and regional phosphorus (P) budgets for agriculture in Turkey by using Eurostat/OECD common methodology. Regional P budgets presented in this paper are the first estimations for Turkey known to date. In Turkey, the values of P surplus for agriculture (PS) and P use efficiency for agriculture (PUE) in 2011 were 2 kg P ha^{-1} yr^{-1} and 77%, respectively. PS values varied from –2 to 15 kg P ha^{-1} yr^{-1} among regions in 2011. In 2008, PS and PUE values (0 kg P ha^{-1} yr^{-1} and 96%, respectively) were lower than the average EU values (3 kg P ha^{-1} yr^{-1} and 104%), including Norway and Switzerland. The relationship between PS values and some socio-economic properties in Turkey regions were also analyzed. According to the results, the correlations of PS with gross domestic product per capita, permanent meadows and pastures share in utilized agricultural area (UAA), population density, illiterate share and arable land share in UAA were statistically significant. We can conclude from the study results that the environmental effect of agricultural phosphorus on water bodies varies greatly both among regions in Turkey and among European countries because of high variations in PS values.

Additional key words: phosphorus surplus; phosphorus use efficiency.

Introduction

Phosphorus (P) is an important nutrient for aquatic and terrestrial plants and animal species (Mallarino & Blackmer, 1992; Poulsen, 2000; Valk *et al.*, 2000; Johnston & Dawson, 2005; White *et al.*, 2010). Plants and animals need to intake enough P to grow properly. While P deficiency negatively affects plant and animal growth, P surplus can cause important problems that affect water quality (Sharpley & Withers, 1994; Smith, 1998; Bennett *et al.*, 2001; Johnston & Dawson, 2005; Bast *et al.*, 2009; Rabalais *et al.*, 2010). These problems include negative effects on biodiversity, eutrophication and low oxygen level in waters, and undesirable taste and odor in waters (Sharpley *et al.*, 1994; Carpenter *et al.*, 1998; Smith, 1998; NRC, 2000; Hansen *et al.*, 2002).

Phosphorus deficiency, P surplus and P use efficiency in agricultural lands are estimated by the P budget that assists to acquire insights of the abovementio-ned problems in the agricultural sector, which is an important source of P in waters (*e.g.* OECD, 2001; CAPRI, 2013; Eurostat, 2013). The P budget is one of the 28 agri-environmental indicators determined by Eurostat and at the same time declared as one of the mandatory indicators for evaluation of water quality to be compiled by the Common Monitoring and Evaluation Framework of European Commission Rural Development Policy (EC, 2006). The P budget studies are also carried out by the European Environment Agency (EEA, 2013) and the Organisation for Economic Co-operation and Development (OECD, 2001). In addition to the studies conducted by international organizations, agricultural P budgets have been estimated at regional, national and international levels in numerous studies (*e.g.* Dobermann *et al.*, 1996; Bach & Frede, 1998; Zhang *et al.*, 2003; Kobayashi & Kubota, 2004; MacDonald *et al.*, 2011).

Agricultural P budgets have been estimated by using farm, land and soil budgets. While the farm budgets

Abbreviations used: EU (European Union); GDP (Gross Domestic Product); HS (Harmonized System); NUTS2 (Nomenclature of Territorial Units for Statistics); P (Phosphorus); PS (P Surplus for Agriculture); PUE (P Use Efficiency for Agriculture); UAA (Utilized Agricultural Area).

are established on the basis of farm boundaries, soil and land budgets are established on the basis of soil and land boundaries (Eurostat, 2012). The inputs and outputs in all three of these methods are different from each other (Eurostat, 2012), so the results of the estimations are also different. Budgets estimated using different methods cause problems in comparable data production. For this reason, the comparisons among countries and regions are only possible by using similar methods. Eurostat (2012) estimates the P budget of EU countries according to common guideline of Eurostat/OECD by using land budget method.

The recent development in Common Agricultural Policy (CAP) requires monitoring of environmental impacts of agricultural activities (*e.g.* pollution, resource depletion, and soil and water quality) at regional level (EC, 2006). The regional data are also needed according to EC Rural Development Policy and EU Water Framework Directive. Performing separate P budget input and output estimations for each region where differences in climate are important ensures more accurate results than the national estimations, especially for the countries where different climates are observed. Regional P budget estimations become widespread at the present day in order to meet the data requirements to perform more accurate estimations and to produce better environmental policies (*e.g.* CAPRI, 2013; Eurostat, 2013).

