ACTA SCIENTIFIC AGRICULTURE (ISSN: 2581-365X)

Volume 3 Issue 8 August 2019

Research Article

Farmer's Perceptions of Soil Tests: A Case Study in the Netherlands

Arjan Reijneveld[1]*, Frans JM Van Bohemen[2], Aad J Termorshuizen[2] and Oene Oenema[2]

[1]Eurofins Agro International Agro Competence Center, Binnenhaven, Wageningen, Netherlands

[2]Wageningen University and Research Centre, Alterra, Wageningen, Netherlands

***Corresponding Author:** Arjan Reijneveld, Eurofins Agro international Agro competence center, Binnenhaven, Wageningen, Netherlands. **E-mail:** ArjanReijneveld@Eurofins.com

Received: June 27, 2019; **Published:** July 11, 2019

DOI: 10.31080/ASAG.2019.03.0570

Abstract

Soil tests are indispensable in farm management, to obtain high crop yields and high nutrient use efficiency, to reduce nutrient losses to the environment and to increase carbon sequestration in soil. Recently the importance of soil tests and fertilization recommendations have been emphasized for among others China, India, and Sub-Saharan Africa implicitly assuming that the soil tests and soil test-based fertilization recommendations are used. There is however surprisingly little information about farmers' perceptions towards these soil tests. Here, we report on a study investigating farmers' opinions about soil tests and fertilization recommendations in the Netherlands where soil tests are common for already nine decades. A written questionnaire was developed. The results showed that interest in soil tests is high; they are regarded as the most important factor in realising a sound fertilization plan. Soil P status was considered most important, however, most farmers (70%) also expressed doubt about the soil P test and associated recommendations. As a result, farmers strived for higher than recommended soil P values, implying that more P is applied than needed which puts additional pressure on the longevity of scarce P reserves, increases the risk of supra-optimal P applications, and losses to the environment.

Keywords: Questionnaire; Soil Fertility; Phosphorus; Soil Organic Matter; Perception Study; Decision Tool; Nutrient Use Efficiency

Introduction

Crops require 14 nutrients in specific amounts; these elements are essential for optimal growth and development of the crop. Element uptake ranges from 0.01 to 1 kg ha-1 year-1 for micro nutrients such as copper (Cu), zinc (Zn), selenium (Se) to 10 to 500 kg ha-1 for macro nutrients such as nitrogen (N), sulphur (S), phosphorus (P), potassium (K), magnesium (Mg), and calcium (Ca), depending on crop type and yield. Commonly, most of the nutrients are supplied to crops by the soil. Soils high in fertility can supply sufficient nutrients to the crop throughout the growing season. Therefore, higher yields per unit of area can be realised easier on fertile soils than on low-fertility soils [1]. If nutrients in harvested crops are not replenished by fertilization, soil fertility will ultimately decline.

The level of soil fertility is assessed through soil tests. These soil tests are commonly done by professional soil labs at farmers' requests once in 3 to 5 years [2]. A soil test report is commonly accompanied by a field-specific fertilization recommendation to improve and maintain the soil fertility status at agronomical optimal ranges.

In theory, soil tests play a major role in farmers' decisions on fertilization and soil management. However, farmers' perceptions of soil tests, fertilization recommendations and soil fertility are largely unknown. Also, the use and appreciation of soil tests by farmers have hardly been evaluated. Nesme., *et al.* [3] found that 80% of the respondents used soil tests, they also found that few farmers used recommendations based on these soil tests. Lithourgidis., *et al.* [4] reported that in Greece only 4% used soil tests for better adjustment of fertilization. Still, the importance of soil tests and fertilization recommendations is emphasized for among others China, India, and Sub-Saharan Africa [5], implicitly assuming that the soil tests and soil test-based fertilization recommendations are used by farmers to increase crop yields, soil fertility and nutrient use efficiency.

