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The effect of nitrogen and phosphorus concentrations on nutrient balances of cereals and grass silage

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Abstract

This pilot study aimed at improving the estimation of nitrogen (N) and phosphorus (P) contents of the main agricultural products in Finland. We first collected and then statistically analyzed the seasonal and regional variability of available N and P concentration data of cereal grains from the sources of Finnish Food Safety Authority (Evira) and grass silage sources of Valio Ltd. The lack of data from cereal grain P concentrations was solved by analyzing representative set of samples from the available regional grain samples from 2002–2012 collected by Evira for cereal quality analyses. Regional and seasonal variation in cereal grain and grass silage NP concentrations and their effect on field and national NP balances was evaluated.

Especially the annual variation of NP concentration was relevant for both the cereals and grass silage. The differences in NP concentrations between the regions were most relevant in spring wheat, where an interaction between years and regions was observed. The differences between the measured and constant values from the Feed Tables and the variation between the years imply that variation of NP concentrations should be included in nutrient balance calculations.

In Finland, a protocol exists for cereal N concentration measurements by Finnish Food Safety Authority. This protocol should be supported and funding continued. The additional P analysis of main cereals would also be beneficial to collect and follow the development of grain P concentrations. The annual cost of analysing P concentrations of 150 samples from grain quality monitoring would be approximately 7500 €. The grass silage NP concentrations analysed by Valio LTd from farm silages have also been publically available.

Keywords:
nitrogen, phosphorus, nutrient balance, annual variation, regional variation, barley, oats, spring wheat, winter wheat, winter rye, silage, grass, forage

Typpi- ja fosforipitoisuuksien vaikutus viljojen ja nurmisäilörehun ravinnetaseisiin

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Tiiviselmä

Tämän työn tarkoituksena oli selvittää Suomen tärkeimpien maataloustuotteiden typen (N) ja fosforin (P) pitoisuuksia. Viljojen ja nurmisäilörehun N- ja P-pitoisuudet kerättiin Eviran ja Valio Oy:n aineistosta ja niiden vuosittainen ja alueellinen vaihtelu analysoitiin tilastollisesti. Viljojen P-pitoisuustietojen puute ratkaistiin analysoimalla otos Eviran vuosilta 2002–2012 keräämistä viljanäytteistä. Työssä tarkasteltiin viljojen ja nurmisäilörehun alueellista ja vuosittaista vaihtelua ja sen vaikutusta kansallisiin N- ja P-taseisiin.

Varsinkin vuosittainen vaihtelu oli merkittävää sekä viljoissa että nurmisäilörehussa. Alueelliset erot N- ja P-pitoisuuksissa olivat merkittävimpiä kevätvehnässä, jossa havaittiin myös yhdysvaikutus vuoden ja alueen välillä. Erot määritettyjen ja Rehutaulukoissa ilmoitettujen pitoisuuksien välillä ja vuosien väliset erot tarkoittavat sitä, että vaihtelu satotuotteiden N- ja P-pitoisuuksissa pitäisi huomioida ravinnetaselaskelmissa.

Suomessa Evira toteuttaa kotimaisen viljasadon laatuseurantaa, jonka mukaan se seuraa viljojen N-pitoisuuksia. Tämän seurannan toteuttamista tulisi tukea ja rahoitusta jatkaa. Näytteistä kannattaisi myös analysoida P, jotta myös sen pitoisuuksien kehittymistä voitaisiin seurata. Kustannus 150 näytteen P-pitoisuuksien analysoinnista olisi noin 7500 € vuodessa. Valion analysoimien nurmisäilörehujen N- ja P-pitoisuudet ovat myös olleet julkisesti saatavilla.

Avainsanat

typpi, fosfori, ravinnetase, vuosittainen vaihtelu, alueellinen vaihtelu, ohra, kaura, kevätvehnä, syysvehnä, syysruis, säilörehu, nurmi, nurmirehu

Contents

1 Introduction

This pilot study aimed at improving the estimation of nitrogen (N) and phosphorus (P) contents of the main agricultural products in Finland. Most of the yield N and P concentrations used in calculation of gross nutrient balances (GNB) in Finland are now based on the values in the Finnish Feed Tables (www.mtt.fi/feedtables). These values provide a reliable and periodically updated average values for GNB calculations but there is still a demand to understand the variation caused by different growing seasons and regions. Cultivation area of cereals and grass silage consists of approximately 75% of total agricultural area of Finland and consequently these crops are the most important in the Finnish GNB calculations (Annex 1).

We aimed first to collect and statistically analyze the seasonal and regional variability of available N and P concentration data of cereal grains from the sources of Finnish Plant Safety Authority (Evira) and grass silage sources of Valio Ltd. The lack of data from cereal grain P concentrations was solved by analyzing representative set of samples from the available regional grain samples from 2002–2012 collected by Evira for cereal quality analyses. The grass silage data is based on farm samples analysed by Valio Ltd. and consists of over 100 000 samples. As a result of further data treatment of N concentration and new results from P analysis, regional and seasonal variation in cereal grain NP concentrations and the effect of field NP rates and NP balances on the NP concentrations was evaluated.

The objective was to provide annual and regional dataset from the N and P concentrations of the main cereals and grass silage, of which datasets exist. Gross nutrient balances calculated with average contents were compared to GNB's calculated with more specific annual and regional NP contents. The variation both between years and regions provides information about how reliable the average values of Feed Tables are and if there would be a need for annual monitoring of yield NP concentrations. Furthermore the costs and feasibility of integrating grain P analyses to the Evira's procedure of cereal grain quality analysis were evaluated.

2 Material and methods

2.1 General description of the cereal dataset

The Finnish Food Safety Authority (Evira), the Grain Section of the Plant Analysis Unit has studied the quality of the domestic grain crop since 1966. The quality monitoring of the grain harvest gives a general view of the quality of the annual domestic grain harvest. The quality factors generally used in grain sales have been analyzed like hectoliter weight, 1000 kernels weight, falling number, protein, starch, wet gluten, zeleny-index and shriveled grains. These results are annually reported by Evira (Viljaseula 1990–2012) and their relationship to N and P fertilizer rates has been estimated in the monitoring of the Finnish Agri-environmental Programme (Salo et al. 2007a and Salo et al. 2010). The quality monitoring is based on the results of the analyses of grain samples sent in by farmers and on the background information they have supplied. The farms taking part in the monitoring are selected randomly from the Farm Register of the Information Centre of the Ministry of Agriculture and Forestry. Selection was performed by region from the 20 rural centers of Finland. (Fig 1.) Farms with less than five hectares of cultivated area were excluded from the sampling. Number of farms taking part in the study averages 1,700 and farms deliver annually altogether approximately 1000 samples for analysis (Evira 2013). Crops sampled include barley (34%), oats (31%), spring (25%) and winter (4%) wheat and winter rye (6%) with their proportions from the year 2012 in parenthesis.

2.1.1 Nitrogen concentrations in cereals

Nitrogen concentrations were calculated for regions (rural centres, Fig. 1) and for years 2002–2012 from the whole dataset of Evira (18620 samples). For statistical analysis of both N and P in field balances, we used only the samples where P concentrations were analysed during this project. We wanted to keep the data for both nutrients similar and to be based on the same grain samples. The selection process is explained in chapter 2.2.

Nitrogen content was measured by NIT –analyzer (Near Infrared Transmittance). The reference method for NIR-analysis was Kjeldahl method (ISO 20843:2006).

2.1.2 Phosphorus concentrations in cereals

MTT Agrifood Research Finland has analysed and stored a subset of grain samples from Evira's Grain Quality Study for the Selenium Monitoring Program every year (Table 1). Selenium monitoring is a long term follow up study where all the samples have been stored creating a valuable food sample bank for the future. This subset was the only possibility to obtain cereal samples for this project from previous years, as Evira has no capacity to store samples over the years. The grain samples have been collected from all the rural centres around Finland weighting somewhat the most important cultivation areas. The amount of the collected cereal samples has varied somewhat over the years depending of the funding of the selenium monitoring project. Wheat has been of bread grain quality. All the samples were conventionally cultivated, as in selenium monitoring the effect of selenium added to compound fertilizers is followed. Area of organic production was 185000 ha in Finland in 2011, which was 8% of the total agricultural area.

In this project the P content of all the spring wheat samples collected for the selenium monitoring from 2002–2010 were analyzed. The number of stored spring wheat samples was close to the number that was planned to be analyzed and selection process would have been problematic. From oats and barley samples a subset was selected for P analyses. Thirty five samples from oats and barley were sampled randomly for each year in 2002–2009 and for 2010, 42 samples were selected.

Table 1. Number of the oats, barley and spring wheat samples collected for the Selenium Monitoring Program during 2002–2010.

Year	Number of samples available			Total
	Oats	Barley	Spring wheat	
2002	99	99	44	242
2003	117	101	32	250
2004	48	50	33	131
2005	57	58	46	161
2006	59	51	23	133
2007	53	45	26	124
2008	73	74	35	182
2009	72	53	41	166
2010	62	68	30	160
Total	640	599	310	1549

Table 2. Number of analysed samples in 2002–2012.

	Oats	Barley	Spring wheat
2002–2009	35	35	23–46
2010	43	42	30
2011	51	65	34
2012	45	56	34

For years 2011–2012, samples were selected from the total dataset collected by Evira, as Selenium Monitoring Program had yet not preselected the samples and all samples were available in Evira. Selection was done according to the following principles: cultivar should be widely grown (i.e. sample number of cultivar in data >10), if there are several samples in a rural centre then at least two samples for this rural centre should be selected. In 2012 also a small set of winter cereals were selected and analysed (9 samples of winter rye and 6 samples of winter wheat).

The grain samples have been stored as whole grains in plastic containers in ca. + 5°C. Before analyses the effect of homogenization (falling number hammer mill, 1 mm sieve) on P contents were tested by analyzing 10 samples of each cereal both as ground and whole grain. Milling is often the standard procedure for determination of nutrient concentrations, but in these analyses we wanted both to avoid loss of stored grain samples in milling and to save work and costs related to milling. Relative differences between ground samples and whole grains were: spring wheat -0.5%, oats, -0.7 % and barley 2.3%, indicating that in wheat and oats samples whole grains resulted on average slightly higher contents and in barley lower P contents. However, the differences were considered insignificant indicating that the unhomogenized sample did not affect the effectiveness of digestion process or otherwise the P results. Thus P determinations were performed from the whole grains.