According to 2009 data, Turkey was ranked as the 29th largest world country in terms of total utilized agricultural area (UAA) and possessed 0.8% of the total agricultural land of the world (FAOSTAT, 2012a). In regard to number of livestock animals around the world, by 2010 Turkey was ranked as the 26th in terms of cattle, 12th in terms of sheep, 22nd in terms of goat, and 15th in terms of poultry animals. Turkey is listed as the number one country compared to EU Member States in terms of number of goats and poultry animals, ranked as 2nd in terms of sheep and 3rd in terms of cattle among these states (FAOSTAT, 2012b). In case Turkey is accepted to EU, 17.1% of the total agricultural land of EU will be within the boundaries of Turkey (FAOSTAT, 2012a). Turkey agriculture is also important in the consumption of phosphate fertilizers. The amount of phosphate fertilizers consumed in Turkey was equal to 15% of that amount consumed in Europe in 2010 (FAOSTAT, 2012c). Due to Turkey's impact on EU and world agriculture, estimation of P budget caused by agricultural sources in Turkey is very important with regards to international influences and assessments.

The main purpose of this study is the estimation of the values of P surplus for agriculture (PS) and P use efficiency for agriculture (PUE) for Nomenclature of Territorial Units for Statistics (NUTS2[1]) territorial division of Turkey by using the methodology recommended in Eurostat/OECD common guideline. The other purposes are to analyze the relation between the PS values and some socio-economic properties of regions and to compare PS and PUE values between EU countries and Turkey.

Materials and methods

The estimations of phosphorus surplus and phosphorus use efficiency for agriculture and input data

The P budget methodology used in this study is based on the methodology recommended in Eurostat/OECD common guideline (Eurostat, 2012). In this methodology, PS and PUE were estimated by using Eqs. [1] and [2].

$$PS = (P_{input} - P_{output}) / A_{ref} \qquad [1]$$

$$PUE = (P_{output} / P_{input}) * 100 \qquad [2]$$

The reference area (A_{ref}) is UAA (arable land, permanent crop land, and permanent grassland). The inputs (P_{input}) and the outputs (P_{output}) used in PS and PUE estimations, and the methodology and the data sources used in the estimations of these inputs and outputs are presented in Table 1. In order to minimize the impact of regional differences in Turkey, where different climates are observed, NUTS2 division was used in the estimations.

Statistical analysis

A Pearson correlation analysis between PS and socio-economic properties of NUTS2 regions was carried out using SAS package software. Turkey's NUTS2 phosphorus budget data from 2007-2011 was used in the analysis. Socio-economic properties used in the analysis are presented in Table 2.

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[1] The NUTS classification, which is used for producing regional statistics, is a hierarchical system for dividing up the economic territory of the EU.

Table 1. Inputs and outputs used in phosphorus surplus and phosphorus use efficiency estimations, the methodology and data sources

	Inputs & outputs in P balance	Calculation method	Data sources
Inputs	1) Mineral fertiliser	Mineral fertiliser * P content	MFAL
	2) Manure production	Number of animals * P excretion ratio	Number of animals: TurkStat Excretion ratio: Eurostat, OECD
	3) Net manure imports/ exports, withdrawals, stocks	Manure imports-manure exports-withdrawals + stock exchange	Neliglible according to mentioned facts in uncertainty part
	4) Other organic fertiliser	Organic fertiliser * P content	TurkStat
	5) Total inputs = sum (1,2,3,4)		
Outputs	6) Crop production	Crop production * P content	Crop production: TurkStat P content: Eurostat, OECD
	7) Fodder production	(Fodder production * P content) + (Pasture and meadows area * Yield * Consumption ratio * P content)	Fodder production, pasture and meadows area: TurkStat. Yield, cosumption ratio: OECD. P content: Eurostat, OECD
	8) Crop residues removed	Crop residues removed * P content	Negligible according to mentioned facts in uncertainty part
	9) Total outputs = sum (8,9,10)		
P surplus	= 5-9		
P use efficiency	= 9/5		

Sources: Eurostat (2012); TurkStat: Turkish Statistical Institute, Ankara (http://www.turkstat.gov.tr/); MFAL: Turkish Ministry of Food, Agriculture and Livestock, Ankara (http://www.tarim.gov.tr/Sayfalar/Eng-1033/Anasayfa.aspx).