The objective of this study is to improve our understanding of farmers' opinions about soil tests and associated fertilization recommendations, and about their concerns related to soil fertility. A written questionnaire was developed, tested and subsequently sent to arable and horticultural farmers in several farming regions in the Netherlands. These regions have a different history, also related to nutrient surpluses, in part because of the availability of animal manure from nearby intensive livestock operations. The Netherlands is of interest since it has already 90 years of experience with soil tests - the number of soil samples per acreage is relatively high [6] – and fertilization recommendations. In addition, the Netherlands has on average a high soil fertility level, and its agricultural production is among the highest in the world, On the other hand, supra-optimal nutrient applications have increased soil P status to above agronomical status, resulting in regulations to limit manure and fertilizer applications during last few decades. We hypothesized that perception towards soil tests and the implementation of their results depend on key farming system characteristics. For this, we considered age and education of the farmer, crop rotation (intensive vs. extensive) and farm type (arable vs. horticultural and arable vs. mixed farming (i.e. rotating arable crops with grass)) and soil type (sand vs. clay). Age reflects experience of the farmer, education reflects knowledge of the farmer; both could affect the farmers' attitude to soil test results. Horticultural farming is more capital-intensive than arable farming, so more investments in soil research could be expected. Sandy soils are more susceptible to changes in soil fertility than clayey soils, so soil tests are possibly more needed on sandy soils. More insight in the use and appreciation of soil tests by farmers will hopefully improve the usability of current and future soil tests and fertilization recommendations worldwide.

Materials and Methods

Agriculture in the Netherlands

The Netherlands is situated along the North Sea in the delta of the rivers Rhine, Meuse, Scheldt, and Ems. Of its surface of 34,000 km2, about 20,000 km^2 is used as agricultural land. Most agricultural land is used for dairy farming (60% of the area), arable farming (33%), with potatoes, sugar beets, onions, winter wheat and flowers as main crops, and horticulture (5%), with leek, asparagus, cabbage, strawberries, apple and pear orchards as main crops (CBS 2016). Arable land is mainly situated on carbonate-rich marine clay soils found in the southwest (province Zealand), north (provinces Friesland and Groningen) and in the centre (province Flevoland). A mixture of arable, horticultural and livestock farms is present on sandy soils in the south (province North Brabant). There are about 12,000 arable farms, and 10,000 horticultural farms (excluding glasshouse farms). These numbers are decreasing whilst average farm size is increasing [7].

We selected five typical arable farming regions (Figure 1 near here): four regions with mainly marine clay soils all laying below sea level, and one region with sandy soils. The clayey soil regions differ in history. The province Zealand was already inhabited before the Roman Era, and has experienced cycles of flooding and reclamation of polders. The Northeast Polder (NOP) was reclaimed in 1942 and the polders Eastern Flevoland and South Flevoland were reclaimed in 1957 and 1968, respectively, all from the former Zuiderzee (IJssel Lake). The fourth clayey soil region is Groningen, along the Wadden Sea. This region has witnessed series of flooding and reclamation of polders during the last millennium. Arable land on sandy soils is also found in Groningen (in the southern part). The sandy soils of the province North Brabant is the 5th region (Figure 1).

Figure 1: The Netherlands with the locations of the 5 selected regions.

Questionnaire

Farm advisors were asked to give comments on draft versions of the questionnaire. Based on their feedback, the draft questionnaires were revised. The questionnaires were sent to 200 farmers in each region. So, in total 1000 questionnaires were sent out. Farmers were selected at random out of the client database of Eurofins Agro (formerly known as BLGG AgroXpertus or Blgg)), which is the leading laboratory for soil and crop analyses in the Netherlands (market share ~80%). This database contains information about location and type of farmers. Early 2010, the questionnaire was sent out by regular mail, together with a short introduction about the background of the study.

There were in total 29 questions, structured in 5 parts. Part 1 contained general questions (type and acreage of farm, crop rotation, age, level of education). Part 2 sought information about the use of information from soil tests and its appreciation (goal of soil tests, which test are important or lacking, how are results used for fertilization plans). Part 3 dealt with the use of animal manures and fertilizers (types, reasons). Part 4 dealt with the soil P testing (what is the target soil P status, how useful are different soil P tests). Part 5 was about soil fertility and soil quality in general (what are the main concerns). The emphasis on P in part 4 is because around the time of sending this survey, P legislation based on soil tests was introduced and also because there were initiatives to change soil P tests and associated recommendations

Data processing and statistical analysis

Mean values obtained in the different groups were compared by t-tests. Chi-square test (χ2) statistics were generated for comparisons of frequencies of categorical data. Flaten., *et al*. [8] and Chataway., *et al*. [8] also used written questionnaires (both focussing on dairy farming) and they also used these statistical tools to test their hypotheses.