In MTT P was determined by ICP-OES (inductively coupled plasma optical emission spectrometry) method. The method is accredited by Finnish Accreditation Service (FINAS). The grain samples (approximately 2 g) were digested in concentrated nitric acid and transferred into 50 ml volumetric flask, diluted and filtered (Kumpulainen & Paakki 1987). P was measured by high resolution ICP-OES (Thermo Jarrel Ash Iris Advantage). In every batch of samples there was a blind sample and 1–2 reference samples which were measured with the samples. In Evira, P was determined with similar method as in MTT.

A comparison test between MTT and Evira was made to ensure that the P results in both laboratories are comparable. In the comparison test 8 samples of oats, barley and wheat were analysed. No significant differences in the P levels between the laboratories were detected (Table 3). Relative differences between the samples varied from -3.8% to 4.4%.

Table 3. A comparison test between laboratories.

	MTT	Evira	Relative difference (%); MTT/Evira
Average P content all samples, g/kg	3.74 ± 0.19	3.71 ± 0.25	0.46
Average P content oats, g/kg	3.61 ± 0.18	3.54 ± 0.13	-0.17
Average P content barley, g/kg	3.79 ± 0.19	3.84 ± 0.24	0.75
Average P content wheat, g/kg	3.82 ± 0.17	3.71 ± 0.25	1.63

2.2 General description of the grass silage data

The laboratory of Valio Ltd. has provided commercial feed sample analyses and is the largest analyser of farm feed samples in Finland. For this research, grass silage samples analysed since 1998 were available on courtesy of Valio Ltd. Only the samples having values for both N and P were included in the statistical analysis. Over 100 000 observations were included in the analysis, which is approximately one third of the total number of silage samples analysed by Valio Ltd. The rest of samples lack information of P which is only available for those samples that were also analysed for a separate mineral analysis.

In this data, results from grass silage are used. The changes in N and P concentrations can however be considered to be small particularly as wilting and good silage making practises are generally used in Finland. Thus the results from grass silage can be considered to represent the concentrations in silage grass (i.e. grass to be ensiled).

2.2.1 Nitrogen and phosphorus concentrations in grass silage

The N concentration of the samples at Valio Ltd. laboratory were analysed by Near Infrared Reflectance Spectroscopy (NIRS) using FOSS equipment. Valio Ltd. uses an own calibration based on a large sample set of Finnish forage samples, which have been analysed using relevant standard laboratory methods. N is relatively easy to analyse by NIRS so that the results should be accurate and precise. In animal nutrition, term crude protein (CP) is generally used instead of N, and was also used in the original data. The CP concentration was converted to N concentration by dividing it by a factor of 6.25.

The P concentration (as well as Ca and K) of the silage samples was analysed by an XRF method, which has been calibrated using samples analysed by an ICP method. The other macro minerals Mg and Na as well as micro minerals Cu, Mn, Zn and Fe were analysed by ICP, and the concentrations of these minerals are also included in the descriptive Tables of the data set.

The DM concentration of the silage samples was determined by oven drying. The water soluble carbohydrate, neutral detergent fibre (NDF) and indigestible NDF concentrations as well as D-value were analysed by NIRS. The silage fermentation quality was analysed by electrometric titration (for more information on silage analyses, see e.g. Nousiainen 2004).

The descriptive statistics of the grass silage samples are presented in Tables 4 and 5. The farmers fill the descriptive information of the samples into the covering letter while sending the silage samples to Valio for analyses. Descriptive information is not always recorded or may sometimes be incorrect. This must be taken into account when interpreting the results – however the large number of data available should prevent serious biases.

Table 4. Classification criteria in the Valio Ltd. silage data.

Variable	Description
Year	Refers to the most probable year of harvest of the grass material. Includes samples analysed from 1 August of the current year until 31 July of the following year.
Harvest	First, second or third cut within the growing season
Harvest date	Available since 2004
Municipality	Available since 2002
Region	Available since 2002
Feed type	Grass silage, leguminous grass silage, ryegrass silage, green cereal silage or mature whole crop cereal silage
Organically farmed	Yes or No; available since 2010
Wilting	Yes or No
Application of slurry	No application, Application on top, Injection into soil

2.2.2 Grass silage data basic description

The data contains a total of 113 075 silage samples which have been analysed by Valio Ltd. from 5 August 1998 until 14 June 2013. The description of the samples is presented in Table 5. Majority of the samples have been coded as grass silages (90.5 %) as the proportions of leguminous grass silages, ryegrass, green cereal and mature whole crop cereal silages are 7.7, 0.3, 0.5 and 1.0 %, respectively. Ryegrass and cereal silages represent annual species and due to their small proportion they were not included into the statistical analysis. Organic samples have been coded separately since year 2010 and the data set contains 1480 organic pure grass or leguminous grass silage samples.

The most common grass species used in Finland are timothy (Phleum pretense) and meadow fescue (Festuca pretense). Of the grass legumes, red clover (Trifolium pretense) is the most widely used. There are no official statistics of the use of legumes, but the Ca concentration of the forage can give some idea about the proportion legumes as forage legumes have clearly higher Ca concentration than grasses (Rinne et al. 2010). In this data (including both grass silages and leguminous grass silages) only 7.1 % of the samples had a calcium content above 7.5 g/kg DM which would be equal to a 30 % proportion of red clover in the sward according to Rinne et al. (2010). Red clover typically has lover P content that grass species (MTT 2013) and the proportion of red clover in a mixed sward is typically higher in the second cut than in the first cut. Thus, for this analysis it makes most sense to concentrate on samples coded as pure grass silages, because they represent the majority of Finnish grasslands.

The use of leguminous forage species (mainly red clover and to some extent alsike clover, white clover and other minor species) is of great interest particularly for organic farmers but also for conventional farmers, so that some analyses include those samples as well. It may also be speculated that the plant nutrition may differ between conventional grass swards and the legume containing swards due to the differences in the N supply of the plant groups.

The samples included in the data set are preserved as silages, and majority of the forages in Finland are used in the form of silage instead of grazed grass or dry hay. For example, according to the feed consumption statistics of Finnish Farm Advisory Service ProAgria (2013), silages form 41.8 % of dairy cow diets, while grazing + green fodder comprises only 5.5 % and dry hay + straw 1.0 %. The rest of the diet includes concentrate feeds such as cereal grains, protein supplements and various by-products.

The mean N concentrations in conventional and organic grass and leguminous grass silages were 22.8 and 20.4 g/kg DM, and the respective P concentrations were 2.79 and 2.64 g/kg DM (Table 5). The N and P concentrations for grass silages in the Finnish Feed Tables (MTT 2014) are 28.0–19.2 and 3.6–2.2 g/kg DM respectively, which are in good accordance with the current data set. The large range in the Feed Table values originates from the decline of both N and P concentrations of grass silage with progressing developmental stage of the plants. The great variation of chemical composition and feed values of the grass in response to progressing growth (Rinne 2000, Kuoppala et al. 2008) as well as between the different seasons (Nousiainen 2004, Huhtanen et al. 2006, Kuoppala et al. 2008) has been well documented in the Finnish scientific literature.

Table 5. Description of grass silages (years 1998–2012, including also silages coded as leguminous silages), and a subset containing organic grass silages (years 2010–2012) coded separately.

	All grass silages				Conventional grass silages*				Organic grass silages**		
	n	Mean	SD		n	Mean	SD		n	Mean	SD
Dry matter (DM; g/kg)	110192	321	108.9		25767	337	111.4		1480	374	127.3
In DM (g/kg)											
Nitrogen (N)	110190	23.5	4.25		25767	22.8	4.00		1480	20.5	4.09
NDF	100094	541	46.1		25767	544	43.0		1480	517	52.4
Indigestible NDF	57723	79	26.8		25756	80	26.7		1479	95	34.3
D–value	110188	674	35.0		25767	671	36.5		1480	655	42.1
Macrominerals (g/kg DM)											
Calcium (Ca)	110348	4.8	1.81		25788	4.8	1.76		1480	7.2	2.72
Phosphorus (P)	110348	2.8	0.50		25788	2.8	0.44		1480	2.6	0.47
Potassium (K)	110345	23.5	6.01		25788	22.9	5.84		1480	21.6	6.03
Magnesium (Mg)	52393	2.1	0.72		10437	2.1	0.66		572	2.4	0.82
Sodium (Na)	47138	0.3	0.28		10436	0.3	0.33		572	0.3	0.34
Microminerals (mg/kg DM)											
Iron (Fe)	30539	196	149.9		10437	205	170.3		572	200	150.0
Copper (Cu)	30539	6.3	4.73		10437	6.2	2.88		572	7.1	2.68
Zinc (Zn)	30539	33.0	26.35		10437	32.5	18.01		572	30.2	16.08
Mangan (Mn)	30539	65.3	44.28		10437	63.9	58.48		572	57.2	30.32
Silage fermentation quality											
pH	110094	4.2	0.44		25767	4.2	0.44		1480	4.4	0.48
In DM (g/kg)											
Lactic acid	110084	44.6	21.24		25767	44.4	21.64		1480	44.0	23.98
Volatile fatty acids	110094	12.8	10.40		25767	13.6	11.18		1480	14.1	10.63
Water sol. carbohydr.	110106	60.8	45.70		25767	67.9	46.12		1480	76.0	48.66
In N (g/kg)											
Ammonium N	110092	4.4	2.48		25767	4.2	2.53		1480	3.1	2.27
Soluble N	110092	41.3	12.99		25767	42.4	13.00		1480	37.6	12.79
Silage quality grades											
Silage DM intake index	109353	102.5	8.24		25450	104.3	9.74		1453	109.3	11.05
Fermentation grade	94267	7.9	1.13		20151	8.1	1.15		997	8.1	1.20
Equivalent ratio	52393	1.6	0.57		10437	1.5	0.54		572	1.1	0.47

*The samples not coded as organic silages, years 2010–2012.
**The samples coded as organic silages, years 2010–2012.

The amount of plant available N compounds in soil (ammonium and nitrate N) defines the amount of N the sward can take up. Grasses are effective in extracting the N from the soil already during the early stages of growth. In practice, the most important factor affecting soil plant available N is the fertilization either from manure or from commercial fertilizers. Based on mineral N fertilization studies, the N concentration of Finnish grass swards increased by 0.039 g/kg DM as mineral N fertilization increased by 1 kg N/ha (Korhonen et al. 2005).

Most samples in this data set originate from dairy farms as feed analyses are mostly done by those farms. Manure is frequently used for the fertilization of the swards. The information of slurry application was available on 67639 samples in the whole data set. Of those, 76.3 % were recorded not having received slurry while 13.8 % had received slurry on top of the grass and 9.9 % slurry had injected into soil.

