# Sustainable Agricultural NP Turnover in the 27 European Countries

**Péter Csathó and László Radimszky**

**Abstract** A deep contrast of NP balances, water nitrate contamination, soil P and rural development has appeared between Western and Eastern European countries since the implementation of the European nitrate directive in 1991 (91/676/EEC). In an economy ruled by free market rich countries become richer and poor countries become poorer from the point of view of water nitrate contamination and soil P overloads. There is a need for a paradigm shift in the European agro-environmental protection legislation. Instead of speaking about it, agro-environmental protection, social, and rural development principles should gain real priority. According to the principle of subsidiarity, the present problems can be solved only at the highest European-level, i.e., in the legislation and in the administration.

We reviewed the anomalies in the NP turnover of the European countries. The major points are: (1) instead of some agronomic factors such as soil NP status, added farmyard manure, and expected yield level, per capita gross domestic product and population density were the major factors affecting the magnitude of mineral and organic NP application. (2) Countries with the highest livestock densities do not take into account previous farmyard manure application and soil P status as mineral NP dose diminishing factors. This practice contradicts to the basic principles of sustainable crop nutrition. As a result, between 1991 and 2005, highest P surpluses, the most positive P balances were reached in the countries with the highest soil P level, further enhancing their agricultural P load to the environment. (3) Similarly, the European countries with the highest organic NP application, The Netherlands, and Belgium, were those who applied most mineral NP fertilisers reversely to the agronomic principles, and, resulting in most positive NP balances, and, as a consequence, the most severe environmental threat, the most severe agronomic NP

P. Csathó (✉) • L. Radimszky
Institute for Soil Science and Agricultural Chemistry, Centre for Agricultural Research, Hungarian Academy of Sciences, Herman O. street 15, H-1022 Budapest, Hungary
e-mail: csatho.peter@agrar.mta.hu

E. Lichtfouse (ed.), *Organic Fertilisation, Soil Quality and Human Health*, Sustainable Agriculture Reviews 9, DOI 10.1007/978-94-007-4113-3_7,

load to the environment. (4) The major cause of heavy agricultural NP loads to the environment was livestock density exceeding 100 livestock units 100 ha agricultural land$^{-1}$. (5) A positive correlation was found in the European countries between cumulative N balances for the period of 1991–2005 and the degree of ground water nitrates contamination. The main added value of this paper is to compare NP balances values to groundwater nitrate contaminations as well as soil P status, and evaluate their correlation from both agronomic and environmental point of views. Former works evaluate these factors, although correlative to each other, separately (Steén I, A European fertilizer industry view on phosphorus retention and loss from agricultural soils. In: Tunney H, Carton OT, Brookes PC, Johnston AE (eds) Phosphorus loss from soil to water. CABI, Wallingford, pp 311–328, 1997; OECD, Environmental indicators for agriculture, vol 3. OECD, Paris, pp 117–139, 2001; OECD, OECD trends of environmental conditions related to agriculture. In: Environmental indicators for agriculture, vol 4. OECD, Paris, Chapter 3, www.oecd.org, 2008).

**Keywords** Agricultural NP loads • Polarization • Livestock density • Nitrates Directives • Inefficiency • New priorities in EU legislation

## Abbreviations

| | |
|---|---|
| EU | European Union |
| EU15 countries | The Western European EU countries including Austria Finland and Sweden |
| FER | Mineral fertiliser |
| FYM | Farmyard manure |
| GDP | Gross Domestic Product |
| NEU12 countries | The newly joined Central- and Eastern European countries including Bulgaria and Romania |
| STP | Soil test phosphorus |

## 1 Introduction

In 2008, all the different sciences, related to planet earth, including disciplines dealing with agro-environmental sciences, receive special attention: as a mutual initiative of the International Union of Geological Sciences (IUGS) and United Nations Educational, Scientific and Cultural Organization (UNESCO), United Nations Organization declared the year 2008 as the "International Year of Planet Earth" (The International Year of Planet Earth. www.esfs.org). This event underlines the importance of sustainable crop nutrition and land use practice all over the world, including the EU.

According to Webster's Dictionary (Webster 1961), the description of "Union" is: "A uniting into a coherent and harmonious whole". The question emerges, whether how much is consistent the plant nutrition practice of the farmers in the different EU countries to this description? And how much does the EU agro-environmental protection legislation help the various

Directives:

- Nitrates Directives/91/676/EEC/;
- Water Framework Directives/2000/60/EC/, etc.

Strategies:

- Principle that environmental dimension should be integrated in all Community policies/The Cardiff European Council, June, 1998/;
- Integrating environmental dimensions into the Common Agricultural Policy/CAP/The Helsinki European Council, December, 1999/;
- EU Sustainable Development Strategy/The Göteborg European Council, June, 2001/;
- Environmental integration and sustainable development incorporated into CAP/The Agricultural Council, April, 2001/, etc.

and Policies:

- Common Agricultural Policy/Swinbank and Daugbjerg 2006/, etc.,

so that the farmers' plant nutrition practice be united "into a coherent and harmonious whole"?

Nutrient balances, especially those of nitrogen and phosphorus, are important environmental indicators. The approaches and methodology of these balance calculations may differ significantly, which is why there are limitations in the comparison of the data. In recognition of their importance, the countries belonging to the Organisation for Economic Co-operation and Development (OECD) group have an obligation to submit yearly calculations on soil surface N and P balances (OECD 2001, 2008). The advantage of OECD calculations is that the countries involved elaborate on their NP balances using the same methodology. Consequently, the NP balance calculations of these individual countries are comparable. As a new initiative, EUROSTAT has started a program of estimating NP balances in the EU countries on NUTS-2 level (TAPAS 2007). The magnitude of mineral and organic NP use has a major effect on NP balances. Therefore, it is essential to investigate the major factors affecting them, such as per capita GDP and population density.

As a synthesis of a literature survey, Johnston and Steén compared the soil P supply data of Western European countries, most of them long-term EU members (Steén 1997). Csathó et al. (2007) have done the same for Central and Eastern European countries, allowing comparisons to be made between NP balances and soil NP supplies within and between these two main European regions, i.e. the former 15 Western European (EU15) and the newly joined 12 Central and Eastern European (NEU12) EU countries.

For interpreting the agricultural OECD NP balances data from both agronomic and environmental points of view, it is essential to compare them to the actual soil NP status of the investigated area so that to evaluate them, whether they are sound from both agronomical and environmental points of view. As an example, strongly positive P balances in areas with very low P status, are justified from agronomic side, and are not a threat to the environment. These soil P statuses are characteristic for the Central and Eastern European EU countries. As an unfavourable phenomenon, opposite to the reasonable practice, these EU countries have the lowest P balances, having unfavourable agronomic, social, and rural development consequences (Csathó et al. 2007; OECD 2001, 2008). Oppositely, strongly positive P balances in areas with very high P status, are unfavourable from agronomic side, and are severe threat to the environment. These soil P statuses are characteristic for the Western European EU countries with the highest livestock densities, as The Netherlands, Belgium, and at some regions within the given countries, as in the Bretagne peninsula, and in the Po valley. As an unfavourable phenomenon, opposite to the reasonable practice, these EU countries and regions have the highest NP balances, having unfavourable environmental protection consequences (Steén 1997; OECD 2001, 2008).

The Göteborg European Council (2001) endorsed the EU Sustainable Development Strategy, which requires that the economic, social and environmental effects of all policies be taken into account in the decision-making processes. It also adopted the conclusion of the Agriculture Council (2001) on environmental integration, requiring that agricultural production must be done in an environmentally friendly way.

In 2008, for their new, environmentally friendly fertiliser recommendation system, elaborated in Institutions belonging to the network of the Hungarian Academy of Sciences, received the Year of 2007 Innovation Grand Prize for Hungary, the highest Prize on innovative research and development (Csathó et al. 1998, 2009; Várallyay 2008). Elements and approach of this fertiliser recommendation system also appear in the suggestions for improving agro-environmental protection legislation and practice in the EU.

The basic approach of this work is to evaluate factors affecting the intensity of organic and mineral NP application per agricultural land unit, and to collide with each other the environmental NP balances – using the OECD methodology – and groundwater nitrates contamination, as well as soil P supplies of the Western European former EU15 countries and new EU12 member countries, in Central and Eastern Europe.

The aim of this work is to answer these questions, and to give some suggestions for a way out from the unfavourable plant nutrition practice of the farmers both in the former EU 15 countries (the environmental problems), and the new EU12 countries (the agronomic, social and rural development problems), not fitting the description of the Webster's Dictionary (Webster 1961), on "Union". In 2001, a review book was published on the nutrient management legislation in the former EU15 countries, as well as in Norway (De Clercq et al. 2001).

In the first part of the paper, factors affecting the level of NP fertilization are discussed. In the next section, contrasts in NP balances and NP supplies between Western and Eastern Europe are evaluated, i.e. over fertilization and environmental problems in the western part, and under fertilization and related agronomic and social problems in the eastern part. In the last section, suggestions are made for altering EU NP turnover towards a sustainable way, either from environmental, or agronomic, social and rural development points of views.

## 2 Scientific Methods Used in the Chapter

Correlations between the national per capita income, the population density, the livestock density, and the quantities of N and P applied as mineral fertiliser and as organic manure were evaluated using the 2005 agricultural statistical database of the FAO (2005). For 2007 and 2008, the database of EUROSTAT was used (http://epp.eurostat.ec.europa.eu). The GDP per capita was estimated using the CIA (2001) database, which also took purchasing power into consideration. The data included in the FAO database were expressed in terms of the agricultural area of the given country. Set-aside areas in the EU15 countries, which have been temporarily removed from cultivation, were not included in the agricultural area. On the other hand, in countries where more than one crop a year is possible, areas harvested twice were counted twice as agricultural land. Countries with an agricultural area of less than a hundred thousand hectares were not included in the calculations. This left a total of 129 countries in the database.