Two-steps cluster model was used to define the clusters of EU countries according to PS values. This model can be used to cluster the dataset into distinct groups when those groups are not known at the beginning. The model has two steps (1) pre-cluster the cases (or records) into many small sub-clusters, and (2) cluster the sub-clusters resulting from pre-cluster step into the desired number of clusters (SPSS, 2007). The analysis was carried out using SPSS Clementine 12.0 package software.

Uncertainties

Mineral fertilizer usage statistics are compiled on the basis of sales amount and these values may be different from the amount of actually used mineral fertilizers in agriculture because of non-agricultural use, stocking and losses. Number of livestock units utilized in farm manure production estimations is based on the number of livestock at the end of the year. This situation may lead to a deviation in the estimation of farm manure production for poultry animals with less than one year of life span and the actual production of farm manure.

Although the data concerning the import and export amount of 3101 Harmonized System (HS) coded animal and plant manures is present, the share of the farm manure within this data is unknown. Review of the data concerning the import and export of 3101 HS coded animal and plant manure sets forth that, even if all of this fertilizer is composed of farm manure (= import-export) amount would refer to 0.83 per hundred thousand of the produced farm manure (TurkStat, 2013a). For this reason, import and export amount of farm manure was neglected in the calculations. Additionally, farm manure stock exchange was neglected in accordance with the Eurostat/OECD common guideline (Eurostat, 2012).

In Turkey, farm manure is subject to be used as combustible material for calefaction and cooking purposes in housings. There is no up-to-date statistical data concerning this issue. According to a study conducted in 1998, the amount of manure used in housings for calefaction purposes is 191 ktons (TurkStat, 2013b) and the P content of this fuel refers to 0.5% of the farm manure P content used in the estimations. Considering that the utilization of manure decreases as the years pass by, utilization of manure for heating purposes was neglected in the calculations.

Table 2. Definitions of socio-economic properties

Socio-economic properties	Definition	Unit	Socio-economic properties	Definition	Unit
Arable land share in UAA	The share of arable land area in UAA	%	Value of livestock per capita	Value of livestock is calculated by multiplying production amount with unit price for each livestock	TL per capita
Permanent area share in UAA	The share of permanent area in UAA	% %	Population density	Population density is a measurement of population per unit area	Population per km²
Permanent meadows and grassland share in UAA	The share of permanent meadows and grassland area in UAA		Number of villages	The number of villages in the region	No.
Organic area share in UAA	The share of organic area in UAA	%	Out-migration rate	The ratio of all migrants who moved out of the region during a given year relative to the total population in the region	%
Export value of agriculture and forestry sector	The value of goods of agriculture and forestry sector exported from the region	US $	GDP per capita	GDP is a value which is equal to the sum of the values of all goods and services produced by residential institutional units engaged in domestic production activities in an economy in a given period of time, minus the total inputs which are used in the production of these goods and services	$ per capita
Value of crops per capita	Value of crops is calculated by multiplying production amount with unit price for each crop	TL per capita	Illiterate share	The share of illiterate population in total population (for 15 years and older)	%

All data were obtained from the Turkish Statistical Institute (http://www.turkstat.gov.tr/). TL: Turkish lira. UAA: utilized agricultural area. GDP: gross domestic product.

Due to lack of excretion coefficients and P content ratios of plant products at regional level, average of EU Mediterranean countries (Spain, Italy, Portugal, Malta) was used for coastal Aegean and Mediterranean regions. Average of Central European countries (Hungary, Slovenia, Slovakia) for Central Anatolia, Eastern Anatolia, South-East Anatolia and Black Sea regions and average P content of EU Mediterranean countries and Central European countries for Marmara and Interior Aegean regions were used in estimations.

In meadow and grassland productivity estimations, OECD approach of the study conducted by Terzioğlu *et al.* (2004) was used. According to this approach, 70% of meadow and grassland productivity is assumed to be consumed.

Atmospheric P deposition, P from seed and planting materials were excluded in accordance with the Eurostat/OECD common guideline (Eurostat, 2012).