Most (80%) of the silages were pre-wilted having a DM concentration of 340 g/kg where as the direct-cut (no wilting) silages had a DM concentration of 243 g/kg. 18.7 % of the silages had a DM concentration above 400 g/kg and only 1 % had a DM concentration above 69.7 %. Most (92 %) of the silage samples included information about the harvest number, and of those samples, 56.8 % were from the first cut, 34.2 % from the second cut and 8. 9 % from the third cut.

2.3 Regional analysis

Fig. 1 shows the geographical locations of the regions used in the analysis both for cereals and silage grass. For silage samples the geographical information was available since year 2002.

Counties for grass silage	Rural Centres for cereals	
1-2. Uusimaa	1. Uusimaa	2. Nylands Svenska Lantbrukssällskap
3-4. Varsinais-Suomi	3. Farma	4. Finska Hushållningssälsskapet
5. Satakunta	5. Satakunta	
6. Pirkanmaa	6. Pirkanmaa	
7-8. Häme	7. Häme	8. Päijät-Häme
9. Kymenlaakso	9. Kymenlaakso	
10. South Karelia	10. South Karelia	
11. Etelä-Savo	11. Etelä-Savo	
12. Pohjois-Savo	12. Pohjois-Savo	
13. North Karelia	13. North Karelia	
14. Central Finland	14. Central Finland	
15. South Ostrobothnia	15. South Ostrobothnia	
16. Österbotten	16. Österbotten	
17. Central Ostrobothnia	17. Central Ostrobothnia	
18. North Ostrobothnia	18. Oulu	
19. Kainuu	19. Kainuu	
20. Lapland	20. Lapland	
21. Åland		

Figure 1. Geographical locations of the counties and rural centres used in the analysis.

2.4 Calculation of balances

2.4.1 Cereal field NP balances

In order to calculate N and P balances of individual fields from which the grain samples were sent for analysis, the information distributed from the farms to Evira was used. We used rural centre, cultivar, yield estimation made by the farmer, and NP fertilizer information given by the farmer. NP balances were calculated simply by the following equation:

field N balance = $(N_{minfer} + N_{solman}) - (Y \times N_{conc\_samp})$,

where

N_{minfer} is nitrogen input in mineral fertiliser

N_{solman} is soluble nitrogen input in manure or other organic fertiliser or soil improver

Y is yield of the field estimated by the farmer (converted to dry matter according to 14% grain moisture)

N_{conc_samp} is nitrogen concentration measured in Evira

We compared the field balance based on actual measurement of grain N concentration to the field balances calculated by constant N concentration of different cereal grains. The N concentration constants used in nutrient balance calculations were 21.4 g/kg DM for spring wheat, 20.2 g/kg DM for barley and 20.8 g/kg DM for oats. The difference between N and P balances based on either measured or constant concentrations were calculated by distracting N and P balances calculated with constant values from the N and P balances calculated with measured N and P values. In order to have sufficient number of observations for regions, rural centres were combined in five regions. These differences were compared with SAS PROC MIXED keeping cultivar as random variable and year and region as explanatory variables. Oats, barley and spring wheat were analysed separately.

The P concentration constants used in the nutrient balance calculations were 4.5 g/kg DM for spring wheat, 4.1 g/kg DM for barley and 4.0 g/kg DM for oats.

Region	Rural centres
1	Uusimaa, Nylands Svenska, Farma, Finska Hushållningssällskapet, Kymenlaakso
2	Satakunta, Häme, Päijät-Häme, Pirkanmaa, South Karelia, Etelä-Savo
3	South Ostrobothnia, Österbotten, Central Ostrobothnia, Oulu
4	Central Finland, Pohjois-Savo, North Karelia
5	Kainuu, Lapland

2.4.2 National N and P balances

In order to estimate the differences between constant and measured concentrations, NP balances were calculated according OECD and Eurostat guidelines with both concentrations for 2002–2012. N balances were calculated for spring wheat, winter wheat, winter rye, barley, oats and silage grass. P balances were calculated for spring wheat, barley, oats and silage grass. Annual mean NP concentrations were used as measured values. The differences obtained in 1000 kg of nutrients were scaled against total agricultural area of Finland.

The N concentration constants used in nutrient balance calculations for grassland have been 26.4 g/kg DM for pasture and grass used directly for feeding and 25.6 g/kg DM for silage grass. The P concentration constants used in nutrient balance calculations for grassland have been 3.3 g/kg DM for pasture, 3.0 g/kg DM for grass used directly for feeding and 2.9 g/kg DM for silage grass.

3 Results and discussion

3.1 Nitrogen in cereals

In Tables 6–9, we show the exact number of samples for N concentrations divided either between regions or years from the whole Evira cereal grain dataset. In addition of spring cereals, there are also results from winter wheat and winter rye. In box-plots (Figures 2–7) we show N concentrations of spring cereals, divided either between regions or years from the sub-sampled dataset.

Table 6. Nitrogen concentrations (g/kg DM) in oats, barley and spring wheat from the whole cereal grain dataset divided by rural centres in 2002–2012.

		Oats			Barley			Spring wheat	
Rural centre	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**
1	342	20.06	2.54	561	18.62	2.60	538	22.52	2.94
2	118	19.85	2.28	207	18.77	2.44	305	22.77	2.96
3	486	20.10	2.26	1174	19.20	2.40	771	23.46	2.96
4	53	20.34	2.15	86	19.35	2.75	101	23.64	2.79
5	809	21.11	2.34	921	19.32	2.34	275	23.65	3.00
6	399	21.65	2.22	307	19.85	2.43	97	24.21	3.63
7	518	20.29	2.36	697	18.78	2.33	281	23.15	3.17
8	146	20.84	2.43	257	19.06	2.42	64	23.89	2.73
9	236	19.97	2.36	282	18.74	2.42	249	22.74	2.99
10	191	21.28	2.39	238	19.99	2.69	68	23.10	3.19
11	191	20.93	2.19	192	19.28	2.33	60	24.08	2.59
12	233	21.50	2.15	417	19.12	2.33	66	24.26	2.97
13	225	21.21	2.18	188	19.17	2.28	66	24.60	2.84
14	216	20.92	2.20	239	19.00	2.33	43	23.61	2.84
15	853	21.81	2.36	1380	20.12	2.37	236	24.36	3.03
16	265	21.99	2.54	454	19.96	2.20	109	24.51	3.13
17	88	21.56	2.50	230	20.29	2.59	28	24.77	3.07
18	320	21.93	2.49	589	19.62	2.64	89	23.68	3.23
19	43	22.21	2.68	95	19.65	2.95	7	22.78	4.85
20	7	21.87	3.14	22	20.55	2.44			
All centres	5740	21.1	2.45	8536	19.4	2.47	3453	23.4	3.07
Constant		20.8			20.2			21.4	

SD = standard deviation

Constant = N concentration from the Feed Tables that is used in N balance calculations

Nitrogen concentrations of all cereals in rural centres have high standard deviation (Table 6 and 7), which implies considerable variation between the years. Means of regional N concentrations vary from 19.85 to 22.21 mg/kg DM with oats, 18.62 to 20.55 mg/kg DM with barley and 22.52 to 24.77 mg/kg DM with spring wheat (Table 6). The constant values of Feed Tables seem to be slightly lower than the mean of measurements for oats and spring wheat but higher for barley. The constant value of winter rye is higher and constant of winter wheat lower than the mean of measured values (Table 7).

Table 7. Nitrogen concentrations (g/kg DM) in winter rye and winter wheat from the whole cereal grain dataset divided by rural centres in 2002–2012.

		Winter rye			Winter wheat	
Rural centre	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**
1	77	17.21	2.06	76	21.54	2.27
2	47	16.10	2.03	63	22.26	2.49
3	132	17.52	2.40	280	22.35	2.44
4	26	17.75	2.05	63	21.32	2.41
5	103	16.96	2.00	72	22.19	2.25
6	57	16.82	1.97	21	21.85	2.33
7	99	16.83	1.99	78	21.56	2.88
8	17	16.96	1.65	7	22.48	2.51
9	27	17.76	2.61	29	22.04	2.50
10	18	16.91	2.14	6	23.48	2.53
11	44	17.47	2.65	1	20.00	.
12	16	17.26	1.92	2	22.46	2.23
13	35	16.88	2.16	1	17.72	.
14	38	17.69	2.12	1	27.54	.
15	77	17.84	2.14	6	23.65	3.54
16	17	18.48	2.81	3	23.27	0.20
17	12	16.84	2.61	1	17.89	.
18	19	17.12	2.01	4	22.41	1.80
19	9	17.19	0.85			
20	4	19.92	1.60			
All centres	714	17.2	2.49	874	22.1	2.20
Constant		17.6			20.0	

SD = standard deviation
Constant = N concentration from the Feed Tables that is used in N balance calculations

Table 8. Nitrogen concentrations (g/kg DM) in oats, barley and spring wheat from the whole cereal grain dataset divided by years in 2002–2012.

		Oats			**Barley**			**Spring wheat**	
Year	n	Mean	SD	n	Mean	SD	n	Mean	SD
2002	715	22.06	2.01	872	20.70	2.10	278	25.93	2.42
2003	809	22.74	1.98	1009	21.65	2.16	376	24.80	2.58
2004	609	20.57	1.88	952	19.47	2.38	376	23.22	2.27
2005	683	20.47	1.89	1154	18.95	2.06	441	22.21	3.16
2006	611	22.00	2.64	1017	19.57	2.24	341	22.32	2.62
2007	619	20.99	2.21	936	19.28	1.92	337	23.92	2.43
2008	501	18.90	2.01	817	17.07	1.96	325	22.16	2.32
2009	385	19.33	2.25	673	17.48	1.89	296	21.13	2.36
2010	267	21.63	2.19	456	20.09	2.19	240	24.66	3.33
2011	281	21.66	2.28	360	20.03	2.00	236	25.84	2.92
2012	260	19.15	2.08	290	18.38	2.03	207	21.82	2.89
All years	5740	21.1	2.45	8536	19.4	2.47	3453	23.4	3.07
Constant		20.80			20.20			21.40	

SD = standard deviation
Constant = N concentration from the Feed Tables that is used in N balance calculations

Annual variation of N concentrations is considerable, and ranges for oats 18.90–22.74, for barley 17.07–21.65 and for spring wheat 21.13–25.93 g/kg DM (Table 8).

Table 9. Nitrogen concentrations (g/kg DM) in winter rye and winter wheat from the whole cereal grain dataset divided by years in 2002–2012.