When calculating the livestock units (LU), the following factors were used: cattle, bullock, horse 0.8; donkey, mule 0.213; pig 0.114; sheep 0.071; goat 0.1065; 1,000 rabbits 4.0; 1,000 chickens 2.0; 1,000 ducks 3.0; 1,000 geese 4.0; 1,000 turkeys 5.0 (Hajas and Rázsó 1969). One LU was considered to produce 10 metric tonnes of farmyard manure with 0.6% N, 0.3% $P_2O_5$, and 0.6% $K_2O$ year$^{-1}$ (Csathó and Radimszky 2005a).

For calculating environmental NP balances, the OECD methodology was used (OECD 1997), each country using their own crop and livestock specific nutrient contents, characteristic for their own countries. For evaluating the soil phosphorus status of the Western European countries, the review of Steén (1997), of the Central and Eastern European countries, the review of Csathó et al. (2007) was used as basis. For strengthening the reliability of the N balance calculations in the EU countries, ground water statuses of the same countries were used. For strengthening the reliability of the P balance calculations in the EU countries, in the other hand, soil P statuses of the same countries were taken into account.

## 3 Reviewing and Evaluating EU Agricultural NP Turnover

### *3.1 Factors Influencing the Use of Organic and Mineral NP*

When investigating the reasons for differences in the quantities of N and P applied as organic manure or mineral fertiliser, it became clear that in countries with a higher national per capita income, combined with greater population density, the

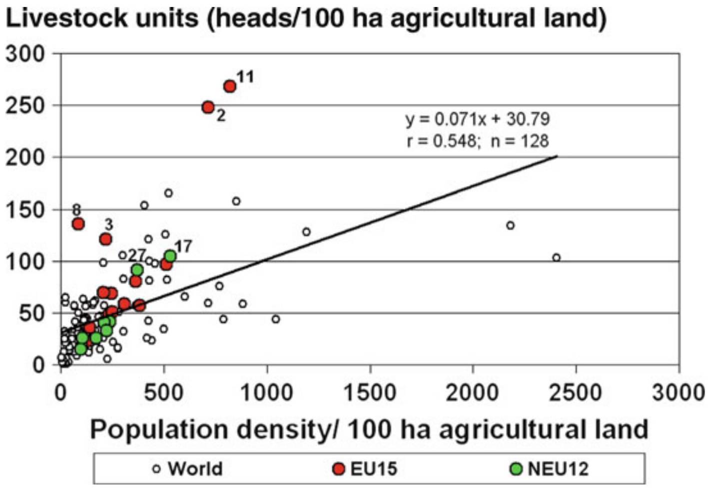


**Fig. 1** Correlation between population density and livestock density in the countries of the world, as well as in the EU15 and NEU12 countries, in 2000. EU15: former western European countries, NEU12: new central-eastern European countries

agriculture was more intensive, involving greater quantities of N and P both from mineral fertiliser and from organic manure. Because of the fact, that organic and mineral N and P use change proportionally in the investigated countries, in Figs. 1, 2, and 3, the two potentially harmful elements appear usually together.

Per capita GDP was almost 2.5 times higher in the former EU15 countries than in the new EU (NEU12) group. In 2000, 56% more fertilizer (FER) N+P was applied in the EU15 than in the NEU12, indicating differences in the intensity of plant nutrition. The highest fertilizer NP rates were applied in the Netherlands, Germany and Belgium-Luxembourg.

The numbers in Fig. 1, represent the EU27 countries, as follows: 1 – Austria, 2 – Belgium and Luxembourg, 3 – Denmark, 4 – Finland, 5 – France, 6 – Germany, 7 – Greece, 8 – Ireland, 9 – Italy, 11 – Netherlands, 12 – Portugal, 13 – Spain, 14 – Sweden, 15 – United Kingdom, 16 – Bulgaria, 17 – Cyprus, 18 – Czech Republic, 19 – Estonia, 20 – Hungary, 21 – Latvia, 22 – Lithuania, 23 – Malta, 24 – Poland, 25 – Romania, 26 – Slovakia, 27 – Slovenia.

Almost twice as much NP was produced from farmyard manure (FYM) in the EU15 than in the NEU12, with the highest figures for the Netherlands (196 kg $ha^{-1}$) and Belgium-Luxembourg (181 kg $ha^{-1}$). This is the result of the unhealthily high Livestock Unit (LU) number per agricultural area. The amount of fertilizer plus farmyard manure NP was 70% higher in the EU15 than in the NEU12, with levels of over 300 kg $ha^{-1}$ in two countries (the Netherlands: 364 kg $ha^{-1}$ and Belgium-Luxemburg: 302 kg $ha^{-1}$), and around 200 kg NP per hectare in three other countries (Germany: 195 kg $ha^{-1}$; Ireland: 193 kg $ha^{-1}$, and Denmark: 190 kg $ha^{-1}$) (FAO 2005). In addition, higher per capita GDP and greater population density were also associated with a higher livestock density per unit area, further increasing the NP

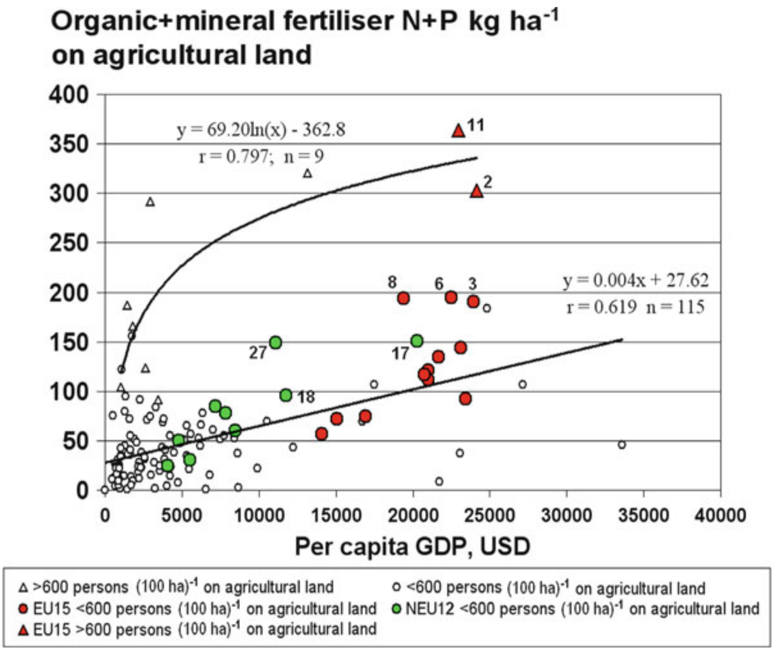


**Fig. 2** Correlation between the national per capita income and the application of organic and mineral fertiliser NP in the countries of the world, as well as in the EU15 and NEU12 countries, as a function of population density in 2000. EU15: former western European countries, NEU12: new central-eastern European countries

load to the agricultural area (Figs. 1, 2, and 3). The average number of livestock per 100 ha of agricultural land was almost twice as high in the EU15 as in the NEU12.

The numbers in Fig. 2, represent the EU27 countries, as follows: 1 – Austria, 2 – Belgium and Luxembourg, 3 – Denmark, 4 – Finland, 5 – France, 6 – Germany, 7 – Greece, 8 – Ireland, 9 – Italy, 11 – Netherlands, 12 – Portugal, 13 – Spain, 14 – Sweden, 15 – United Kingdom, 16 – Bulgaria, 17 – Cyprus, 18 – Czech Republic, 19 – Estonia, 20 – Hungary, 21 – Latvia, 22 – Lithuania, 23 – Malta, 24 – Poland, 25 – Romania, 26 – Slovakia, 27 – Slovenia.

The numbers in Fig. 3, represent the EU27 countries, as follows: 1 – Austria, 2 – Belgium and Luxembourg, 3 – Denmark, 4 – Finland, 5 – France, 6 – Germany, 7 – Greece, 8 – Ireland, 9 – Italy, 11 – Netherlands, 12 – Portugal, 13 – Spain, 14 – Sweden, 15 – United Kingdom, 16 – Bulgaria, 17 – Cyprus, 18 – Czech Republic, 19 – Estonia, 20 – Hungary, 21 – Latvia, 22 – Lithuania, 23 – Malta, 24 – Poland, 25 – Romania, 26 – Slovakia, 27 – Slovenia. The highest livestock densities per 100 ha were reported in the Netherlands (268 heads) and in Belgium & Luxembourg (248 heads). The livestock density was extremely high compared with the population density in Belgium & Luxembourg and the Netherlands.