In Eurostat/OECD methodology, the estimation of crop residues removed from soil is recommended by using the country specific data. The P from crop residues removed from soil was excluded owing to no data at regional level in Turkey. In Eurostat database, P from crop residues removed from soil is present for only 12 countries. The share of P from crop residues removed from soil in total output for these countries is fairly low, at the value of 4.70%.

Regional GDP per capita and permanent meadows and grassland datasets from 2007-2011 period are absent for Turkey. Regional GDP shares from 2000 are available, and these shares were used for estimating regional GDP per capita values for the 2007-2011 period. The regional shares of permanent meadows and grassland in 2001 General Agricultural Census were used for estimating regional permanent meadows and grassland data set for the 2007-2011 period.
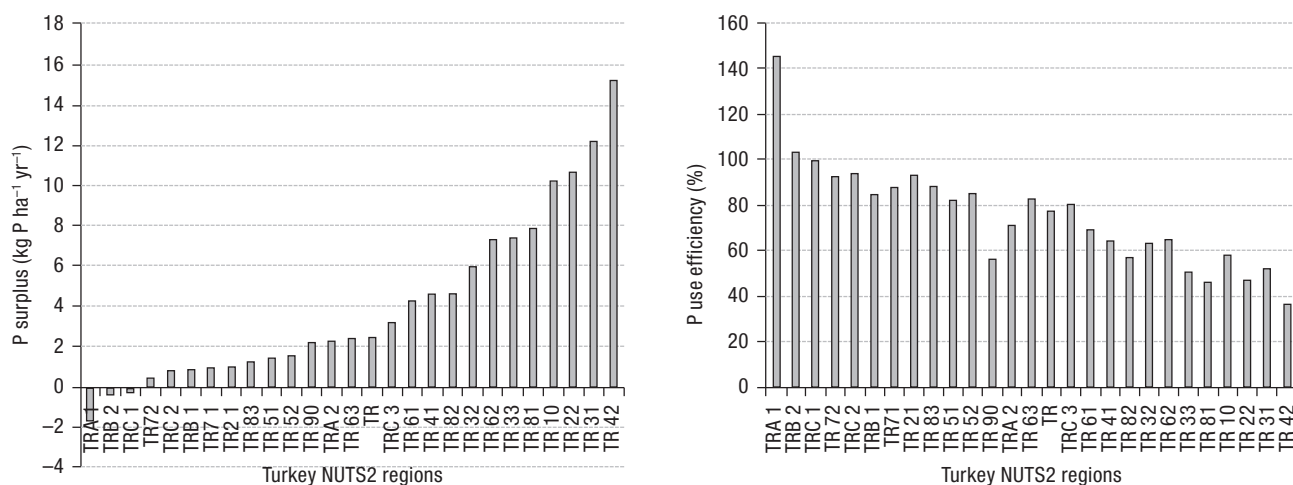
Figure 1. Phosphorus surplus and phosphorus use efficiency values of Turkey and NUTS2 regions (http://tuikapp.tuik.gov.tr/DIESS/FileDownload/Yayinlar/Siniflamalar/IBBS,_2005.doc).

Results

Phosphorus surplus and phosphorus use efficiency estimations of Turkey agriculture at national and regional levels

Fig. 1 shows PS and PUE values of Turkey and NUTS2 regions. PS and PUE values in 2011 were 2 kg P ha^{-1} yr^{-1} and 77%, respectively. The highest PS value was found in TR42 region close to the northwest border of Turkey with 15 kg P ha^{-1} yr^{-1}, whilst the lowest was observed in TRA1 close to the northeast border of Turkey with –2 kg P ha^{-1} yr^{-1}. The maximum PUE value was encountered in TRA1 with 146% and the minimum value was observed in TR42 with 37%.

The biggest contribution to P budget originated from mineral fertilizer (51%) input. This input was followed by farm manure (49%). The contribution of crop production and fodder production to P budget outputs was 66% and 34%, respectively. Assuming a share of P from crop residues removed from soil similar to European countries, PS would decrease slightly (from 2.49 to 2.07 kg P ha^{-1} yr^{-1}), so it would not relevant in the obtained results.