Results and Discussion

General information

Farmers’ perceptions studies are uncommon; there are as yet not many studies available to reflect on and to evaluate whether our results (n = 187; response rate of 20%) about soil tests and fertilization recommendations are biased. The response rate of our written survey (20%) was comparable with those obtained by Vanclay and Clyde [10], and Hayman and Alston [11], but was lower than that of Chataway., *et al* [9]. A reminder letter and the use of new questionnaire techniques by for example e-mail might have improved the response rate. Doll and Jackson [12] had a response rate of 56% (after a reminder), but Brook and McLachlan [13] obtained a response rate of 25% after a reminder, which is not much different from our study

Farm size ranged from less than 20 ha to more than 80 ha. Small farms (<20 ha) were mostly located in North Brabant ($p<0.01$), large farms (>80 ha) in Groningen, Flevoland and Northeast Polder ($p<0.01$). The level of education varied between the regions. In Flevoland and the Northeast Polder, 90% of the respondents had succeeded agricultural vocational education and training or agricultural college. In Groningen and Zealand this was about 70%, and in North Brabant 50%. Most respondents were between 45 – 55 years (~35%), followed by 35 – 45 years (~25%), and 55 – 65 years (~25%). The age distribution of the respondents was comparable among the regions. All farms in Flevoland and the Northeast Polder had potatoes in their crop rotation, and were highest in percentage sugar beets. The crop rotations of the arable farms in North Brabant included the common arable crops but also maize, peas, lettuce, carrots, and strawberry. The horticultural farms in North Brabant typically had a large diversity of crops, with strawberries, leek, asparagus, and lettuce being most common. Soil tests were used by 97% of our respondents.

Appreciation of soil tests

Arable and horticultural farmers rate soil tests and fertilization recommendations differently. According to arable farmers, the importance decreased in the order soil P status > K status > SOM > fertilization recommendations. In contrast, horticultural farmers had the opinion that soil Ca status was most important ($p<0.01$), followed by Mg status > K status > fertilization recommendation > P status > SOM.

When asked about the relevance of soil fertility status to different crops, one third replied: for all crops equally, while others mentioned a specific crop. Arable farmers found soil fertility status most important for potatoes (ware, seed, starch) > sugar beet > onions >> winter wheat. Also carrots, spinach, peas, tulips, and beans were mentioned. Horticultural farmers responded that soil fertility status is most relevant for strawberries and asparagus, likely related to the higher economic yield per hectare of these crops .

When asked ‘what is missing on the soil test report?’, 37% replied ‘nothing’. Other respondents indicated that information was missing about (i) soil life, (ii) soil structure, (iii) quality of soil organic matter and micronutrients. Respondents from Zealand notably missed information about the SOM quality, while respondents from Groningen, Flevoland and Brabant mentioned soil structure parameters.

When asked ‘who or what is important for making fertilization plans’, the responses were, in decreasing order of importance: soil test results > extension services = own knowledge > agricultural magazines > farmers’ study groups (Figure 2 near here). Respon-

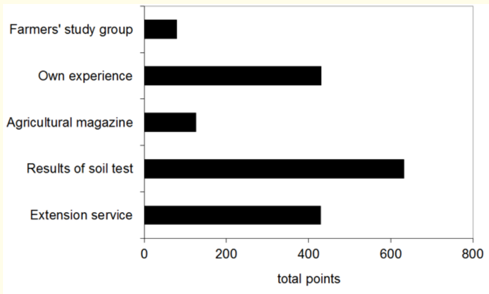

Figure 2: Responses to question ‘who or what is most important when making a fertilization plan?’ Results differ significant from each other ($p<0.01$), except for ‘Agricultural magazine – Farmers’ study group’ ($p<0.05$), and ‘Own experience – Extension service’ (not significant).

dents with a BSc and/or MSc degree placed their own knowledge as equally important as the results of soil test, and appreciated the results of soil tests less than those without such degrees ($p<0.001$). Farmers using soil mineral N tests attached significantly ($p<0.001$) more importance to extension services compared to farmers using results of basic soil tests only.

Fertilizer and manure use

Arable and horticulture farmers have the choice to import fertilizer and/or animal manure. While fertilizers may constitute 5-20% of the total costs in arable farming, manure was – in The Netherlands – available for free or even with a goodwill fee during the last decades. A total of 68% of the respondents used mineral P fertilizers (range 44% in Groningen to >80% in the Northeast Polder and Flevoland; Table 1 near here). Furthermore, 78% of the respondents used mineral K fertilizers and 96% mineral N fertilizers. A total of 67% of the respondents used pig slurries, especially in North Brabant and Zealand, where its availability is largest.