When these two factors were compared for all the countries in the world, it was again these two countries that deviated to the greatest extent from the general trend. Denmark and Ireland also had above-average livestock densities compared with the

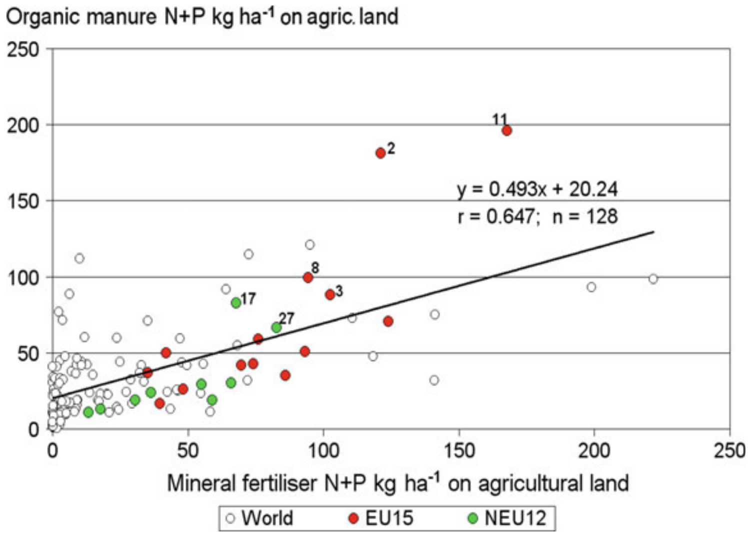


**Fig. 3** Correlation between the NP quantities applied as mineral fertiliser and produced as farmyard manure in the countries of the world, as well as in the EU15 and NEU12 countries, in 2000. EU15: former western European countries, NEU12: new central-eastern European countries

population density. Among the NEU12 countries, only Slovenia and Cyprus, the agricultural area of which was only just over 100,000 ha, had a livestock density slightly greater than the average.

### *3.2 Phosphorus Balance of Central and Eastern European Countries Between 1960 and 2000*

The intensive use of phosphorus fertiliser began several decades later in Central and Eastern Europe than it did in Western Europe. In most cases this is why the phosphorus balances for these countries were far lower in the 1960s than in the 1980s. The only exception was Slovenia, where the application of phosphorus continued to be as intensive as in Western European countries even after 1990. In Central and Eastern Europe, with the exception of Czechoslovakia, Latvia and Estonia, phosphorus balances in the 1960s were below 11 kg ha$^{-1}$ P and were sometimes negative. In the 1980s, due to the intensive application of fertilisers, the phosphorus balances were positive throughout the region, with values ranging from 4 to 31 kg ha$^{-1}$ P. As a consequence of the rapid decline in P fertiliser use since 1990, the P balances have reached an all-time low, ranging from −7 to +7 kg ha$^{-1}$ P. This can be partly attributed to the fact that the substantial residual P effects still make it possible for the crops to extract large quantities of P, resulting in relatively high yields. The only exception is again Slovenia, with a positive balance of 20 kg ha$^{-1}$ P (Csathó et al. 2007). The reasons for these low P balances can be the economic difficulties of the NEU12 (CEE) countries and their farmers, as well as the lower amount of subsidies received by the NEU12 countries, than by the EU15 countries, according to the Copenhagen Treaty.

**Table 1** NP balances in the EU15 countries, Norway and Switzerland, and in the NEU12 countries of Central and Eastern Europe in 1991 (Csathó et al. 2007)

| Country | N balance, kg ha$^{-1}$ N | P balance, kg ha$^{-1}$ P |
|---|---|---|
| Netherlands | 262 | 40 |
| Belgium | 205 | 34 |
| Luxemburg | *132* | *25* |
| Germany | 129 | *21* |
| Denmark | *129* | *8* |
| Ireland | 76 | 10 |
| France | *75* | *29* |
| Finland | 72 | 20 |
| Sweden[a] | 66 | 6 |
| United Kingdom | *64* | *6* |
| Greece | *58* | *14* |
| Austria | 49 | 5 |
| Portugal[a] | 43 | *4* |
| Italy | 39 | *13* |
| Spain | *25* | *12* |
| Switzerland | 80 | 12 |
| Norway | 69 | 13 |
| Czech Republic | 40 | 2 |
| Slovakia | 38 | 6 |
| Poland | 18 | 5 |
| Hungary | –20 | –9 |

Numbers in italics were taken from Brouwer et al. (1995), while the other data were reported by Steén (1997), OECD (2001, 2008), Klir (2005), Torma (2005), Kopinski (2005) and Csathó and Radimszky (2005b)

[a]Data for 1994/1995

## 3.3 NP Balances Based on Environment Protection Considerations in the Early 1990s

N and P balances in 1991 for the EU15 countries, Switzerland, Norway and some of the Central and Eastern European NEU12 countries are presented in Table 1.

Nitrogen balances were in excess of 200 kg ha$^{-1}$ in the Netherlands and Belgium, above 100 kg ha$^{-1}$ in Luxemburg, Germany and Denmark, above 75 kg ha$^{-1}$ in Switzerland, Ireland and France, over 50 kg ha$^{-1}$ in Finland, Norway, Sweden, the United Kingdom and Greece, around 50 kg ha$^{-1}$ in Austria, and 40 kg ha$^{-1}$ or less in Portugal, Italy, the Czech Republic, Slovakia, Spain, the Netherlands and Hungary. In 1990/1991 high yields were obtained in Hungary, combined with the most negative NP balance of the century, a situation made possible by the high first-year residual NP effects.

Phosphorus balances followed much the same pattern as the N balances: the greatest phosphorus surpluses were recorded in the Netherlands and Belgium (34–40 kg ha$^{-1}$ P), while the P balances in France, Luxemburg, Germany and Finland

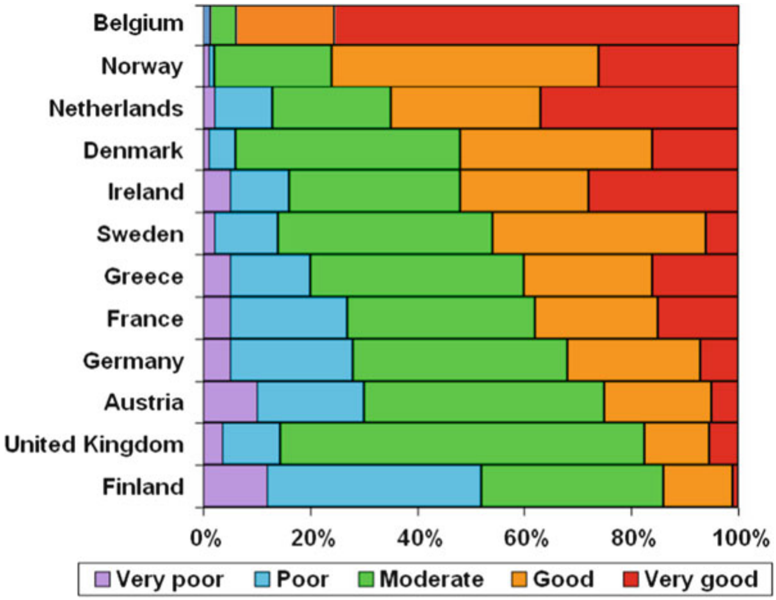


**Fig. 4** Phosphorus supplies in the soils of Western European countries in 1991 (Steén 1997); Belgium: (Bodemkundige Dienst van België. 2006)

ranged from 22 to 31 kg ha$^{-1}$ P. In the remaining countries the phosphorus balance was below 13 kg ha$^{-1}$ P, with values below 7 kg ha$^{-1}$ P in the NEU12 countries and in the United Kingdom, Sweden, Austria and Portugal. As the result of legislation aimed at environment protection, the use of N fertiliser has declined by around 10% and that of P fertiliser by around 40% since 1988. Despite the lower NP fertiliser rates, the NP balances have continued to be positive in most of the EU15 countries. The dramatic reduction in NP fertiliser in the NEU12 countries, on the other hand, was caused by the collapse of the economy.

## *3.4 Soil P Supplies in the EU15 Countries*

The distribution of soil P supply categories in 11 Western European countries in the early 1990s is illustrated in Fig. 4 (Steén 1997). The fact that fertilisation has led to positive P balances and to the accumulation of P in the soil is also clear from the levels of soil P supplies in certain countries.

The soil P supplies in Western Europe were still relatively poor at the end of the 1800s, when mineral P fertilisation has first begun. Half a century or more of soil-enriching P fertilisation, however, led to an increase of 30–50% in the P content compared to the 1920s.

Due to the more intensive application of P fertiliser, the P-supplying capacity of the soil is much greater in Western Europe than in the central and eastern parts of the continent. The proportion of land well or very well supplied with P was around 95% (!) in Belgium (The Flamand part), around 75% in Norway, 65% in the Netherlands, 50% in Denmark, Ireland and Sweden, 40% in Greece and France, 30% in Germany, 25% in Austria, 20% in the United Kingdom and 15% in Finland (Steén 1997). Comparing the P status data to the P balance data, the opinion of the authors is, that the P supply data of the Netherlands is highly underestimated. According to the opinion of the authors, soil P soil P saturation in the Netherlands is even higher than in Belgium. For example, the official lower limit of good P supply for grassland in the Netherlands is 300 mg $kg^{-1}$ AL-$P_2O_5$, (ammonium-lactate-soluble P, Egner et al. 1960) (Handboek melkveehouderij 1997), while above 100 mg $kg^{-1}$ AL -$P_2O_5$, no responses of less P-demanding crops like grass to P fertilisation is expected according to the results of field trials for acid sandy loam – loam soils (Csathó 2003a, b) (Fig. 4).

According to estimations made by the European Soil Bureau, the NP content of the soil was unfavourably high on 17 million hectares of Western Europe, i.e. on 12% of the agricultural land, representing a serious environmental threat to surface and subsurface waters.

### *3.5 Soil P Supplies in the NEU12 Countries*

Figure 5 illustrates the P status of the soil in Central and Eastern European countries. As in the case of the Western European countries, the countries were ranked according to the proportion of land with good or very good supplies of phosphorus.