		Winter rye			Winter wheat	
Year	n	Mean	SD	n	Mean	SD
2002	105	17.98	1.99	72	21.55	2.10
2003	103	18.97	2.05	114	24.35	2.53
2004	93	17.96	1.86	113	22.32	2.33
2005	68	16.42	2.48	50	20.35	2.11
2006	92	17.06	1.74	66	21.36	1.77
2007	96	16.96	2.19	80	21.14	1.90
2008	74	16.66	1.73	58	21.57	2.36
2009	49	15.60	1.91	33	21.38	1.60
2010	84	16.28	2.06	47	22.10	1.94
2011	60	17.83	1.94	47	23.52	1.63
2012	50	15.96	1.74	34	19.94	2.66
All years	**714**	**17.2**	**2.49**	**874**	**22.1**	**2.20**
Constant		17.69			20.0	

SD = standard deviation
Constant = N concentration that is used in N balance calculations

Nitrogen content of oats seemed to be slightly lower in southern rural centres compared to the other regions both in the whole dataset (Table 6) and in the dataset sub-sampled for P analysis (Fig. 2). There was no correlation between N concentrations and estimated yield.

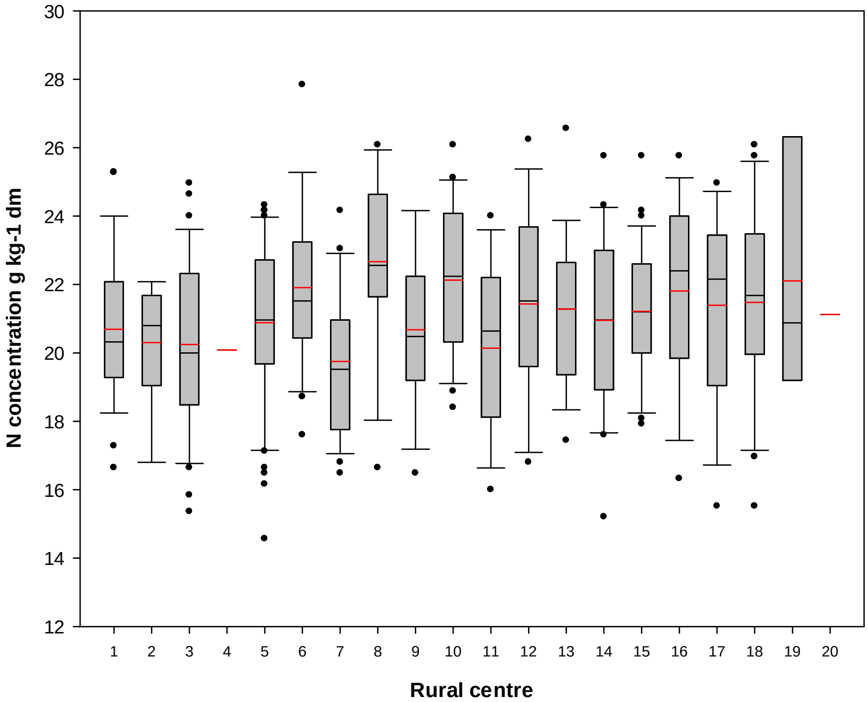

Figure 2. Nitrogen concentration in oats in different regions during 2002–2012 in the sub-sampled dataset. The horizontal black line within the box plot represents median and the red line represents mean. The box-plot limits refer to 25th and 75th percentiles and the box-plot bars include the 10th and 90th percentiles.

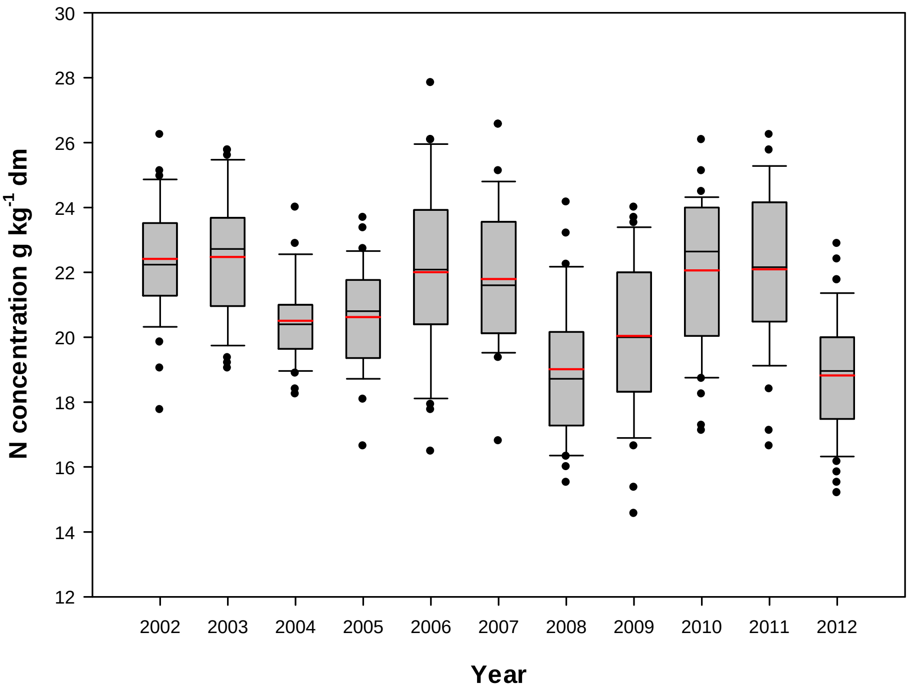

Figure 3. Nitrogen concentration in oats during 2002–2012 in the sub-sampled dataset.

The annual variation of N content of oats was similar in the whole dataset (Table 8) and in the sub-sampled dataset (Fig. 3). For example, N concentrations in oats grains averaged below 20 g/kg DM in 2008, 2009 and 2012 in both datasets. In these years, oats yields were slightly above average.

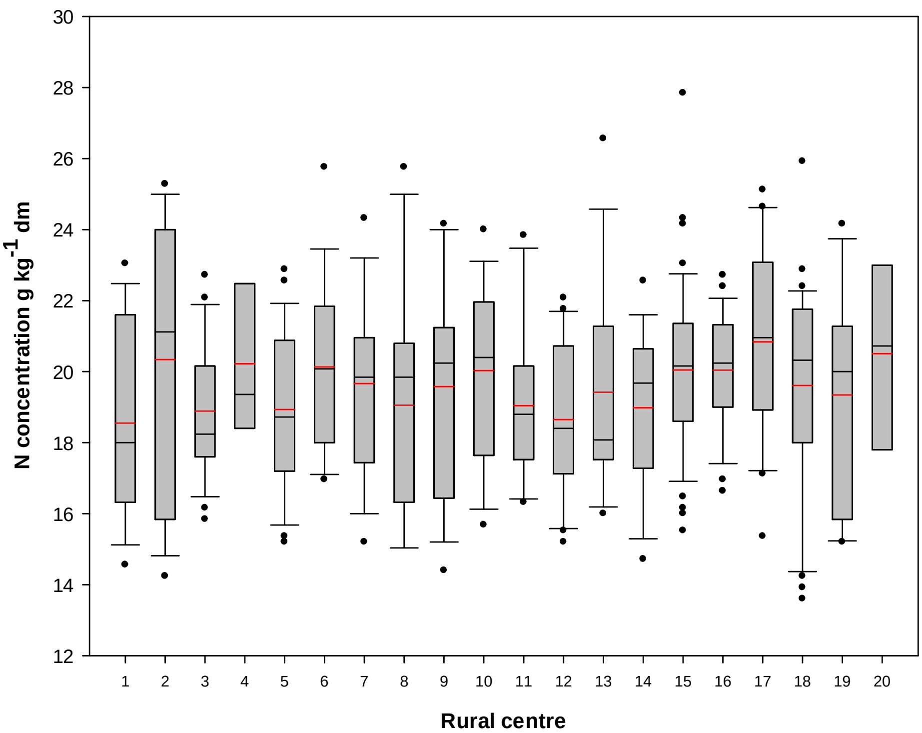

Figure 4. Nitrogen concentration in barley in different regions during 2002–2012 in the sub-sampled dataset.

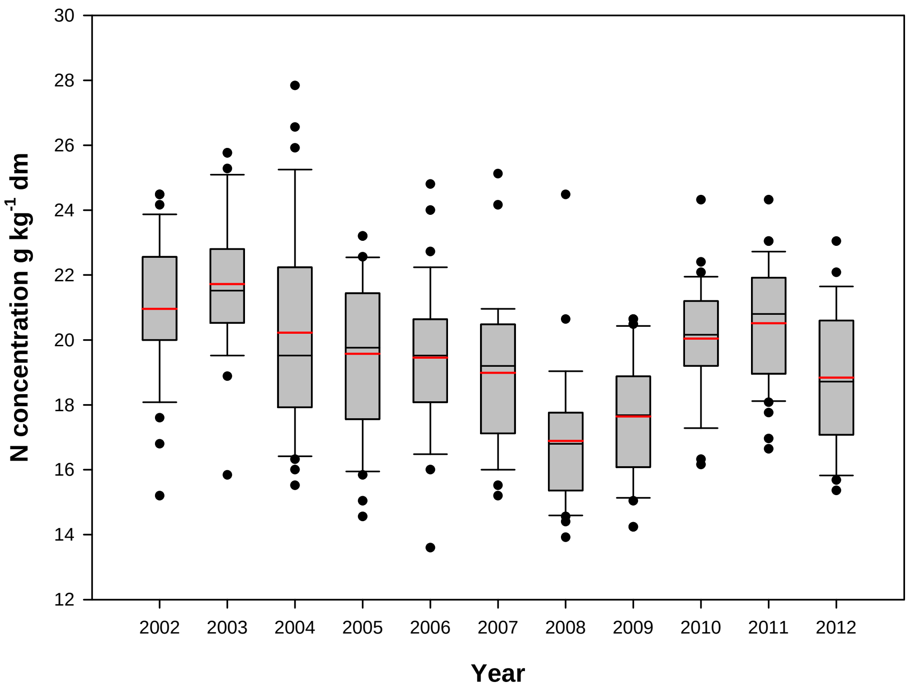

Figure 5. Nitrogen concentration in barley during 2002–2012 in the sub-sampled dataset.

Nitrogen content of barley grains averaged between rural centres from 18.6 to 20.6 g/kg DM in the whole dataset (Table 6). The growing seasons with the lowest grain N concentrations were 2008 and 2009 when both in the whole dataset and in the sub-sampled dataset (Fig. 5) N concentrations averaged below 18.0 g/ kg DM. In these years barley yields were not above average.