	Groningen	Northeast Polder	Flevoland	North Brabant Arable	North Brabant Horticulture	Zealand	The Netherlands
N-mineral fertilizer	100	94	94	94	95	100	96
P-mineral fertilizer	44	81	86	50	52	76	68
K-mineral fertilizer	64	92	82	75	71	80	78
Ca-mineral fertilizer	21	6	20	31	24	8	17
Pig manure	64	69	65	88	43	80	67
Poultry manure	28	17	31	6	0	0	18
Dairy cattle manure	23	11	31	56	38	20	27
Compost	21	44	24	25	43	8	27
Other[&]	23	14	10	25	33	16	18

Table 1: Usage of mineral fertilizers, animal manures, and composts (%).
&: champost, earth foam, duck manure, horse manure, Mg-artificial fertilizer

Most respondents rated the value of animal manure in the following order of importance: organic matter supply > nutrient supply >> source of income > suppression of soil-borne diseases. In Groningen, nutrient supply was more valued than organic matter supply ($p<0.01$).

Appreciation of soil phosphorus status

When asked 'what is your reference for P fertilization?', 35% of respondents replied the soil P status, 30% responded the permissible application amount of animal manure and another 30% responded crop type (Figure 3 near here). In total, 70% of the respondents aimed at improving the soil P status, though with significant differences between regions and farm types. In the Northeast Polder, 90% of the respondents aimed at a higher soil P status than recommended, but less than 30% for the horticultural farmers in North Brabant reported this strategy. None of the respondents aimed at a soil P status below the agronomical optimal range. Most important tools to improve P status were animal manure >> mineral fertilizers >> green manure > compost > crop rotation.

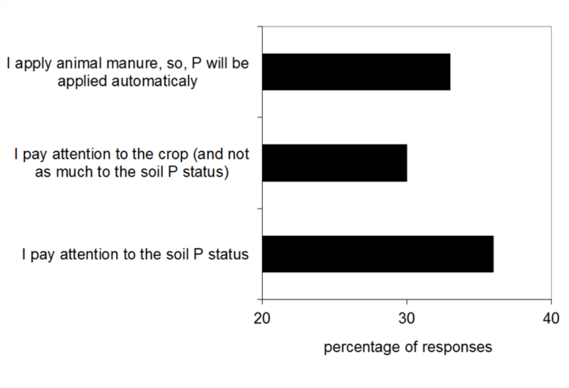

Figure 3: Responses to question 'what is reference for P fertilization?' The responses do not significant differ from another.

More than half of the respondents had the opinion that soil P status will decrease following the implementation of P application limits as function of soil P status from 2010 onwards. Surprisingly, 73% of the respondents felt unsure about the diagnostic value of the soil P test for plant available P. Uncertainty about the value of the soil P test was largest in the Northeast Polder and lowest in Brabant-horticulture. So, farmers in our sample population appreciate soil P test values, but at the same time distrust the diagnostic value of the soil P test.

There were two questions about the soil P tests (several answers were allowed). A test to indicate the capacity of the soil to supply crops with P throughout the season is considered important for 57% of the respondents. Forty per cent of the respondents indicated that no matter the soil P status or what is recommended, a starting gift of P fertilizer is always needed. For 14% of the respondents the methodology of the soil tests are of little importance, as long as the recommendations are good. In a second question about soil P tests, 64% of the respondents indicated that information about P intensity tests (i.e., concentrations of plant available P) is important. About 25% of all respondents indicated that more communication about soil tests and recommendations is necessary.

Soil fertility

More than 90% of the respondents indicated that fertilization practices have changed during the last 10 years due to legislation on manure use, more attention for SOM status, soil structure, micronutrients, and because of increasing fertilizer prices and decreasing animal manure prices. Farmers in Flevoland and Zeeland paid more attention to SOM and soil structure than farmers in other regions, while arable farms on sandy soils paid significantly more attention to micronutrients than respondents on clayey soils. The vast majority of farmers indicated to aim at improved soil fertility, in the first place by using animal manure/compost and in the second place with crop rotation (Table 2 near here).