In the early 1990s the proportion of land well or very well supplied with phosphorus was far smaller (by 10–25%) in Central and Eastern Europe than in Western Europe. This proportion was around 50% in Slovenia and Hungary, 40% in the Czech Republic, Poland and Slovakia, 30% in Latvia and Bulgaria, 25% in Austria, Albania, Estonia and Romania, 15% in Lithuania and Serbia and 10% in Ukraine (Csathó et al. 2007).

An estimation of the soil P supplies in 2005 is complicated by the fact that an evaluation similar to that published in 1991 is not available for the Western European countries. In addition to the compulsory annual preparation of NP balances by OECD countries, there is an urgent need that the every-5-years changes in the groundwater nitrate-N contents and soil P supplies in these countries to be published.

### *3.6 Correlations Between P-supplying Capacity and P Balances*

One fundamental characteristic of fertiliser recommendations aimed at environmental sustainability is (or should be) that on areas poorly supplied with a given nutrient a quantity larger than that taken up by the crop is applied, slightly more than crop

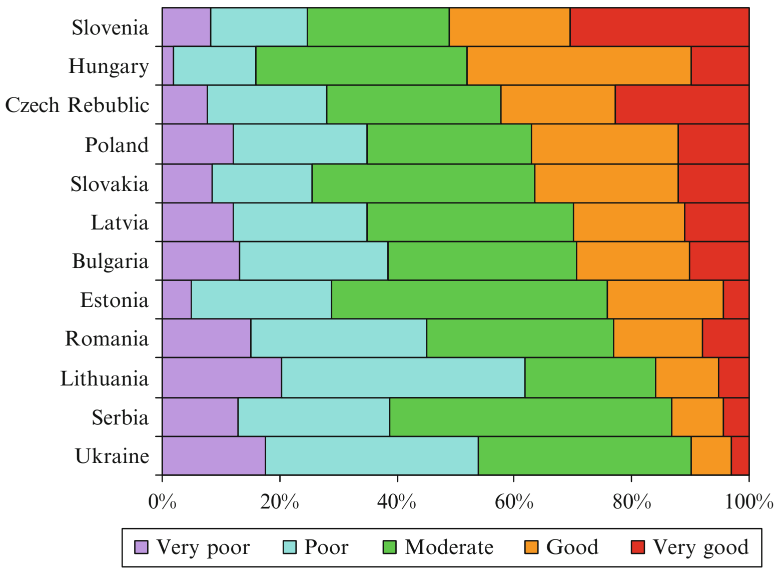


**Fig. 5** Phosphorus supplies of soils in Central and Eastern European countries in the early 1990s (Csathó et al. 2007)

**Fig. 6** Phosphorus fertiliser recommendation for fields in Germany based on soil fertility class soil test phosphorus (*STP*) based on Vetter and Fruchtenicht (1974), cit: Tunney et al. (1997)

| Fertility Class | Fertiliser Ratio | |
|---|---|---|
| E: Veryhigh | 0 | |
| D: High | 0.5 | |
| C: Moderate | 1.0 | C= Maintenance |
| B: Low | 1.5 | |
| A: Very low | 2.0 | |

uptake on soil with moderate supplies, an amount equal to or slightly less than crop requirements on soils with good supplies, little or none on soils with very good supplies, and no P fertiliser on soils with an excessive supply level (Fig. 6).

The P recommendations, normally shown as kg P $ha^{-1}$ $year^{-1}$, are usually based on soil test phosphorus (STP) values and the following is an example of a typical fertiliser strategy (Tunney et al. 1997) (i) no P fertiliser required for optimum production for a number of years when STP is high, (ii) maintenance P (replacing removals) required when STP is moderate, (iii) build-up of P recommended when STP is low. An example of an approach used in Germany to recommend fertiliser

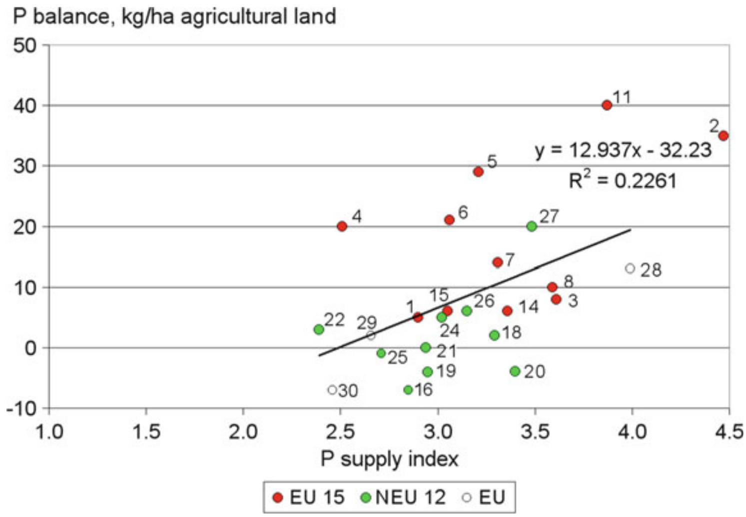


**Fig. 7** Correlation between the soil P supply index and the P balance in the countries of Europe in the early 1990s (The numbers in Fig. 7, represent the EU27 countries, as follows: *1* – Austria, *2* – Belgium, *3* – Denmark, *4* – Finland, *5* – France, *6* – Germany, *7* – Greece, *8* – Ireland, *9* – Italy, *10* – Luxembourg, *11* – Netherlands, *12* – Portugal, *13* – Spain, *14* – Sweden, *15* – United Kingdom, *16* – Bulgaria, *17* – Cyprus, *18* – Czech Republic, *19* – Estonia, *20* – Hungary, *21* – Latvia, *22* – Lithuania, *23* – Malta, *24* – Poland, *25* – Romania, *26* – Slovakia, *27* – Slovenia; as well as some non-EU countries: *28* – Norway, *29* – Serbia and Montenegro, *30* – Ukraine)

application at field level is illustrated in Fig. 6 (Vetter and Fruchtenicht 1974). It is based on STP level and shows, for example, that at fertility class A (very low fertility), two times the maintenance P fertiliser dressing is recommended and at fertility class D, only 0.5 times the maintenance level is recommended. At fertility class E (very high fertility) fertiliser P is not recommended (Fig. 6).

If this logic is followed, in the EU27 countries of Western Europe, where the soils were far better supplied with phosphorus in the early 1990s, far lower rates of (N) P should be applied and far lower (N) P balances are justified both from the agronomic and environment protection points of view than in the countries of Central and Eastern Europe, where P supplies were far poorer in the early 1990s.

Let us see how far this theory is put into practice. Figure 7 illustrates the correlation between the P supply index, indicative of the P status of the soil, and the P balance. In order to calculate the P supply index, a value of 1 was applied for areas very poorly supplied with phosphorus, 2 for poorly supplied areas, 3 for moderately well supplied areas, 4 for well supplied areas and 5 for very well supplied areas. This was then multiplied by the percent of land belonging to the given supply category, i.e. by 0.1 for 10% of the land, by 0.2 for 20%, etc. The figures obtained for each category were then summed to give the P supply index of the country.

A country very poorly supplied with phosphorus over 100% of its area would thus have a P supply index of 1.0, while the other extreme would be a country with very good supplies over 100% of its area, having a P supply index of 5.0. The introduction of a sixth category for excessive supplies of P would also be justified, but the necessary data are not available at present.

In Fig. 7, the data of Brouwer et al. (1995) and the OECD (2001, 2008) were used for P balance estimations for the EU15 countries and Norway in the early 1990s, while the following data were used for the CEE countries: Bulgaria: Nikolova (2005); Czech Republic: Klir (2005); Estonia: Astover and Roostalu (2002); Hungary: Csathó and Radimszky (2005a); Latvia: Karklins (1998); Lithuania: Lazauskas (2005); Poland: Kopiński (2005); Romania: Csathó and Radimszky (2005b); Slovakia: Torma (2001, 2005); Slovenia: Csathó and Radimszky (2005a); Serbia and Montenegro: Manojlović (2005); Ukraine: Lisovoj and Nikitjuk (2004).

In the case of soil P status, the data of Steén (1997) were used for the EU15 countries and Norway in the early 1990s, and the following data for the CEE countries: Bulgaria: Nikolov (1998); Czech Republic: Čermák and Budňáková (2003); Estonia: Järvan et al. (1996); Hungary: Csathó (2005); Latvia: Karklins (1998); Lithuania: Mazvila et al. (1996); Poland: Obojski and Straczynski (1995); Romania: Hera et al. (1998); Slovakia: UKSUP (2000); Slovenia: Leskošek (1998); Serbia and Montenegro: Bogdanović et al. (1993); Ukraine: Nosko et al. (1994).

If P fertilisation were carried out in a manner acceptable from the agronomic and environment protection points of view, a negative correlation would have been plotted in Fig. 7., with P balances declining as the P supplies improved. By contrast, the opposite was observed in Europe in the early 1990s: the P balances in Central and Eastern Europe, where the P supply index was lowest, were the smallest, and in some cases negative (between −5 and −10 kg ha$^{-1}$ P), while Western European countries, which had the highest P supply indexes, had the most positive P balances, with surpluses of 18–40 kg ha$^{-1}$ P each year. This unfavourable situation (i.e. the polarization between the Western and Eastern part of the EU) has even accelerated and has become much worse since the introduction of the Nitrates Directive, as is clear from the cumulative nitrogen and phosphorus balances of European countries over the last 15 years.

### *3.7 Cumulative N and P Balances in the European Union*

The cumulative N balances of certain European countries, many of them EU member countries, are presented in Fig. 8. for the period 1991–2005, i.e., the yearly N balances of this period were summed up.