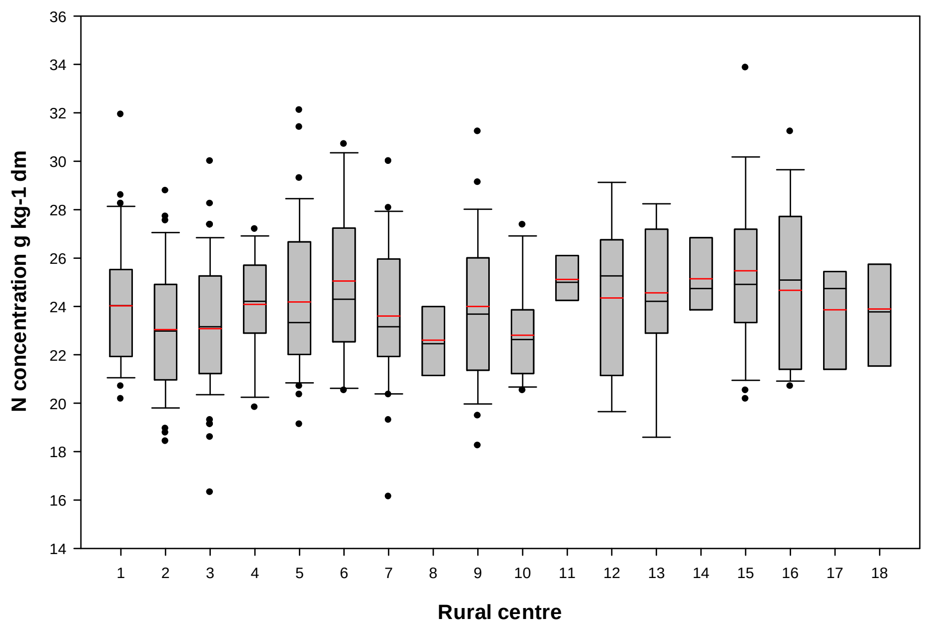

Figure 6. Nitrogen concentration in spring wheat in different regions during 2002–2012 in the sub-sampled dataset.

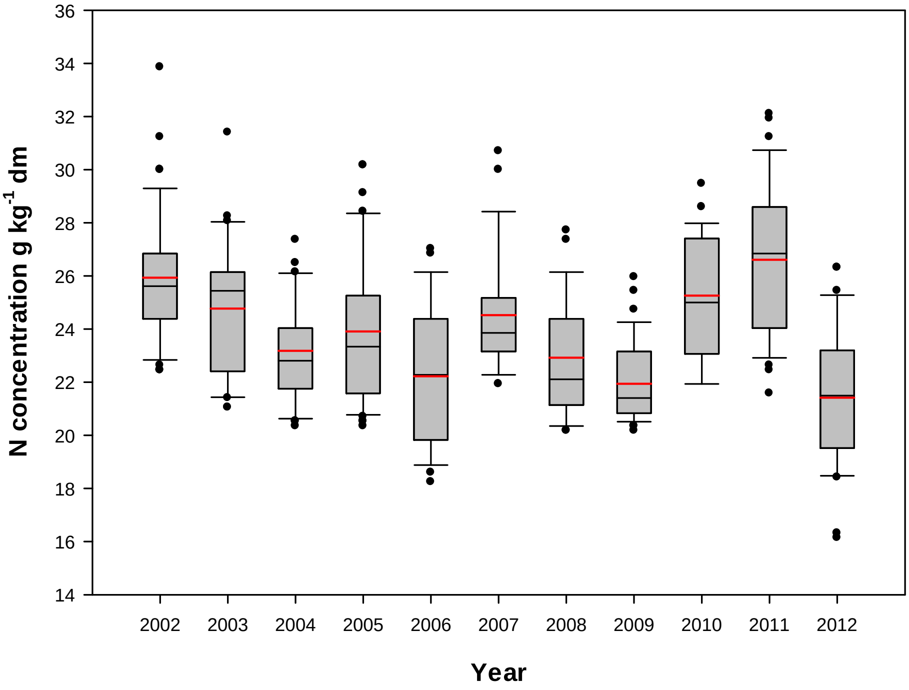

Figure 7. Nitrogen concentration in spring wheat during 2002–2012 in the sub-sampled dataset.

Nitrogen concentrations in spring wheat grains were rather similar between the rural centres (Table 6 and Fig. 6). The annual average N concentrations were lowest in 2009 and 2012, below 22 g/kg DM in both datasets. The highest N concentrations averaged close to 26 g/kg DM in 2002 and 2011.The variation in N concentrations was not related to average yields of individual years.

The measured N concentrations were generally higher in oats and spring wheat than the used constant values from the Feed Tables. Thus crop N uptakes were higher with the measured values than with the constant values for these crops. Field N balances calculated with the measured N concentrations were 0.9 kg/ha lower with oats ($p = 0.028$), and 9.2 kg/ha lower with spring wheat ($p<0.001$) but 2.5 kg/ha higher for spring barley ($p<0.001$).

Cultivar effect explained from the variation in N uptakes 39%, 33% and 28% for oats, spring wheat and barley, respectively. For oats, the year effect was clearly significant ($p<0.001$), but the region effect was not clear ($p=0.052$). Their interaction was rather weak for oats. For spring wheat both the year effect ($p<0.0001$) and the regional effect ($p=0.009$) were clear. There was also a clear interaction ($p=0.024$) showing that annual variation in N uptake of spring wheat was different between the regions. For barley, both year ($p<0.001$) and regional effect ($p<0.001$) were significant, and there was no interaction between them.

3.2 Phosphorus in cereals

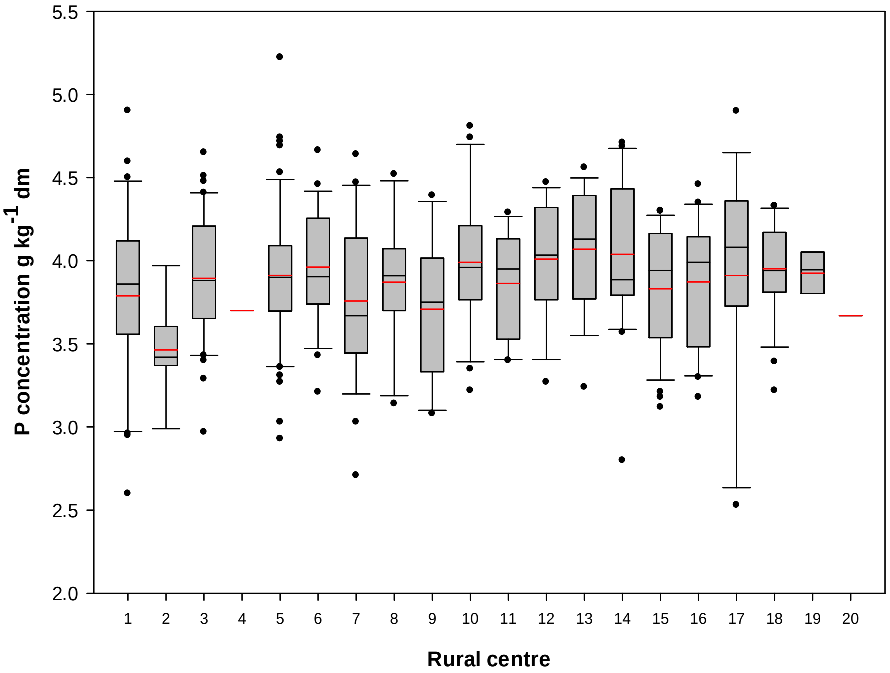

Figure 8. P concentration in oats in different regions during 2002–2012.

Oats P concentrations ranged from 3.5 to 4.0 g/kg DM between the regions (Fig. 8). The annual P concentrations ranged slightly more, from 3.5 to 4.3 g/kg DM between the years (Fig. 9).

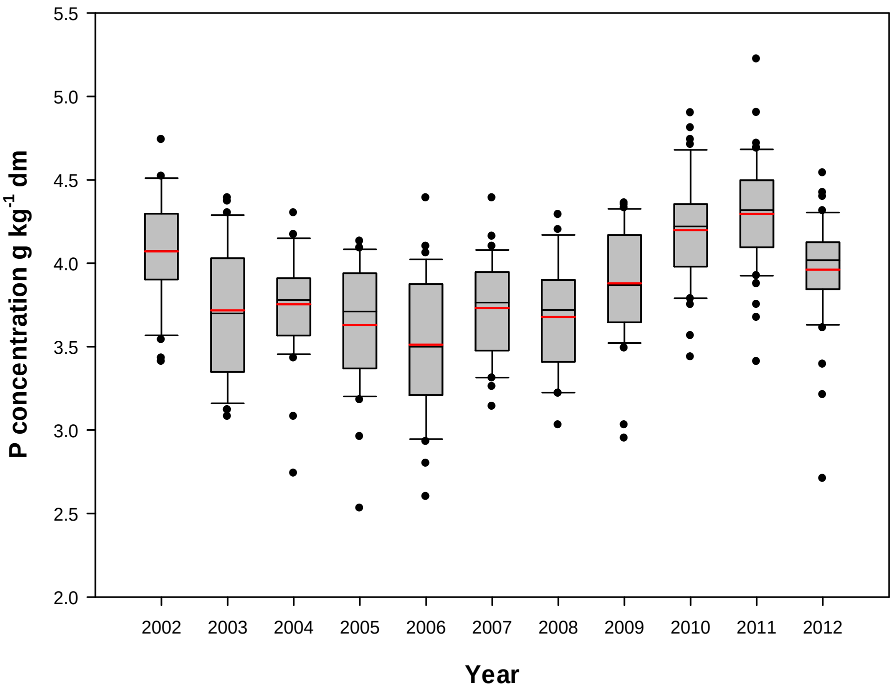

Figure 9. P concentrations in oats during 2002-2012.

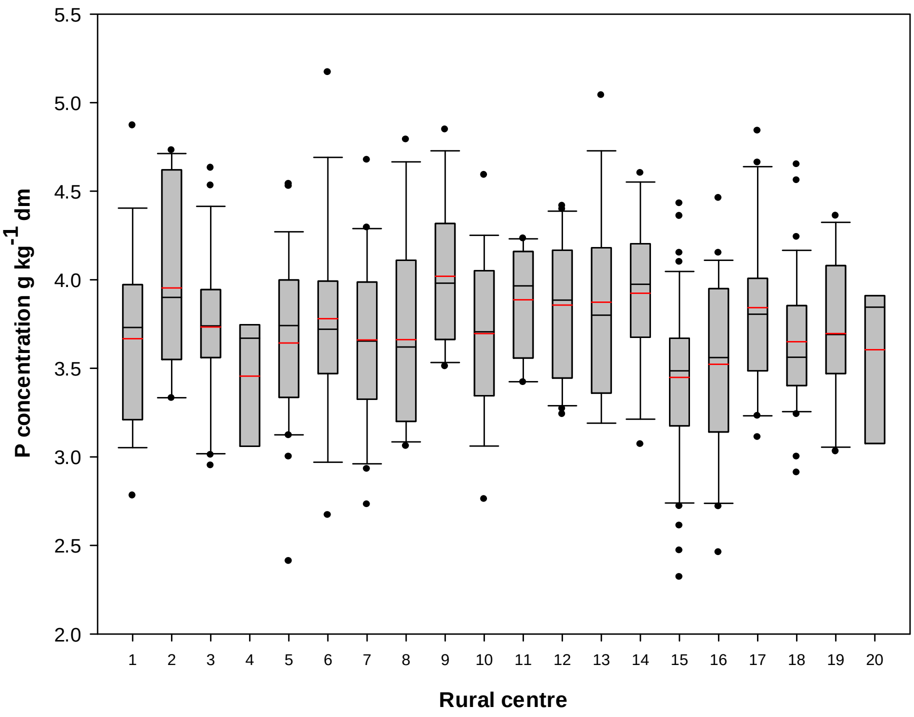

Figure 10. P concentrations in barley in different regions during 2002–2012.