The relation between phosphorus surplus for agriculture and socio-economic properties of the regions

Examination of Pearson correlation coefficients (r) of PS and some socio-economic properties, introduced the GDP per capita as the strongest variable in terms of relation with PS ($r = 0.52$; Table 3). This variable was followed by permanent meadows and grassland share in UAA with a correlation coefficient va-

Table 3. Correlation coefficients between phosphorus surplus for agriculture (PS) and socio-economic properties

Socio-economic properties	r (p-value)	Socio-economic properties	r (p-value)	Socio-economic properties	r (p-value)
Arable land share in UAA*	0.21 (0.0164)	Number of villages	–0.13 (0.1549)	Permanent meadows and grassland share in UAA*	–0.35 (< 0.0001)
Export value of agriculture and forestry sector	0.03 (0.7588)	Organic area share in UAA	–0.05 (0.5444)	Population density*	0.26 (0.0034)
GDP per capita*	0.52 (< 0.0001)	Out-migration rate	–0.18 (0.0706)	Value of crops per capita	–0.17 (0.0796)
Illiterate share*	–0.26 (0.0069)	Permanent area share in UAA	0.06 (0.5313)	Value of livestock per capita	–0.11 (0.253)

* The properties whose relationship with PS is statistically significant *(p < 0.05)*. UAA: utilized agricultural area. GDP: gross domestic product.

lue of –0.35. PS also showed statistical significant relationships with population density, illiterate share, and arable land share in UAA. The correlation coefficients of other socio-economic properties in Table 3 were relatively low, and their relationships with PS were not statistically significant.

Comparison of the values of phosphorus surplus and phosphorus use efficiency for agriculture in Turkey with EU countries

According to the data of PS and PUE in EU countries for 2008 (Eurostat, 2013), the maximum PS value was observed in Cyprus with 21 kg P ha^{-1} yr^{-1} and the minimum PS value was obtained in Hungary with –15 kg P ha^{-1} yr^{-1} (Fig. 2). The maximum PUE value in EU countries was registered in Hungary with 279% and the minimum in Cyprus with 24%. PS and PUE values of Turkey (0 kg P ha^{-1} yr^{-1} and 96%, respectively) were lower than the average EU values (3 kg P ha^{-1} yr^{-1} and 104%), including Norway and Switzerland.

When we clustered EU countries, including Norway, Switzerland and Turkey, by using two-steps cluster model, we observed that EU countries can be classified in three clusters (Table 4): cluster 1, Bulgaria, Estonia, Greece, Hungary, Italy, Lithuania, Romania, and Slovakia (PS mean, –6 kg P ha^{-1} yr^{-1}); cluster 2, Austria, Czech Republic, France, Germany, Latvia, Luxembourg, Sweden, and Turkey (PS mean, 1 kg P ha^{-1} yr^{-1}); and cluster 3, with the rest of countries, Belgium, Cyprus, Denmark, Finland, Ireland, Malta, Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Switzerland, United Kingdom (PS mean, 8 kg P ha^{-1} yr^{-1}).