The Netherlands and Belgium lead the field for N balances. During the 15 years that have elapsed since the Nitrates Directive was introduced the total N surplus was 2,800 kg ha$^{-1}$ in Belgium and 3,500 kg ha$^{-1}$ in the Netherlands, and was also well above 2,000 kg ha$^{-1}$ in Denmark. So much for the effectiveness of the Nitrates Directive!

The cumulative N balance was also above average in Germany, Norway and Ireland, while the countries of Central and Eastern Europe came last, as expected (Fig. 8).

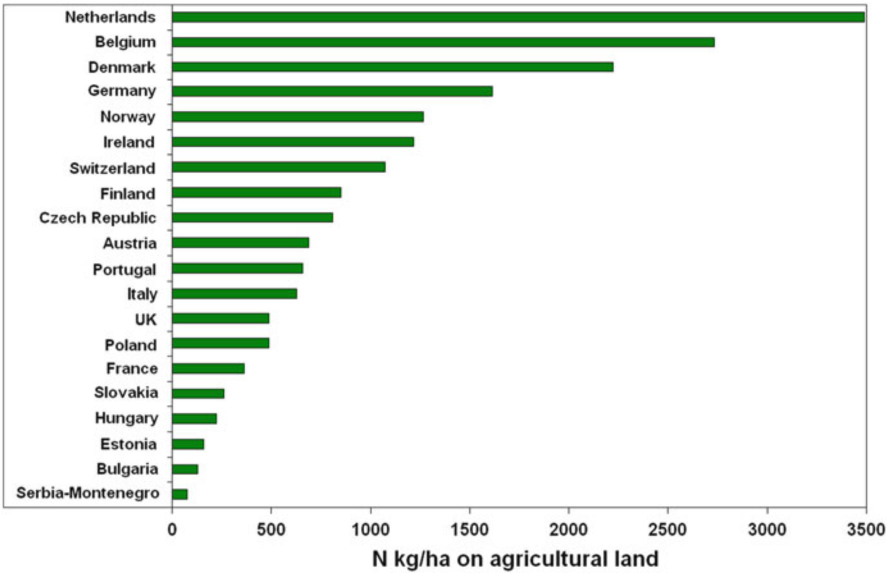


**Fig. 8** Estimated cumulative N balance of European countries, 1991–2005 (Csathó and Radimszky 2007, 2009)

For strengthening the trends in cumulated N balances surpluses in the EU27 countries, the ground water quality data of the EU countries are shown in Fig. 9 (Csathó and Radimszky 2007, 2009).

It is important to note that the same sequence of countries is observed both in the 15-year cumulated N balances, and in the percentage of ground water samples above the maximum permissible limit value for ground water nitrate-N, i.e. 50 mg $kg^{-1}$.

The cumulated P balances are estimated for the period of 1991–2005 in Fig. 10 (Csathó and Radimszky 2007, 2009). For countries where data were only available until 2002 or 2003, NP balances for the missing years were taken as being equal to the last recorded year. The P surplus accumulated over this 15-year period was more than 400 kg $ha^{-1}$ P in the Netherlands and 300 kg $ha^{-1}$ P in Belgium (Fig. 10).

The highest P surpluses (from the environmental point of view), were recorded also in these Benelux countries in the early 1990s (Fig. 11) (Stanners and Bourdeau 1995). A World Bank map on pig density in Western Europe shows the same pattern and feature, indicating, that highest P surpluses were found at the areas with the highest livestock densities (Fig. 12) (World Bank 2005).

Not to mention, that the situation has become even more threatening since 1991, indicating the definite inefficiency of the Nitrates Directive, implemented the same year, i.e. in 1991, aiming to regulate both N and P regime in the EU countries. Slovenia, Norway, Denmark and Finland also registered above-average increases in P over the last 15 years, and the Central and Eastern European countries were again at the bottom of the list.

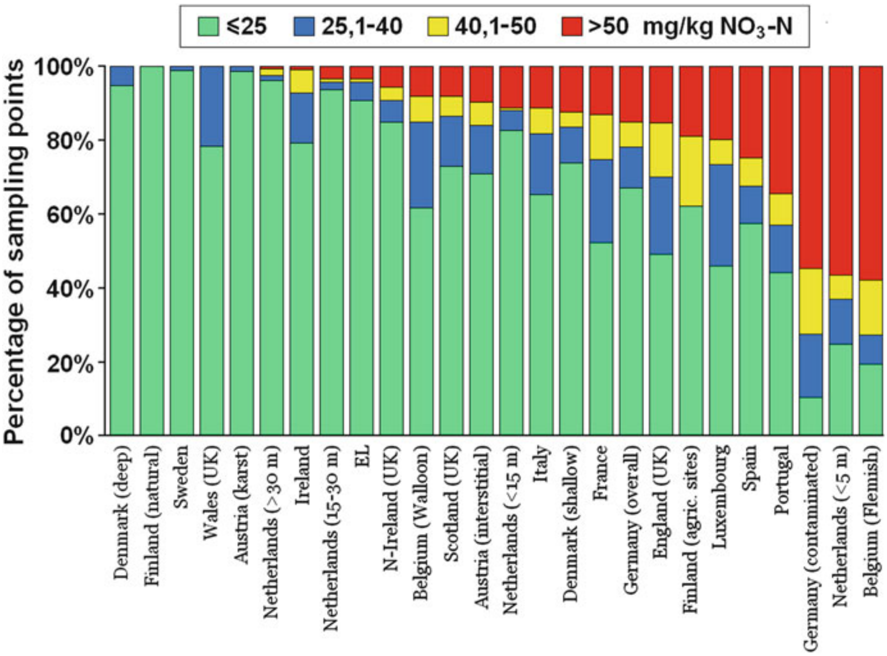


**Fig. 9** Ground water nitrates contamination of some EU 15 countries in the mid 2000s (Hamell 2007)

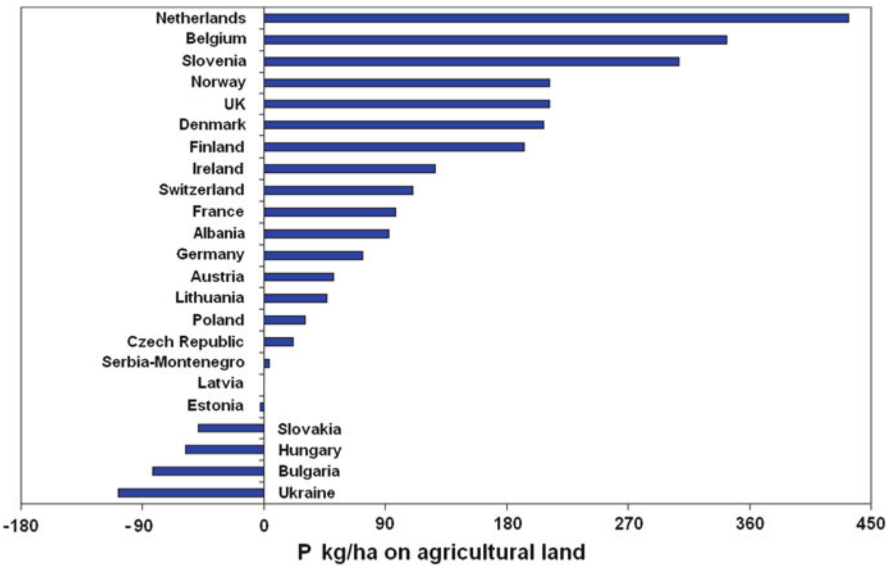


**Fig. 10** Estimated cumulative P balance of European countries, 1991–2005 (Csathó and Radimszky 2007, 2009)

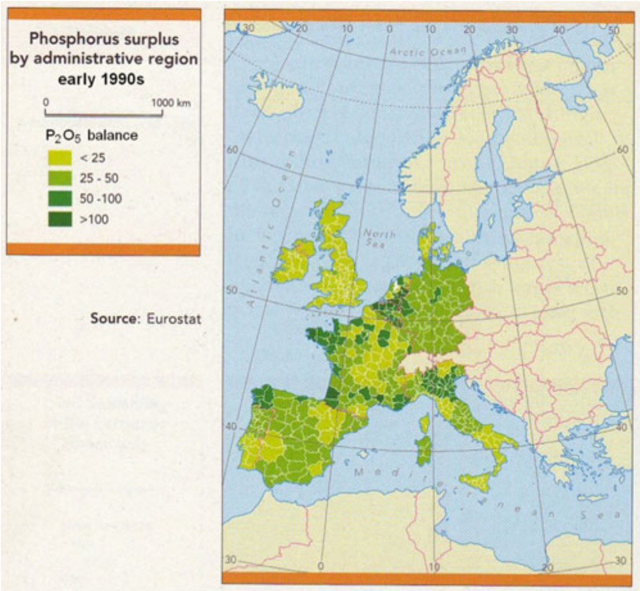


**Fig. 11** Phosphorus balances in the EU12 countries, in the early 1990s, in NUTS 2 levels (Stanners and Bourdeau 1995)

**Fig. 12** Pig population density in Western Europe (World Bank 2005)

## 4 Insights, Discussion and Suggestions

In a perfectly correct and justifiable manner, the European Union made investments in environment protection a strict condition for the accession of the Central European countries to the EU. One essential obligation was the satisfactory disposal of sewage, as a water protection measure. The steps taken by the EU to protect surface waters have thus led to a dramatic reduction in point-source pollution caused by the (N) P contained in sewage.

The EU is consistently strict in curbing the comparably low point-source NP pollution caused by agriculture, forcing the farmers in the whole EU, include in the NEU12 countries, to build their slurry and manure storing facilities for the period their distribution to agricultural field is prohibited.