	Groningen	Northeast Polder	Flevoland	North Brabant Arable	North Brabant Horticulture	Zealand	The Netherlands
Nothing, soil fertility is good	13	3	4	6	10	0	6
Currently nothing, but I used to	5	6	0	6	0	4	3
Use of animal manure/ compost	74	86	78	81	76	80	79
Exchange with grassland	8	8	8	19	10	0	8
Crop rotation	21	53	65	44	24	68	47
Other (e.g. green manure)	28	22	25	13	24	32	25

Table 2: Frequency of responses (%; more than one answer was possible) to the question "what actions are taken to improve soil fertility?".

A possible decline of SOM content and soil structure worries arable farmers (Figure 4 near here), which is in line with the findings of Van Dam., *et al.* [14] and Dieleman (2012, pers. comm.). Scientific reports about declining SOM contents in the world [15] may have had an effect on their own concern. However, average SOM contents are relatively high in the Netherlands, and they do not show declining trends [16]. Among others Patzel., *et al.* [17] already noticed that farmers are not likely to accept a possible decrease of soil fertility indices, even when the level is high.

In future, soil fertility may decline in the presence of N and P application limits, and soil structure, soil health, and drainage (and SOM) become more important to maintain or increase crop yields [18,19]. Not surprisingly, our respondents indicated that information about soil structure and soil life are missed on cur-

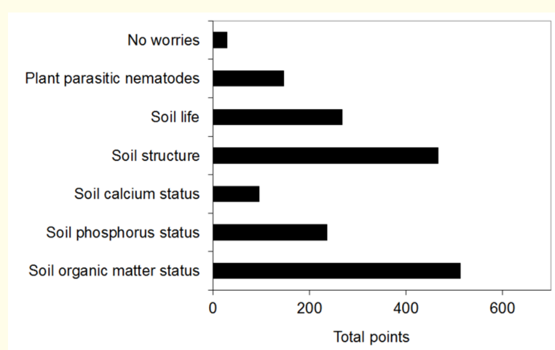

Figure 4: Responses to question 'What is most worrisome regarding soil fertility in the future?'. All significant from another with p<0.01, except for Soil P status – Plant parasitic nematodes (p<0.05), and except for SOM status – Soil structure, and Soil P status – Soil life, and Soil Ca status – Plant parasitic nematodes (not significant).

rent reports. However, by introducing more soil characteristics, the amount of information increases and may make recommendations more complex. Arguably further explanations of soil tests results by extension services is needed when more information is added to soil tests reports. We already found that farmers who have both basic soil tests as well as mineral N soil tests appreciate the role of extension services significantly more. Besides a more significant role for extension services, integration of the results of soil tests in decision support systems for optimal nutrient and SOM management are options, and to some extent already available [20]. Decision support systems can embed fertilization recommendations and may consider differences between potential yield and likely attainable yields, as function of for example weather conditions [21]. However, the many examples of decision support systems that simply were not used, illustrate the resistance of farmers to have their decision processes by-passed. If on the other hand the decision support system is designed to serve as a tool to assist or adjust farmers' decision process than its use may increase [22]. These applications should therefore, in our opinion, only be seen as an additional tool for making farm management decisions.

Notions on soil tests

Results of soil tests reported to farmers are usually accompanied with soil-specific and crop-specific fertilization recommendations. As such, soil tests seem straightforward in their application, but in reality it is only one of multiple information sources a farmer gets to decide on managing soil fertility. Other possible stakeholders are inorganic and organic (including compost) fertilizer suppliers, soil conditioner suppliers, study groups, extension services, and family members and neighbours. Reasons to deviate from soil test-based fertilization recommendations include own observations and notions about crop responses to soil fertility and fertilization, field-specific characteristics, and cultivar-based differences. The question we put forward here is whether farming system, as characterized by crop rotation, soil type, size, and farmers' age and education, interacts with appreciation of soil test results and the recommendations based on that. Our results indicate that especially soil type leads to significant differences in appreciation (most significant differences between 'arable farming sand' and 'arable farming clay'). Arable farmers on sandy soil appreciated information about the soil Ca-, Mg-, K- and micronutrients status more than arable farmers on clay soils. Farmers on clay soils considered SOM status significantly more important than their colleagues on sandy soils. These differences were however partly intertwined with farm size (more small farms on sandy soils), soil P status (higher soil P status on sandy soils: Reijneveld., *et al.* [23]), (lower) education and age (farmers were on average older on sandy soils than on clay soils).