Discussion

The values of PS (2 kg P ha^{-1} yr^{-1}) and PUE (77%) of Turkey for 2011 were close to zero and 100%, respectively, indicating that most of the P input in soil was consumed by the outputs. PS values may vary significantly from one region to another, due to differences in the use of P inputs and outputs (*e.g.*, Liu *et al.,* 2008; Gourley *et al.,* 2011; MacDonald *et al.,* 2011). PS values of Turkey varied from –2 to 15 kg P ha^{-1} yr^{-1} among regions. This means that the variations of use of P inputs and outputs between Turkey NUTS2 regions are very high. In the regions of Turkey where intensification level in agriculture is high, hence mineral fertilizer usage and the number of livestock animals per unit area that directly effects farm manure production is high, it is observed that the PS values are also high and the PUE values are low. On the contrary, in the east and interior regions of Turkey the intensification level in agriculture is low and consequently the PS values are low and the PUE values are high.
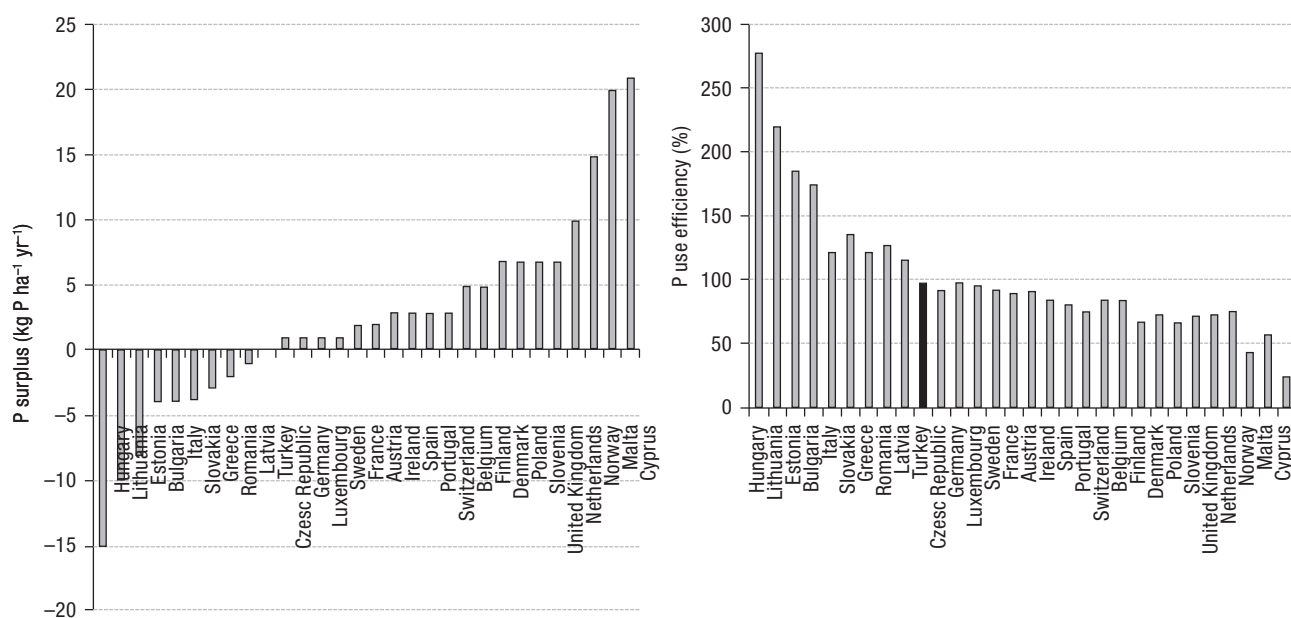

Figure 2. Phosphorus surplus and phosphorus use efficiency values of Turkey and EU countries in 2008. *Source:* Eurostat (2013).

Table 4. The clusters of EU countries (including Norway, Switzerland, and Turkey) according to the phosphorus surplus for agriculture (PS) values

Clusters	Countries	PS (kg P ha^{-1} yr^{-1})	Average PS (kg P ha^{-1} y^{-1})
1	Hungary	−15	−6
	Lithuania	−10	
	Estonia	−8	
	Bulgaria	−4	
	Italy	−4	
	Slovakia	−4	
	Greece	−3	
	Romania	−2	
2	Latvia	−1	1
	Turkey	0	
	Czech Republic	1	
	Germany	1	
	Luxembourg	1	
	Sweden	1	
	Austria	2	
	France	2	
3	Ireland	3	8
	Portugal	3	
	Spain	3	
	Switzerland	3	
	Belgium	5	
	Finland	5	
	Denmark	7	
	Poland	7	
	Slovenia	7	
	United Kingdom	7	
	Netherlands	10	
	Norway	15	
	Malta	20	
	Cyprus	21	

Phosphorus surplus value of Turkey is lower than the values of many European countries due to the higher mineral fertilizer usage per unit area and the number of livestock per unit area in European countries. Therefore the potential effect of agricultural P on water bodies has a lower risk than many European countries. The possible EU membership of Turkey will positively affect PS value of EU. Taking into account the PS value of Turkey for 2008 (0.34 kg P ha^{-1} yr^{-1}), the EU 27 PS value which is 1.09 kg P ha^{-1} yr^{-1} according to 2008 data (Eurostat, 2013) will drop to 0.95 kg P ha^{-1} yr^{-1} if Turkey is accepted into EU membership.

According to the cluster analysis result, EU countries can be classified in three groups according to PS values: the countries with P deficit, the countries within P balance, and the countries with P surplus. In the first group with P deficit, most of the countries are in Eastern Europe where intensification level in agriculture is relatively low. The main reasons of high P surplus in the countries mostly in Western and Northern Europe are the high livestock densities and the high intensification level in agriculture. Turkey placed in the cluster of the countries within P balance because PS of Turkey was very close to zero as a result of different intensification levels among the regions.