The EU should be just as consistently strict in curbing the by magnitudes higher diffuse NP pollution caused by agriculture, especially of those countries with the highest livestock densities. In the United States, for example, in many states effective legislation has been passed to reduce P loads of agricultural origin, despite the fact that the situation is far less serious than in many European countries (Sharpley et al. 1994; Gartley and Sims 1994). The directives passed by the EU should also be compulsory, not simply recommended.

According to principles of sustainable crop nutrition, the amount supplied by previous farmyard manure and/or slurry application (i.e., in the previous 3–4 years), should be taken into account as mineral fertiliser NP demand reducing factors. For the effective preservation and rehabilitation of the environment from agricultural NP loads, it seems that this principle should be built in the EU agro-environmental legislation, i.e. into **the EU Nitrates Directive**:

(a) On nitrate-sensitive areas, while retaining the maximum permitted application of 170 kg ha$^{-1}$ N of organic origin, the rate at which farmyard manure is utilized by the crops should also be considered, calculating with 50% in the first year, 30% in the second and 20% in the third on sandy or sandy loam soils, and 40% in the first year, 30% in the second, 20% in the third and 10% in the fourth on loam, clay loam and clay soils. If organic manure is applied every year, the total quantity of organic manure that will exert its effect in the given year should not exceed the 170 kg ha$^{-1}$ limit on nitrate-sensitive areas.

(b) Irrespective of nitrate sensitivity, regulations should be passed making it compulsory for fertiliser recommendation systems in EU countries to reduce the recommended mineral fertiliser N rates by the quantity of N applied in the form of farmyard manure, expressed in fertiliser N equivalency, and taking into account the rate at which farmyard manure is utilised by the crop, within the 3–4-year period (see previous paragraph). The fertiliser N equivalency of FYM nitrogen can be considered as 50% on average, varying according to the livestock species and the technology (Kemppainen 1989). The results of long-term field trials, set up on the basis of mineral and organic NP equivalency, it turned out, that, as compared to the nitrogen in mineral fertiliser, the efficiency of total N in solid cow and pig manure ranges from 25% to 70% (Sluijsmans and Kolenbrander 1977; Anonymous 1982; Sarkadi 1993; Árendás 1999), that in solid poultry manure from 60% to 85% (Anonymous 1980, 1982; Beauchamp 1983), that in cow slurry from 30% to 70% (Kemppainen 1989; Anonymous 1980, 1982; Laine 1967; Amberger 1982), that in pig slurry from 65% to 75% (Sluijsmans and Kolenbrander 1977; Anonymous 1982; Amberger 1982; Sutton et al. 1982), that in poultry slurry from 65% to 70% (Anonymous 1980, 1982; Amberger 1982), and that in liquid manure from 75% to 80% (Sluijsmans and Kolenbrander 1977).

(c) Only fertiliser recommendation systems that have been tested under field conditions for a number of years and that meet strict environment protection and economic criteria should be authorized for use in practice. The application of a total nitrogen quantity equivalent to more than 200 kg $ha^{-1}$ mineral fertiliser (applied as farmyard manure + mineral fertiliser) usually cannot be justified from the agronomic point of view and should be officially banned in the interests of environment protection in most cases.

(d) In each EU27 country, annual and cumulative nitrogen balances should be prepared following the OECD environment protection approach for every year of the twentieth century.

As an excess of P rather than N causes eutrophication in the majority of EU countries, according to the authors, a **Phosphates Directive** should be urgently compiled, incorporating the following principles:

(a) When distinguishing soil P supply categories the P fertiliser responses of the crops should be taken into consideration. The upper limit of good P supplies, and thus the lower limit of very good supplies, should not be more than 1.5 times the lower limit of good P supplies. In the same way, the upper limit of very good P supplies, and thus the lower limit of excessive supplies, should not be more than 1.5 times the lower limit of very good P supplies (Table 2). According to the suggestion of Kamprath (2005), soil P limit values of the same soil P test method should somehow differ according to the soil properties as well.

(b) Irrespective of phosphate sensitivity, regulations should be passed making it compulsory for fertiliser recommendation systems in EU countries to reduce the recommended mineral fertiliser P rates by the quantity of P applied in the form of farmyard manure, expressed in fertiliser P equivalency, and taking into account the rate at which farmyard manure is utilized by the crop within the 3–4-year period. In field experiments, the phosphorus in manure has often been observed to be just as effective as that in mineral fertilizer (Kemppainen 1989; Amberger 1982; Asmus et al. 1971; Sharma et al. 1980; Tunney 1980; Smith and van Dijk 1987). In the literature, the phosphorus in manure is also generally considered to be as effective as that in mineral fertilizer (Anonymous 1980; Valmari 1933; Rieder 1983)

(c) Only fertiliser recommendation systems that have been tested under field conditions for a number of years and that meet strict environment protection and economic criteria should be authorized for use in practice. The application of a total phosphorus quantity of more than 50 kg P $ha^{-1}$ (applied as farmyard manure + mineral fertiliser) cannot be justified from the agronomic point of view and should be officially banned in the interests of environmental protection.

(d) The concept of excessive P supplies should be compulsorily introduced in all EU countries. The application of phosphorus in either organic or mineral form should be **prohibited** on soils with excessive P supplies (Table 2).

**Table 2** Lower limits for good soil supplies, and suggested lower limits for very good and excessive P supplies for the main soil P test values used in EU countries

| Method | Lower limit for good soil P supply | Suggested lower limit: For very good soil P supply | Suggested lower limit: For excessive soil P supply | References for good soil P supply |
|---|---|---|---|---|
| $H_2O$ | 10 | 15 | 23 | Jungk et al. (1993) |
| Olsen | 20 | 30 | 45 | Johnston et al. (1986) |
| Bray-1 | 22 | 33 | 50 | McCallister et al. (1987) |
| Mehlich-3 | 27 | 40 | 60 | McCollum (1991) |
| Mehlich-3 (for org. soils) | 30 | 45 | 68 | Kamprath (2005) |
| Mehlich-3 (for sandy soils) | 40 | 60 | 90 | Kamprath (2005) |
| AL (for acid soils) | 44 | 66 | 99 | Csathó (2002, 2003a, b) |
| CAL | 47 | 70 | 105 | Spiegel (2007) |
| DL | 60 | 90 | 135 | Baumgärtel (1989) |
| AL (for calcareous soils) | 66 | 99 | 149 | Csathó (2002, 2003a, b) |
| Mehlich-3 (for sandy loam soils) | 80 | 120 | 180 | Kamprath (2005) |
| Mehlich-3 (for clay soils) | 300 | 450 | 675 | Kamprath (2005) |

(e) The use of P fertilisers should be banned above this level, at least on environmentally sensitive areas, but preferably throughout the country, and this principle should be introduced in the whole of the EU.
(f) In each EU27 country, annual and cumulative phosphorus balances should be prepared following the OECD environment protection approach for every year of the twentieth century in order to obtain a picture of the dynamics and extent of either soil P enrichment or depletion.
(g) In addition to the annual publication of OECD P balances, it should be compulsory to prepare an every-5 year evaluation of the P supply levels of all agriculturally cultivated land for submission to the OECD, the EEA, EUROSTAT, etc.
(h) The benefit from all these changes should go to the local communities.

## 5 Changes in the Livestock Densities in the EU Countries, and Their Correlation to the Cumulative NP Balances

One of the major problems of agricultural diffuse NP loads to the environment is livestock density exceeding 100 LU/100 ha agricultural land in certain countries or regions in the EU (Fig. 13).

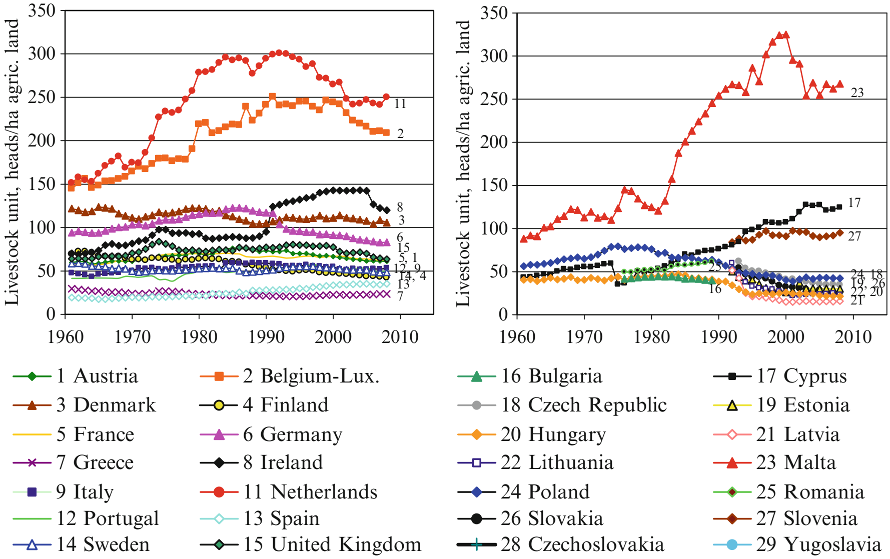


**Fig. 13** Changes in livestock density in the former EU15 countries, as well as in the new EU12 countries, 1960–2008 (FAO 2005; EUROSTAT 2005)

If we take into consideration, that the three leading new EU12 countries, respecting livestock density, i.e., Malta, Cyprus and Slovenia, occupy only 1.1% of agricultural land of the new EU12 countries, we can recognize how dramatic is the difference in livestock density between the western and eastern part of EU.

Within the EU countries, there is a strong positive correlation between cumulative NP balances and livestock densities, expressed in livestock units (Fig. 14).