Irrespective of these soil type based differences we observed that arable farmers find soil P status most important. The fact that soil P status was valued as the most important soil fertility characteristic is likely related to the introduction in 2010 of P application limits that depend on soil P status. At the same time, the value of the soil P test to establish plant available P was questioned by ~70% of the farmers. This is comparable to the results of Nesme., *et al.* [3], who found that soil P value was perceived as more important than the recommendation derived from this value. This perception may have contributed to the strive for supra-optimal soil P values and P applications (70% of the respondents). In contrast, Nesme., *et al.* [3] reported that the amount of P used by farmers was lower than recommended. Further, farmers indicated to want to apply a P starter at the beginning of the growing season, irrespective of soil test results.

Various suggestions have been made for improving soil P test and P fertilization recommendations. Most studies suggest the use of two or more soil tests, so as to obtain more insight in soil processes and soil P pools [24-27]. Implementing new techniques and soil tests was endorsed by most arable farmers. Irrespective of soil type, an equal number of farmers expressed preference for a 'plant-based' P fertilization strategy as for a 'soil-based' fertilization strategy. This contrasts with results obtained by Nesme., *et al.* [3]; they found that most farmers opt for a 'plant-based' fertilization strategy. 'Soil-based fertilization' is a strategy to improve soil fertility status on a longer term, whereas 'plant-based fertilization' can be seen as investments on year-level, i.e. direct investments in the current crop. The ability of Dutch farmers to choose for both a plant- and soil-based-strategy likely reflects the availability of cheap animal manure as a source of SOM and nutrients. In contrast, crop rotation, residue management and fertilizer applications are regarded as important but costly measures to sustain SOM, P, and K levels in areas with little animal production [28].

Farmers make fertilization plans mainly on the results of soil tests. Some farmers though relied on extension services and own knowledge, and/ or on agricultural magazines and farmers' study groups. This is somewhat in contrast with Morton [29] who reported that factors determining the application rate of animal manure were in the order of: farmers' own judgement and experience (38%) > crop requirements (29%) > soil test (12%) > consultant's recommendation (6%).

Conclusion

This study explored farmers' perceptions related to soil tests and fertilization recommendations. It is to one of the first studies that made an integrated assessment of nearly all soil fertility aspects that are interesting to farmers. We conclude that:

- In our study, results of soil tests are appreciated by farmers; soil tests form an important ingredient for setting up a fertilization scheme and could therefore be a useful tool for prudent use of nutrients as was emphasized by Sutton., *et al.* [5], for among others China, India, and Sub-Saharan Africa.
- The most appreciated soil test is the soil P test, which on the other hand is also distrusted as predictor of plant available P, increasing the risk of above optimal nutrient applications. Extension services may play an important role in translating soil tests results to farmers to farmers' management and increase the confidence in (new) soil tests and recommendations.
- Farmers show interest in additional soil characteristics, especially regarding soil biological and physical characteristics. Such additional information will require more efforts of advisors to assist farmers with interpretation of the soil test. Ultimately, such an extended soil test could be integrated in a decision support system which includes, among others yield potential and weather information.
- The survey should preferable be conducted in several countries on the several continents to get more insight in farmers' perceptions towards soil tests and in possibilities to optimise this tool for crop yield, crop quality, and nutrient use efficiency.