Turkey regional agricultural P budgets presented in this paper are the first regional estimations for Turkey known to date. At the national level, only OECD estimated Turkey agricultural P budget. OECD (2013) estimated PS, the average of 2007-2009, as 5 kg ha^{-1} for Turkey, while the average PS was estimated as 2 kg ha^{-1} for the same years in this study. This fact shows that the non regionalisation of P balance might cause notably different national PS estimations in comparison to the results obtained from the regionalisation of P balance. Hence, the regionalisation of P balance is so important in order to obtain more accurate results. The main reason for these differences was the P content ratios of total harvested crops used in the calculations. OECD used the average P content ratios of European countries for Turkey PS, whereas in this study different P content ratios of European countries with different climates were used for different regions of Turkey depending on their climate characteristics. This fact highlights the importance of the availability of regional country specific ratios in P balance calculations.

The PS values obtained in this study were close to the values observed by others authors. For example, Kopiński *et al.* (2006) estimated an average PS of 3 kg ha^{-1} for Poland from the data for the period 1999-2003. This value is close to the PS values of Turkey NUTS2 regions (2 kg ha^{-1}) with similar climate characteristics to Poland. MacDonald *et al.* (2011) found PS is positive for all regions for the year 2000 in Turkey. This result is convenient with the results of this study, except for TRA1, TRB2 and TRC1 which showed negative PS values. The main reason for this difference is the different coefficients (excretion coefficients and P content ratios) used in the studies. The country and crop specific ratios and coefficients were used at the level of the regions of Turkey in this study, while MacDonald *et al.* (2011) used crop specific P content ratios obtained from US Department of Agriculture, Natural Resources Conservation Service, and the regional excretion coefficients at continental level. TRA1 and TRB2

showed negative PS values as the cattle densities on the grassland were relatively low. This density was 0.4 head ha^{-1} for both regions while it was 0.9 head ha^{-1} for Turkey. TRC1 showed negative PS value as the crop response to applied mineral fertilizer was relatively high (1.5 kg N from harvested crops per kilogram of N from mineral fertilizer for TRC1; 1.0 kg N kg^{-1} N for Turkey).

Syers *et al*. (2010) mentioned that when the efficiency was assessed using the "balance" method, the efficiency of P use was high and could be larger than 100%. In this study, PUE values of three regions (TRA1, TRB2, TRC1) were estimated as larger than 100%. PUE values larger than 100% indicates that P in the outputs exceeded the amount of P by inputs and that soil P depletion occurred in these regions. Consequently, this study states that soil P depletion occurred in some regions of Turkey, and throws fresh light on the studies about the estimation of the quantity of the soil P depletion in Turkey.

PS values were significant and positively correlated with some socio-economic properties such as GDP per capita, population density, arable land share in UAA, indicating that the regions with high GDP per capita have a high risk for water quality degradation in comparison to other regions. Although PS is not only one or main indicator for measuring water quality degradation, it is well known that the P surplus can cause important problems that affect water quality (*e.g.* Sharpley *et al*., 1994; Carpenter *et al*., 1998; Smith, 1998; Bast *et al*., 2009; Rabalais *et al*., 2010, etc.). On the other hand, it was found that the correlations of PS with permanent meadows and grassland share in UAA and illiterate share were negative. The inverse relationship of PS with permanent meadows and pastures and illiterate shares can be explained as follows; in the regions where permanent meadows and pastures and illiterate shares were high, the extensification level in agriculture was also high and consequently low mineral fertilizer usage. Therefore PS values of these regions were relatively low, indicating that the regions with high permanent meadows and pastures and illiterate shares have a low risk for water quality degradation in comparison to other regions.

Although the actual risk of phosphorus leaching, run-off or changes in soil stocks of phosphorus depend on many factors such as meteorological conditions, soil characteristics, farmer management practices, etc. (Eurostat, 2012), the above results show PS could be a valuable analysis tool to estimate the environmental effect of agricultural phosphorus on water bodies. We can therefore conclude from the study results that the environmental effect of agricultural phosphorus on water bodies varies greatly both among regions in Turkey and among European countries because of high variations in PS values.

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