Averaged barley P concentrations ranged from 3.5 to 4.0 g/kg DM between the regions (Fig. 10). The annual P concentrations ranged much more, from 3.0 to 4.2 g/kg DM between the years (Fig. 11). Especially the year 2006 resulted in low barley P concentrations.

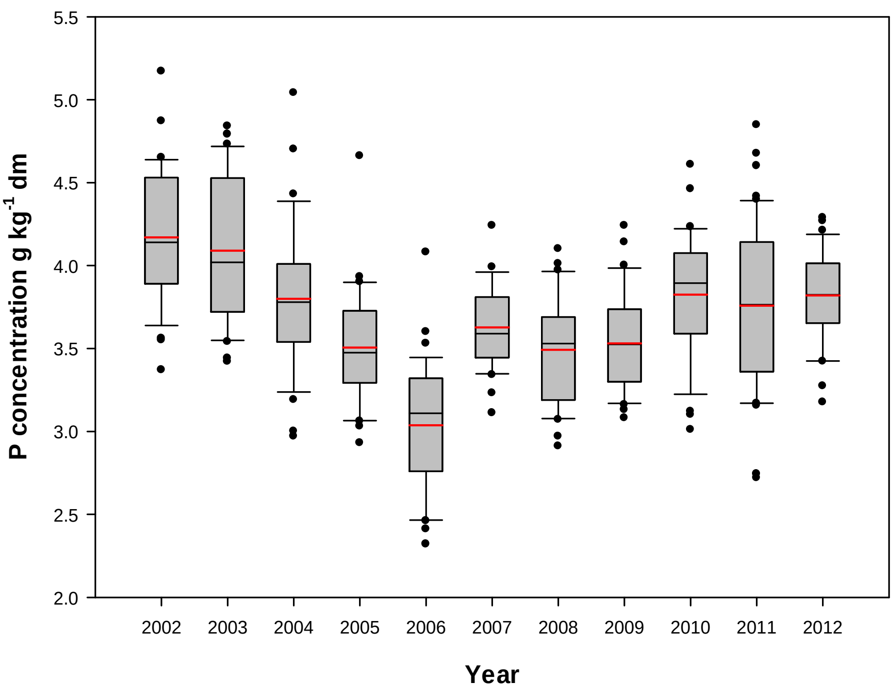

Figure 11. P concentrations in barley during 2002–2012.

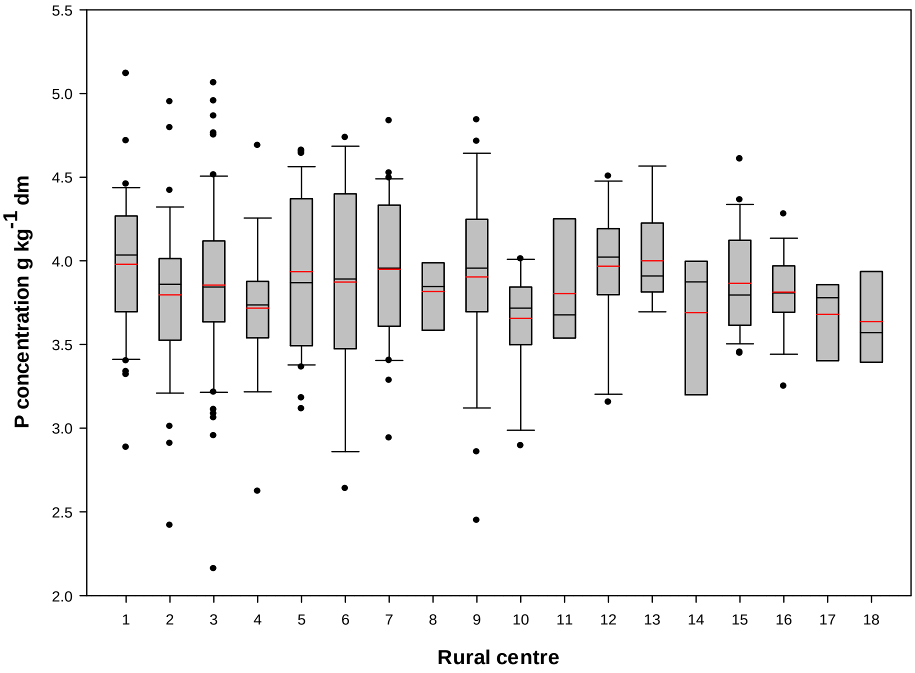

Figure 12. P concentrations in spring wheat in different regions during 2002–2012.

Averaged spring wheat P concentrations ranged from 3.6 to 4.0 g/kg DM between the regions (Fig. 12). The annual P concentrations ranged considerably, from 3.1 to 4.3 g/kg DM between the years (Fig. 13).

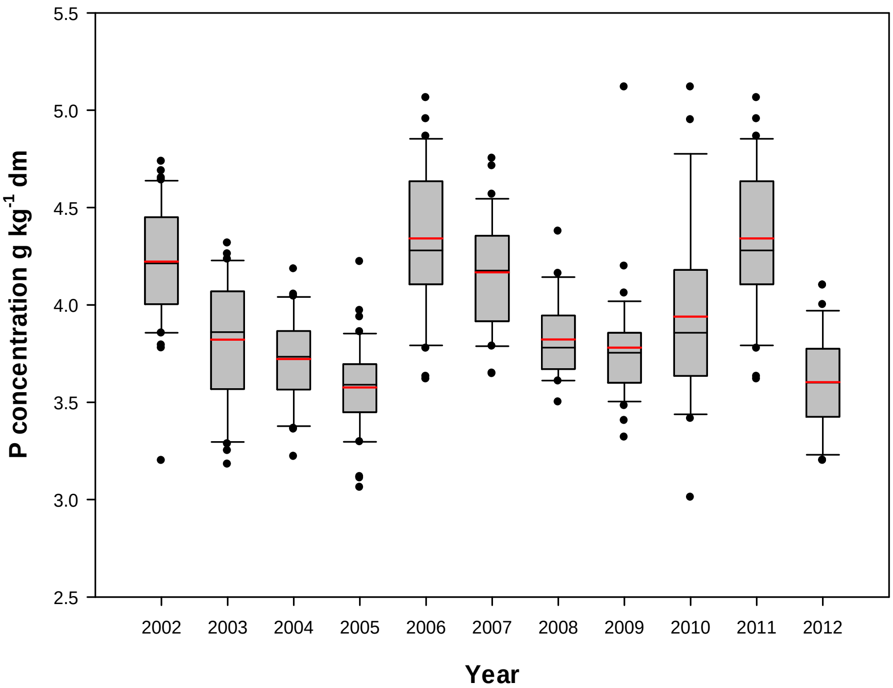

Figure 13. P concentrations in spring wheat during 2002–2012.

The measured P concentrations were generally lower than the used constant values from the Feed Tables. Thus crop P uptakes were lower with the measured values than with the constant values. Consequently, calculated P balances according to measured values were higher compared to the ones calculated with constant P concentrations with all studied cereals (oats, barley and spring wheat). The difference was 0.9 kg/ha for oats ($p<0.001$), 1.8 kg/ha for barley ($p<0.001$) and 2.6 kg/ha for spring wheat ($p<0.001$).

Cultivar effect explained from the variation in P uptakes 32%, 22% and 30% for oats, spring wheat and barley, respectively.

For oats, the year effect was clearly significant ($p<0.001$), and the region had no effect. For spring wheat both the year effect ($p<0.001$) and the regional effect ($p=0.028$) were observed. There was also a clear interaction ($p<0.001$) showing that annual variation in P uptake of spring wheat was different between the regions. For barley, both year ($p<0.001$) and regional effect ($p=0.023$) were significant. There was also slight interaction between them ($p=0.088$).

3.3 Nitrogen and phosphorus in grass silage

3.3.1 Variables correlated to nitrogen and phosphorus content of the grass silage

Due to the large number of samples (101686 grass silages, legumes not included) nearly all the variables in the data set had statistically significant effects on both the N and P concentrations of the grass silages (Table 10). It is clear that many correlations have biological basis, but management factors may modify them, e.g. nutrient losses in the form of effluent may affect both N and P concentrations. The significance of the regional variation is small compared to many other factors (Table 10), thus the regional differences may reflect differences in management factors such as extent and success in pre-wilting.

Table 10. The test of fixed effects in the analysis of variance (n=101686). Only grass silages (feedtype 1) included (for units, see Table 5).

Effect	Degrees of freedom	N as dependent variable		P as dependent variable	
		F Value	Pr > F	F Value	Pr > F
Year of the harvest	6	98	<0.001	250	<0.001
Region	19	26	<0.001	39	<0.001
Slurry application	2	28	<0.001	63	<0.001
Harvest number (1, 2 or 3 cut)	2	4	0.020	160	<0.001
Year×harvest	12	49	<0.001	120	<0.001
Dry matter	1	721	<0.001	19	<0.001
Lactic acid	1	1273	<0.001	209	<0.001
Volatile fatty acids	1	3193	<0.001	34	<0.001
Sugars	1	16685	<0.001	128	<0.001
Ammonium N	1	5062	<0.001	29	<0.001
Soluble N	1	3514	<0.001	77	<0.001
Phosphorus	1	1958	<0.001		
Nitrogen				1958	<0.001
Neutral detergent fibre (NDF)	1	10301	<0.001	77	<0.001
Indigestible NDF	1	1062	<0.001	98	<0.001
Digestibility (D-value)	1	2303	<0.001	88	<0.001
Calcium	1	278	<0.001	1069	<0.001
Potassium	1	3	0.087	6811	<0.001

3.3.2 Regional variation in silage parameters

To assess the level of variation between counties in different silage parameters, the averages for each parameter were calculated for all 21 counties. The largest variation between the regions was in the micronutrient composition (Na, Mg, Mn and Fe) whereas the variation in P and N content was relatively small (Table 11). Differences in DM concentration might reflect differences in weather conditions and the DM concentration may be correlated to most other parameters either trough fermentation quality or due to its correlation to the effluent losses.