Bibliography

1. Van Ittersum MK and Rabbinge. "Concepts in production ecology for analysis and quantification of agricultural input-output combinations". *Field Crops Research* 52.3 (1997): 197-208.
2. Voss R. "Fertility recommendations: past and present. Communications in Soil Science and Plant Analyses 29.11-14 (1998): 1429-1440.
3. Nesme T., *et al*. "An analysis of farmers' use of phosphorus fertiliser in industrial agriculture: a case study in the Bordeaux region (south-western France)". *Nutrient Cycling in Agroecosystems* 91.1 (2011): 99-108.
4. Lithourgidis CS., *et al*. "Farmers'attitudes towards common farming practices in northern Greece: implications for environmental pollution". *Nutrient Cycling in Agroecosystems* 105.2 (2016): 103-116.
5. Sutton MA., *et al*. "Our Nutrient World: The challenge to produce more food and energy with less pollution". Global Overview of Nutrient Management. Centre for Ecology and Hydrology, Edinburgh and United Nations Environment Programme, Nairobi. (2013).
6. Reijneveld JA and O Oenema. "Developments in soil phosphorus status in a recently reclaimed polder in the Netherlands". *Nutrient Cycling in Agroecosystems* 94.1 (2012): 33-45.
7. CBS. Central Bureau for Statistics. Available at: www.cbs.nl and www.statline.nl. (in Dutch). (2016).
8. Flaten O., *et al*. "Do the new organic producers differ from the 'old guard'? Empirical results from Norwegian dairy farming". *Renewable Agriculture and Food Systems* 21.3 (2006): 174-182.
9. Chataway TG., *et al*. "A survey of dairy farmers' practices and attitudes towards some aspects of arable-land management in the Darling Downs and South Burnett regions of Queensland". *Australian Journal of Experimental Agriculture* 43 (2003): 449-457.
10. Vanclay F and S Glyde. "Land degradation and land management in Central NSW-farmer's knowledge, optinions and practice. Centre for Rural Social Research, Charles Sturt University: Wagga Wagga. (1994).
11. Hayman PT and CL Alston. "A survey of farmer practices and attitudes to nitrogen management in the northern New South Wales grain belt". *Australian Journal of Experimental Agriculture* 39.1 (1999): 51-63.
12. Doll JE and RD Jackson. "Wisconsin farmer attitudes regarding native grass use in grazing systems". *Soil and Water Conservation Society* 64 (2009): 276-285.
13. Brook RK and SM McLachlan. "Factors influencing farmers'concerns regarding bovine tuberculosis in wildlife and livestock around Riding Mountain National Park". *Journal of Environmental Management* 80 (2006): 156-166.

14. Van Dam AM., *et al*. "Sustainable land use in agriculture: recommendations from agricultural practise (in Dutch). Praktijkonderzoek Plant en Omgeving, PPO nr (2006): 340101.

15. Bellamy PH., *et al*. "Carbon losses from all soils across England and Wales 1978-2003". *Nature* 937 (2005): 245 -248.

16. Reijneveld JA., *et al*. "Soil organic contents of agricultural land in the Netherlands between 1984 and 2004". *Geoderma* 152.3-4 (2009): 231-238.

17. Patzel N., *et al*. "Soil fertility-Phenomenon and concept". *Journal of Plant Nutrition and Soil Science* 163.2 (2000): 129-142.

18. Hanegraaf MC., *et al*. "BFI-an indicator for the biological quality of soils. Integrating efficient grassland farming and biodiversity". *Grassland Science in Europe* 10 (2005): 515-518.

19. Haneklaus S., *et al*. "Soil analysis for organic farming". *Communications in Soil Science and Plant Analysis* 36 (2005): 65-79.

20. Van der Burgt GHM., *et al*. "The NDICEA model: a supporting tool for nitrogen management in arable farming. In 9th European summer Academy on organic farming (2009): 24-26.

21. Ros GH. "Predicting soil nitrogen supply. PhD Thesis, Wageningen Agricultural University, Wageningen (2011).

22. McCown RL. "New thinking about farmer decision makers. In: The farmer's decision: Balancing economic successful agriculture production with environmental quality". Hatfield JL (ed.). Soil and water conservation society, Ankeny, Iowa, USA, (2005): 11-44.

23. Reijneveld J.A., *et al*. "Changes in the soil phosphorus status of agricultural land in the Netherlands during the 20th century". *Soil Use and Management* 26.4 (2010): 399-411.

24. Ehlert P., *et al*. "Potential role of phosphate buffering capacity of soils in fertilizer management strategies fitted to environmental goals". *Journal of Plant Nutrition and Soil Science*166.4 (2003): 409 -415.

25. Achat D., *et al*. "Process-based assessment of phosphorus availability in a low phosphorus sorbing forest soil using isotopic dilution methods". *Soil Science Society of America Journal* 73 (2009): 2131-2142.

26. Van Rotterdam-Los AMD. "The potential of soils to supply phosphorus and potassium, processes and predictions". PhD thesis Agricultural University Wageningen, The Netherlands. (2010).

27. Schröder JJ., *et al*. "Improved phosphorus use efficiency in agriculture: A key requirement for its sustainable use". *Chemosphere* 84.6 (2011): 822-831.

28. Wivstad M., *et al*. "Perspectives on nutrient management in arable farming systems". *Soil Use and Management* 21.1 (2005): 113-121.

29. Morton LW. "Farmer decision makers: what are they thinking". In: Morton LW, Brown SS (eds.) Pathways for getting to better water quality: The citizen effect (2011): 213-227.

Volume 3 Issue 8 August 2019