## 6 Conclusions and Recommendations

Based on the results found in investigating the NP turnover of the EU 27 countries since 1991, it seems to be obvious, that in the present situation, when livestock densities are marked–driven (regulated by free moving of capital), EU agro-environmental, social, and rural development policies are not effective.

It is suggested that legislation in the European Union should be consistent against both point source, and diffuse NP loads to the environment, derived from agricultural production.

It seems that only through a major restructuring the livestock distribution in the EU, and only trough a major restructuring of the export-import policy of agricultural goods, and the price policy of the agricultural goods within the EU, the aims of the various directives, strategies, and policies, and the new SPS system can and will be fulfilled.

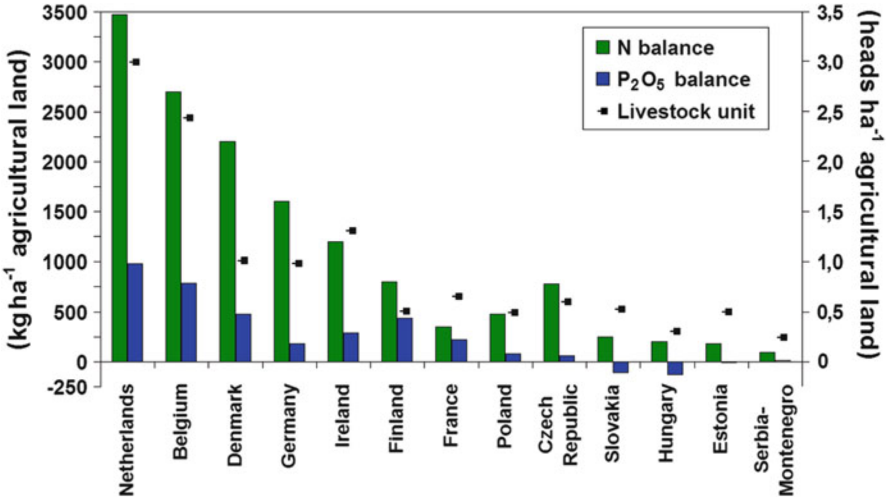


**Fig. 14** Estimated cumulative NP balances between 1991 and 2005 as well as livestock density of several European countries (Csathó and Radimszky 2009)

For effective agro-environmental policy in the future, it seems that, based on NUTS-2 levels, EU should pay 0.75 livestock unit per hectares agricultural land subsidies for every EU countries/NUTS-2 levels as an average, regardless the existing livestock densities. This way the EU would be able to work for establishing sustainable livestock densities in each EU country. For turning towards effective environmental protection policy in the EU, it seems to be, that a paradigm shift would be needed, from the market driven economy, into an economy, in which the effective environmental protection, agronomic, social, and rural development policies should enjoy priorities over market based interests.

Based on the principle of subsidiarity it seems that this problem can be solved only in highest EU level, through the EU legislation and EU administration.

The benefit from the changes should go towards the local farmers, farmer associations, and the local communities.

**Acknowledgements** Much of the work in this paper was due to the initiative of the COST Action 832 entitled "Quantifying the agricultural contribution to eutrophication" (1997–2003) and COST Action 869 entitled "Mitigation options for nutrient reduction in surface and groundwaters" (2006–2012). The authors wish also to thank Prof. E. Frossard, ETH Zurich, Switzerland, for initiating a throughout review on NP balances and soil P status of the CEE countries, Prof. A.E. Johnston, IACR, Rothamsted, UK, for his valuable advice on how to improve the manuscript, and Prof. E. Kamprath, North Carolina State University, Raleigh, USA, for encouraging and supporting the authors to publish the manuscript. Authors are grateful to the Editors and Reviewers for their valuable suggestions to improve the quality of this work.

## References

Amberger A (1982) Gülle – Ein Schlechtgenutzter Dünger. DLG Mitt 97:78–80
Anonymous (1978) The spreading of animal excrement on utilized agricultural areas of the community. I. CEC. Inf Agric 47:1–154
Anonymous (1980) Profitable and sensible use of poultry manure, vol 274, Pennsylvania State University, College of Agriculture, Extension Service. Special circular. Pennsylvania State University, College of Agriculture, Extention Service, University Park, p 6
Anonymous (1982) Profitable utilization of livestock manures, vol 2081, Booklet. Ministry of Agriculture, Fisheries and Food, Alnwick, pp 1–22
Árendás T (1999) Effect of mineral and organic fertilizers on a Chernozem soil with forest residues and other typical Hungarian soils (In Hungarian). PhD thesis, Keszthely-Martonvásár, Hungary
Asmus F, Specht G, und Lange H (1971) Zur Wirkung der Nährstoffe aus Gülle. Archiv für Acker- und Pflanzenbau und Bodenkunde 15:905–912
Astover A, Roostalu H (2002) Nutrient balance of arable soils in Estonia. In: 7th Congress of the European Society for Agronomy, Book of proceedings, ESA, Cordoba, Spain, pp 729–730
Baumgärtel G (1989) Phosphat-Düngbedarf von Getreide und Zuckerrüben im Südniedersächsischen Lössgebiet. Zeitschrift für Pflanzenernährung und Bodenkunde 152:447–452
Beauchamp EG (1983) Manure for crop production, Factsheet. Ontario Ministry of Agriculture and Food, Toronto, May 4
Bodemkundige Dienst van België (2006) De chemische bodemvruchtbaarheid van het Belgische akkerbouw- weilandareaal (1989–2003), Heverlee, 138p
Bogdanović D, Ubavić M, Dozet D (1993) Chemical properties of Vojvodina soils and their provision with essential macroelements. In: Heavy metals and pesticides in the soils of the Vojvodina Province, Faculty of Agriculture, Institute of Field and Vegetable Crops, University of Novi Sad, Serbia and Montenegro, pp 197–216 (In Serbian)
Brouwer FM, Godeschalk FE, Hellegers PJ, Kelholt HJ (1995) Mineral balances at farm level in the European Union, vol 137, Onderzoeksverlag. Agricultural Economics Research Institute (LEI-DLO), Den Haag
Čermák P, Budňáková M (2003) Fertilization in the Czech Republic – the consumption of fertilizers and content of nutrient in the soil. In: Schnug E et al (eds) Proceedings of the 14th CIEC symposium “Fertilizers in context with resource management in agriculture”, vol 1, Debrecen, Hungary, pp 227–232
CIA (2001) World of Factbook. http://www.mrdowling.com
Council Directive of 12 December 1991 concerning protection of waters against pollution caused by nitrates form agricultural sources (91/676/EEC)
Csathó P (2002) Evaluation of the corrected AL-P model on the database of Hungarian winter wheat P fertilization experiments, 1960–2000. Agrokémia és Talajtan 51:351–380 (In Hungarian)
Csathó P (2003a) Factors affecting winter wheat responses to P fertilization, obtained in the database of the Hungarian field trials, published between 1960 and 2000. Növénytermelés 52:679–701 (In Hungarian)
Csathó P (2003b) Factors affecting maize responses to P fertilization, obtained in the database of the Hungarian field trials, published between 1960 and 2000. A review. Agrokémia és Talajtan 52:455–472 (In Hungarian)
Csathó P (2005) Estimations on changes in soil P status in the CEE countries in the periods where there are not published data, based on changes in P balances. RISSAC HAS, Budapest, Hungary. Manuscript
Csathó P, Radimszky L (2005a) Agronomic and environmental protection approached NPK balances of the Hungarian agriculture, 1901 to 2000. A review. Agrokémia és Talajtan 54:217–234 (In Hungarian)
Csathó P, Radimszky L (2005b) Environmental NP balance of Albania, Bulgaria, Latvia, Lithuania and Romania in 1961, 1985 and 2000. RISSAC HAS, Budapest, Hungary. Manuscript