Table 11. The amount of regional variation in different measured silage parameters within the dataset (21 counties, 82657grass silages (legumes not included), years 2002–2012; for units, see Table 5). The variables are sorted based on the amount of variability between regions.

Variable	Average over the counties	Minimum county average	Maximum county average	Max-min	(Max-min)/ average, %
Sodium	0.3	0.3	0.5	0.19	60.6
Magnesium	2.0	1.6	2.6	1.05	51.1
Manganese	63.2	50.3	79.6	29.31	46.4
Iron	195.4	133.2	221.4	88.23	45.2
Volatile fatty acids	12.9	9.6	15.0	5.43	42.1
Equivalent ratio	1.6	1.2	1.9	0.64	38.8
Calsium	4.7	4.4	6.0	1.60	33.7
Dry matter	330.2	286.7	397.4	110.72	33.5
Potassium	24.3	19.6	27.5	7.89	32.5
Sugar	62.8	56.4	76.8	20.40	32.5
Copper	6.2	5.6	7.5	1.87	30.0
Lactic acid	44.7	38.6	49.2	10.60	23.7
Zink	32.8	29.1	36.4	7.27	22.2
Ammonium N	4.4	4.1	4.8	0.79	17.9
Indigestible NDF	76.6	69.9	82.4	12.47	16.3
pH	4.2	4.1	4.5	0.46	10.9
Phosphorus	2.9	2.8	3.1	0.31	10.9
Dry matter intake index	102.7	101.0	110.7	9.63	9.4
Soluble nitrogen	42.1	39.8	43.3	3.50	8.3
Neutral detergent fibre (NDF)	538.2	502.2	546.9	44.69	8.3
Nitrogen	23.5	22.7	24.6	1.90	8.1
Fermentation grade	7.9	7.8	8.1	0.35	4.4
Digestibility (D-value)	676.0	670.5	686.8	16.28	2.4

The mean N and P concentrations in the data containing region information were 23.5 and 2.88 g/kg DM, respectively (Table 12). The variation between regions was small (Fig. 14) although statistically significant.

Table 12. Concentrations of N and P in grass silages (legumes not included) by county (county information was available during years 2002–2012).

	Nitrogen (g/kg dry matter)					Phosphorus (g/kg dry matter)				
County	n	Mean	SD[1]	Min	Max	n	Mean	SD	Min	Max
1	1080	22.9	4.39	6.2	37.9	1083	2.88	0.438	1.42	4.45
2	1713	22.7	4.31	8.3	38.3	1717	2.87	0.488	1.23	6.02
4	470	23.1	4.06	8.7	36.1	470	2.84	0.520	1.49	5.04
5	2038	23.2	4.09	8.3	39.4	2038	2.88	0.464	1.20	5.20
6	2531	22.7	4.15	5.1	36.9	2534	2.84	0.468	1.27	4.71
7	1600	23.3	4.34	8.3	38.5	1601	2.93	0.491	0.40	5.11
8	1680	23.3	4.19	9.3	42.8	1682	2.86	0.458	0.90	4.81
9	1615	23.5	3.95	10.7	42.4	1618	2.86	0.449	1.18	5.81
10	4325	23.3	3.88	8.1	37.9	4339	2.82	0.455	1.34	6.80
11	13512	23.4	4.02	5.9	40.2	13524	2.89	0.449	0.10	6.36
12	5197	23.2	3.93	6.7	39.1	5201	2.86	0.444	0.90	5.10
13	3551	23.4	4.21	9.1	40.0	3554	2.90	0.446	0.90	4.90
14	5607	23.8	3.91	6.0	40.0	5651	2.90	0.464	0.10	4.97
15	2646	23.5	4.13	7.5	39.0	2654	2.91	0.488	1.36	5.25
16	4555	24.6	4.03	10.7	38.3	4560	3.00	0.478	0.40	5.40
17	12603	24.5	4.08	7.8	41.9	12611	2.92	0.475	0.20	5.87
18	4247	23.5	4.03	6.9	37.8	4251	2.85	0.469	1.28	5.09
19	3910	24.2	3.83	5.2	38.7	3912	2.86	0.499	0.73	6.07
20	819	23.4	4.32	8.1	37.7	819	2.95	0.451	1.66	4.54
21	76	24.2	4.06	16.2	34.7	76	3.14	0.510	2.01	4.60
Mean	82517	23.5	4.20	5.1	42.8	82657	2.88	0.472	0.10	6.80

[1]SD=Standard deviation

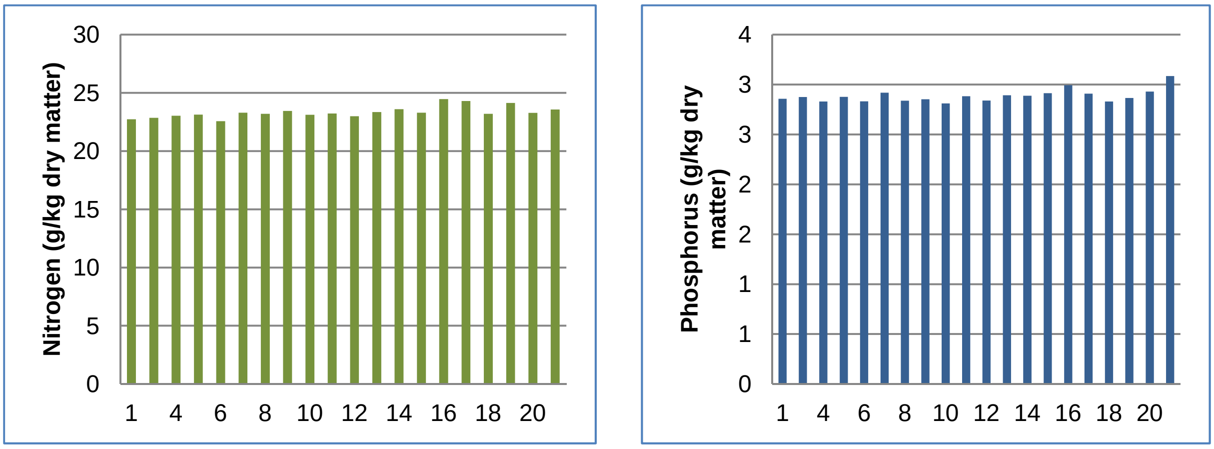

Figure 14. Regional variation in the N and P concentrations in all grass silages (n = 82517–82657).

3.3.3 Annual variation in silage parameters

The annual variation of N and P concentrations is presented in Table 13. The annual variation was greater than that between regions based on comparison of Figures 14 and 15.

Table 13. Annual variation in the concentrations (g/kg dry matter) of N and P in all grass silages.

	Nitrogen				Phosphorus		
Year	n	Mean	SD[1]		n	Mean	SD
1998	4524	23.5	4.54		4524	2.43	0.664
1999	4215	25.1	4.13		4216	2.80	0.393
2000	5205	25.0	4.40		5206	2.49	0.427
2001	5083	23.9	4.09		5083	2.97	0.471
2002	7111	24.5	4.13		7116	3.03	0.468
2003	7419	24.9	4.17		7489	3.15	0.482
2004	8379	22.8	4.25		8379	3.07	0.467
2005	7357	23.9	4.12		7359	2.97	0.462
2006	7076	24.7	4.23		7087	2.72	0.453
2007	6926	24.0	4.05		6946	2.85	0.437
2008	7514	22.3	4.16		7519	2.81	0.448
2009	7177	23.4	4.06		7184	2.75	0.412
2010	7369	23.2	3.71		7375	2.67	0.387
2011	7846	23.5	4.12		7853	2.80	0.455
2012	8343	22.0	4.04		8350	2.88	0.449

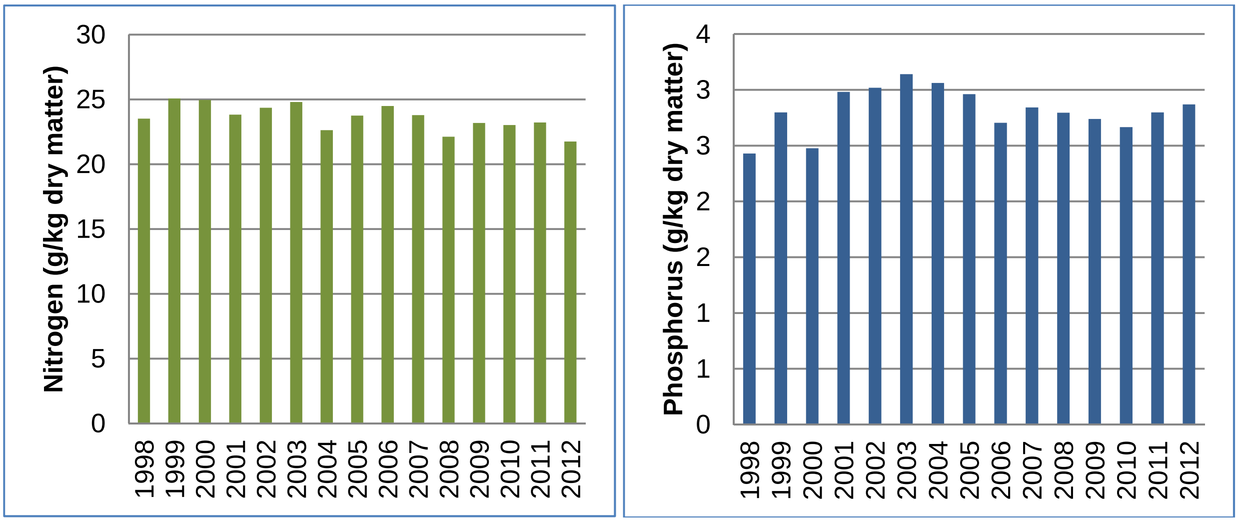

Figure 15. Annual variation in the nitrogen and P concentrations in all grass silages (n =101544–101686).

3.3.4 The effect of harvest within growing season on grass silage quality

In contrast to cereal grains, grass silages are harvested several times over the growing season and at immature and variable developmental stages. This causes much greater variation in the crop quality and chemical composition in grasses than in cereal grains. In Finland, typically two cuts of grass are taken annually, but sometimes also a third cut is taken in the autumn. In the sample set including both pure grass and leguminous silages, the proportions of samples from first, second and third cut were 56.8, 34.2 and 8.9 %, respectively. Typically the DM yield per hectare is highest in first cut and lowest in third cut, but the current data does not include information of the grass yields.