Csathó P, Radimszky L (2007) The first 15 years of the Nitrates Directive: results, failures, and urgent tasks in reducing agricultural NP loads to the environment within the EU. A forum. Növénytermelés 56:83–110 (In Hungarian)
Csathó P, Radimszky L (2009) Two worlds within EU27: sharp contrasts in organic and mineral NP use, NP balances and soil P status. Widening and deepening gap between Western and Central Europe. Commun Soil Sci Plant Anal 40:999–1019
Csathó P, Árendás T, Németh T (1998) New, environmentally friendly fertiliser advisory system, based on the data set of the Hungarian long-term field trials set up between 1960 and 1995. Commun Soil Sci Plant Anal 29:2161–2174
Csathó P, Sisák I, Radimszky L, Lushaj S, Spiegel H, Nikolova MT, Nikolov N, Čermák P et al (2007) Agriculture as a source of phosphorus causing eutrophication in Central and Eastern Europe. Soil Use Manag 23(suppl 1):36–56
Csathó P, Árendás T, Fodor N, Németh T (2009) Evaluation of different fertilizer recommendation systems on various soils and crops in Hungary. Commun Soil Sci Plant Anal 40:1689–1711
De Clercq P, Gertsis AC, Hofman G, Jarvis SC, Neeteson JJ, Sinabell F (eds) (2001) Nutrient management legislation in European countries. Wageningen Pers, Wageningen, 348p
Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy
Egner H, Riehm H, Domingo WR (1960) Untersuchungen über die chemische Bodenanalyse als Grundlage für die Beurteilung des Nahrstoffzustandes der Böden. II. Lantbr Högsk Ann 26:199–215
EUROSTAT. http://epp.eurostat.ec.europa.eu
FAO (2005) Statistical database for agriculture. www.fao.org
Gartley KL, Sims JT (1994) Phosphorus soil testing: environmental uses and implications. Commun Soil Sci Plant Anal 25:1565–1582
Hajas I, Rázsó J (1969) Agriculture in numbers. Mezőgazdasági Kiadó, Budapest (In Hungarian)
Hamell M (2007) Implementing the nitrates directive. European Commission. DG Environment. Unit Agriculture, Forest and Soil. In: 16th international symposium of CIEC, A PPT presentation, Gent, Belgium, Sept 2007, pp 17–19
Handboek melkveehouderij (1997) Themaboek 25. Wageningen UR, Wageningen (http://www.pv.wageningen-ur.nl/index.asp?producten/boeken/themaboek/rsp/25.asp)
Hera C, Borlan Z, Stefanescu D (1998) Some aspects of phosphorus fertilizer use in Romania during the last two decades (1975–1995). Bibliotheca Fragmenta Agronomica, Tom 3:327–338
Järvan U, Kanger J, Kevvai L, Sisask M, Tüür R (1996) Establishment of agrochemical status of the arable land in Estonia. Trans Estonia Agric Univ 187:15–22
Johnston AE, Lane PW, Mattingly GEG, Poulton PR (1986) Effect of soil and fertilizer P on yields of potatoes, sugarbeet, barley and winter wheat on a sandy clay loam soil at Saxmundham, Suffolk. J Agric Sci, Cambridge 106:155–167
Jungk A, Claassen N, Schulz V, Wendt J (1993) Pflanzenverfügbarkeit der Phosphatvorräte ackerbaulich genutzter Böden. Zeitschrift für Pflanzenernährung und Bodenkunde 156:397–406
Kamprath E (2005) North Carolina phosphorus loss assessment: 1. Model description and II. Scientific basis and supporting literature, The N.C. Plat Committee, North Carolina Agricultural Research Service Technical Bulletin 323, North Carolina State University, Raleigh
Karklins A (1998) Plant available phosphorus in Latvian soils and trends in fertilizer use. Bibliotheca Fragmenta Agronomica, Tom 3:310–316
Kemppainen E (1989) Nutrient content and fertilizer value of livestock manure with special reference to cow manure. Annales Agric Penniae 28:163–284
Klir J (2005) OECD soil surface nitrogen and phosphorus balances for the Czech Republic, 1950 to 2004. Research Institute of Crop Production, Prague-Ruzyne. Manuscript
Kopiński J (2005) OECD soil surface nitrogen and phosphorus balances for Poland, 1960 to 2004. Institute of Soil Science and Plant Cultivation, Puławy. Manuscript
Laine T (1967) Lietelännan Käyttöarvo. Koetoin. Ja Käyt 40:28
Lazauskas S (2005) OECD soil surface nitrogen and phosphorus balances for Lithuania, 1950 to 2004. Lithuanian Institute of Agriculture, Dotnuva, Lithuania. Manuscript

Leskošek M (1998) Phosphorus in soil and phosphorus fertilization in Slovenia. Bibliotheca Fragmenta Agronomica, Tom 3:401–406
Lisovoj MV, Nikitjuk ML (2004) Nutrient balances in Ukrainian agriculture. Agrarna Nauka, C55-58. Kiev, Ukraine (In Ukrainian)
Manojlović M (2005) Soil surface nitrogen and phosphorus balances for Serbia and Montenegro, 1955 to 2003. Faculty of Agriculture, University of Novi Sad, Novi Sad, Serbia and Montenegro. Manuscript
Mazvila J, Vaisvila Z, Masauskas V (1996) Phosphorus and potassium available in Lithuanian soils, their effect on the yield of agricultural crops. Agric Sci 2:21–29 (In Lithuanian)
McCallister DL, Shapiro CA, Raun WR, Anderson FN, Rehm GW, Engelstad OP, Ruselle MP, Olson RA (1987) Division S-8. Fertiliser technology and use. Soil Sci Soc Am J 51:1646–1652
McCollum RE (1991) Buildup and decline in soil phosphorus: 30-year trends on a typic umprabuult. Agronomy J 83:77–85
Nikolov N (1998) Use and future needs of mineral fertilizers for sustainable crop production in Bulgaria. Bibliotheca Fragmenta Agronomica Tom 3:290–297
Nikolova M (2005) Soil surface nitrogen and phosphorus balances for Bulgaria, 1986 to 2002. University of Forestry, Faculty of Agronomy, Sofia. Manuscript
Nosko BS, Loboda MB, Khristenko AO (1994) The nutritious substances contents variation in soils according to data of agrochemistry examination. The data book of agrochemical and agroecological state of soils in Ukraine (In Ukrainian). Kiev: Urozhai, pp 109–111
Obojski J, Straczynski S (1995) Soil pH and content in major and trace elements (In Polish). IUNG, Pulawy
OECD (1997) Methodology handbook for calculating OECD surface nitrogen balances. A manuscript. OECD, Paris
OECD (2001) Environmental indicators for agriculture, vol 3. OECD, Paris, pp 117–139
OECD (2008) Chapter 3: OECD trends of environmental conditions related to agriculture. In: Environmental indicators for agriculture, vol 4. OECD: Paris, France. www.oecd.org
Rieder JB (1983) Gülle als Dünger Richtig Einschätzen. DLG-Mitt 98:394–398
Sarkadi J (1993) Efficiency of the nutrient contents in organic manure and mineral fertiliser in long-term experiments. I. Nitrogen turnover. Agrokémia és Talajtan 42:293–308 (In Hungarian)
Sharma RG, Crewal JS, Sengh M (1980) Effects of annual and biannual applications of phosphorus and potassium fertilizer and farmyard manure on yields of potato tubers, on nutrient uptake and on soil properties. J Agric Sci 94:533–538
Sharpley AN, Chapra SC, Wedepohl R, Sims JT, Daniel TC, Reddy KR (1994) Managing agricultural phosphorus for protection of surface waters: issues and options. J Environ Qual 23:437–451
Sluijsmans CMJ, Kolenbrander GJ (1977) The significance of animal manure as a source of nitrogen in soils. In: Proceedings of the international seminar on soil environment and fertility management in intensive agriculture (SEFMIA), Tokyo, pp 403–411
Smith KA, van Dijk TA (1987) Utilization of phosphorus and potassium from animal manures on grassland and forage crops. In: Van der Meer HG et al (eds) Animal manure on grassland and fodder crops. Fertilizer or waste? Martinus Nijhoff, Dordrecht, pp 87–102
Spiegel H (2007) Comparison of fertilizer advisory systems based on Austrian soil sample results. In: 19th MOEL meeting of the Central and Eastern European Countries, CD-ROM edition, Visegrad, Hungary, 25–27 Apr 2007
Stanners D, Bourdeau Ph (eds) (1995) Europe's environment. The Dobřiš assessment. European Environment Agency, Copenhagen
Steén I (1997) A European fertilizer industry view on phosphorus retention and loss from agricultural soils. In: Tunney H, Carton OT, Brookes PC, Johnston AE (eds) Phosphorus loss from soil to water. CABI, Wallingford, pp 311–328
Sutton AL, Nelson DW, Hof JD, Mairose WD (1982) Effects of infection and surface applications of liquid swine on corn yield and soil composition. J Environ Qual 11:468–472
Swinbank A, Daugbjerg C (2006) The 2003 CAP reform. Accomodating WTO pressures. Comp Eur Polit 4:47–64

TAPAS (2007) Agreement number 67101.2006.001-2007.097. Gross nutrient balances: to calculate the technical coefficients needed to compile the national and regional nitrogen and phosphorus balances. Eurostat, Luxemburg

The Agricultural Council, April, 2001

The Cardiff European Council, June, 1998

The Göteborg European Council, June, 2001

The Helsinki European Council, December, 1999

The International Year of Planet Earth. www.esfs.org

Torma S (2001) Crop production and nutrient balances in the Slovak Republic. In: Balanced fertilisation for crop yield and quality, Proceedings of workshop, Research Institute of Crop Production, Prague – Ruzyne, Czech Republic, pp 35–40

Torma S (2005) OECD soil surface nitrogen and phosphorus balances for Slovakia, 1960 to 2004. Soil Science and Conservation Research Institute, Bratislava. Manuscript

Tunney H (1980) Fertiliser value of animal manures. Farm Food Res 11:78–79

Tunney H, Breeuwsma A, Withers PJA, Ehlert PIA (1997) Phosphorus fertiliser strategies: present and future. In: Tunney H, Carton OT, Brookes PC, Johnston AE (eds) Phosphorus loss from soil to water. CABI, Wallingford, pp 177–204

UKSUP (2000) Results of agrochemical soil testing in Slovakia in the period 1995–1999 (10th cycle). UKSUP, Bratislava, p 100

Valmari J (1933) Karjanlannan talteenonosta ja hoidosta. Pellervo 34:52–55

Várallyay Gy (2008) Innovation grand prize, 2007. Agrokémia és Talajtan 58:207–208 (In Hungarian)

Vetter H, Fruchtenicht K (1974) Wege zur Ermittlung des Dungerbedarfs mit grosserer Treffsicherheit (Methods of determining fertiliser requirements with more accuracy). Landwirtschaftliche Forschung 31(1):290–320.; cit: Tunney H, Csathó P, Ehlert P (2003) Approaches to calculating P balance at the field-scale in Europe. J Plant Nutr Soil Sci 166:438–446

Webster N (1961) Webster's third new international dictionary of the English language unabridged I-II. Bell and Sons, London, 2662p

World Bank (2005) Food safety and agricultural health standards: challenges for opportunities in developing country exports. Report No. 31207, World Bank, Washington, DC