Based on experimental evidence, the primary growth and regrowth grass silages have clear differences (Huhtanen et al. 2006, Kuoppala et al. 2008). The higher fibre concentration and simultaneously higher digestibility in primary growth compared to regrowth grass was also visible in the current data set (Table 14) although the differences were rather small. The harvest within the growing season had only minor effects on the N and P concentrations of the grass silages (Fig. 16).

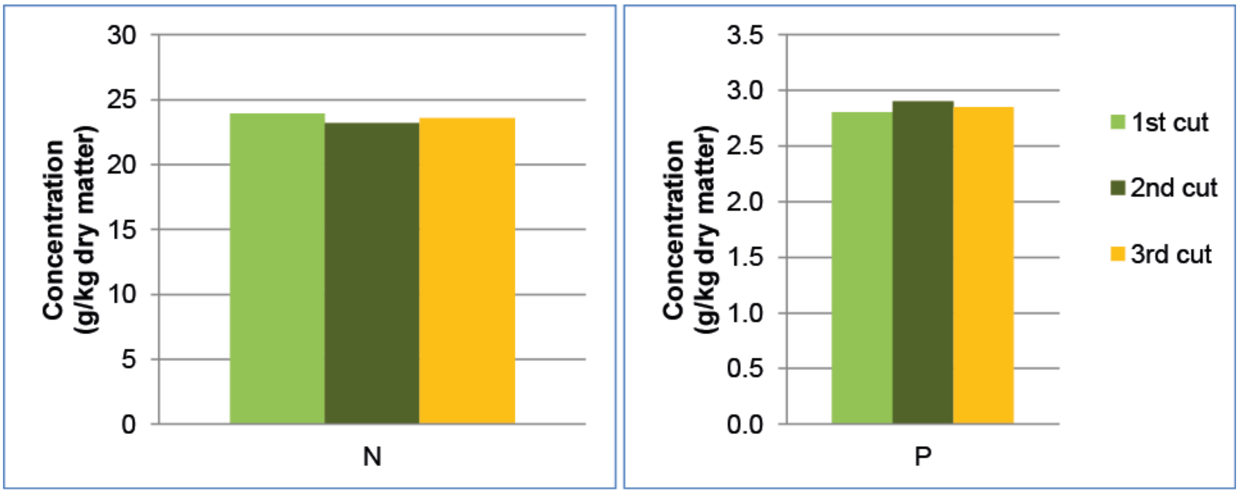

Figure 16. Nitrogen (N) and phosphorus (P) concentrations in grass silages harvested as first (n=53460), second (n=31962) or third cut (n=8682) within the growing season.

Table 14. Description of grass silages divided to subsets by harvest (first, second or third cut within the growing season, leguminous silages not included).

	Harvest 1			Harvest 2			Harvest 3		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
Dry matter (DM; g/kg)	53405	317	105	31915	326	111	8660	304	107
In DM (g/kg)									
Nitrogen (N)	53404	23.9	4.19	31914	23.2	4.13	8660	23.7	4.66
NDF	48264	552	44.9	29324	535	39.8	6528	523	47.5
Indigestible NDF	29364	74.8	26.16	18624	80.5	23.02	1965	74.3	27.00
D-value	53404	683	34.2	31913	664	31.3	8659	670	33.4
Calcium (Ca)	53455	4.20	1.26	31958	5.05	1.55	8679	4.99	1.75
Phosphorus (P)	53455	2.80	0.463	31958	2.89	0.505	8679	2.85	0.594
Potassium (K)	53454	23.3	5.74	31957	23.8	6.20	8678	23.4	6.46
Magnesium (Mg)	25431	1.88	0.546	14407	2.24	0.701	4233	2.26	1.020
Sodium (Na)	22654	0.29	0.276	13095	0.30	0.301	3227	0.30	0.239
Iron (Fe)	15549	194	151.8	9302	194	145.5	1167	213	150.8
Copper (Cu)	15549	6.36	5.330	9302	5.91	3.450	1167	5.75	2.762
Zinc (Zn)	15549	34.8	27.85	9302	31.0	21.21	1167	30.4	53.35
Mangan (Mn)	15549	59.6	44.26	9302	75.6	47.54	1167	78.2	41.39
pH	53345	4.19	0.428	31901	4.22	0.429	8655	4.22	0.450
In DM (g/kg)									
Lactic acid	53340	45.0	21.22	31899	43.5	20.67	8653	44.5	20.60
Volatile fatty acids	53345	12.9	10.62	31901	12.4	10.08	8655	12.0	9.14
Water sol. carbohydr.	53356	53.3	41.68	31902	71.2	49.83	8655	71.0	47.84
In N (g/kg)									
Ammonium N	53344	47.8	25.14	31900	40.3	23.99	8655	41.9	22.13
Soluble N	53344	437	130.4	31900	390	124.1	8655	385	120.2
Silage quality grades									
Silage DM intake index	52918	104	7.9	31727	100	7.3	8633	101	7.0
Fermentation grade	45815	7.90	1.134	26345	7.99	1.101	8151	7.73	1.081
Equivalent ratio	25431	1.75	0.559	14407	1.50	0.508	4233	1.49	0.546

3.3.5 The effect of organic farming on N and P concentrations

Organic farming relies on circulating nutrients on farm and on the N fixing ability of legumes while use of commercial mineral fertilizers is not allowed. The information about organic farming was added in the data in 2010 so that the data set covers only 3 years. The most clear difference between typical conventional and organic silages is that organic silages contain more clover. This is clearly demonstrated by the higher Ca concentration of organic samples (Table 2) and Ca concentration can even be used to estimate the proportion of clover in the forage (Rinne et al. 2010). Using that approach, the average clover proportion in the organic silage data set would be 28% in whole forage DM and in conventional silages 15%.

The conventional grass silages had somewhat higher nutrient concentrations than organic (grass and legume) silages both for N (22.8 vs. 20.5 g/kg DM) and P (2.79 vs. 2.64 g/kg DM). This may originate from the lower plant available nutrients in the soils due to restrictions in the use of mineral fertilizers under the organic farming regime, and may have some significance in animal feeding as well as in calculating nutrient balances.

Forage legumes are not dependent on the soil plant available N concentration in their N supply similarly as grasses because of the symbiosis with N assimilating rhizobia in their roots, which are able to utilize atmospheric N_2. The assimilation is temperature dependent and is thus relatively low early in the growing season. The development of the N concentration of grasses and red clover are demonstrated in Fig. 17, where the same organically farmed swards were sampled with progressing growth, and grasses and red clover where analysed separately. Although the N concentration in red clover is much higher than that of grasses (Table 15), the decline of it with progressing growth seems to be similar for both plant species. However, the amount of N captured by the harvestable mass keeps increasing in red clover, while that of grasses remains almost stable. This demonstrates the fact that grasses take up the N early in the growing season and that amount is diluted into the herbage mass with progressing growth, while the N supply to red clover is more continuous.

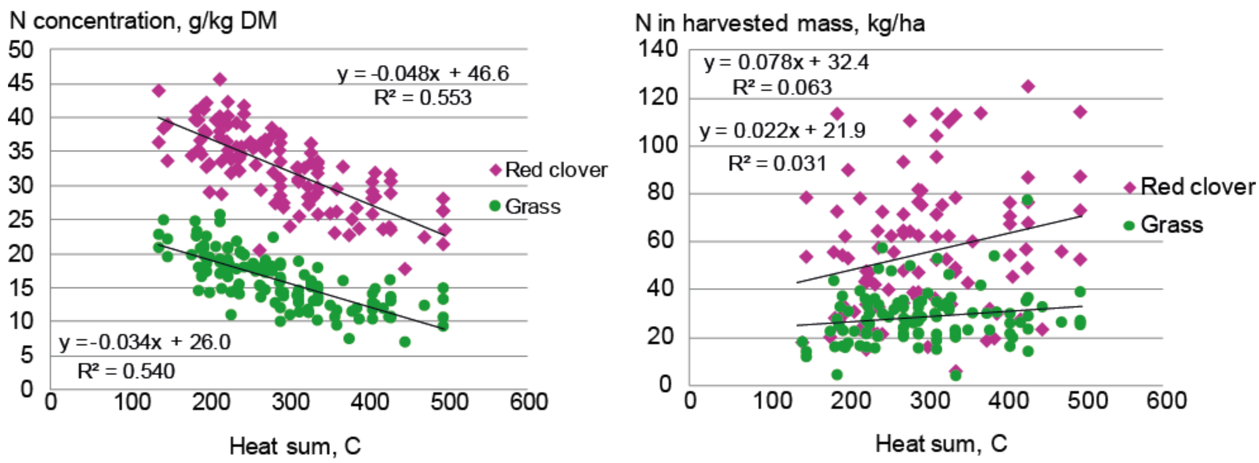

Figure 17. Concentrations of N (left) and amount of N in harvested mass (right) in red clover and grass grown as mixed organic leys on practical dairy farms and expressed in relation to accumulation of heat sum. Recalculated from data presented by Rinne et al. (2007).

Table 15. Comparison of red clover and grasses grown as a mixed sward under organic regime. The data is from practical dairy farms collected as part of ARTTURI® forage harvest time service (Rinne et al. 2007).

	First cut	Second cut	On average / Total
n	134	62	196
Clover proportion in dry matter (DM)	0.47	0.52	0.50
DM yield (kg/ha)	3753	3136	6888
N concentration (g/kg DM)			
Clover	3.3	3.2	3.2
Grasses	1.6	2.1	1.8
N harvested (kg/ha)			
In clover	58	53	110
In grass	32	31	62
Total	89	83	173

3.3.6 The correlation between silage N and P concentrations

There was a positive correlation of N and P concentrations in the grass silage data overall (R^2 = 0.355) and within harvest (first cut R^2 = 0.384, second cut R^2 = 0.323 and third cut R^2 = 0.356). All correlations were statistically significant (P<0.001).

3.3.7 The correlation between silage yield and its N and P concentrations

The silage yield data were obtained from Finnish farm statistics (Information Centre of the Ministry of Agriculture and Forestry) and the information is provided by region based on data provided by subjective estimates of the farmers. The total fresh silage yield per hectare was used in the analysis. For the annual analysis, the DM yield was calculated by multiplying the fresh matter yield with the annual average silage DM concentration derived from the ARTTURI® data.

Fig. 18 shows that on annual basis, the correlations between silage yield and its N and P concentrations were weak. Expressing the results per fresh matter or DM yield resulted in a similar conclusion. In Fig. 19, the same correlations are presented using a data set where regional yield and concentration data is used. Again, the correlations are very weak.

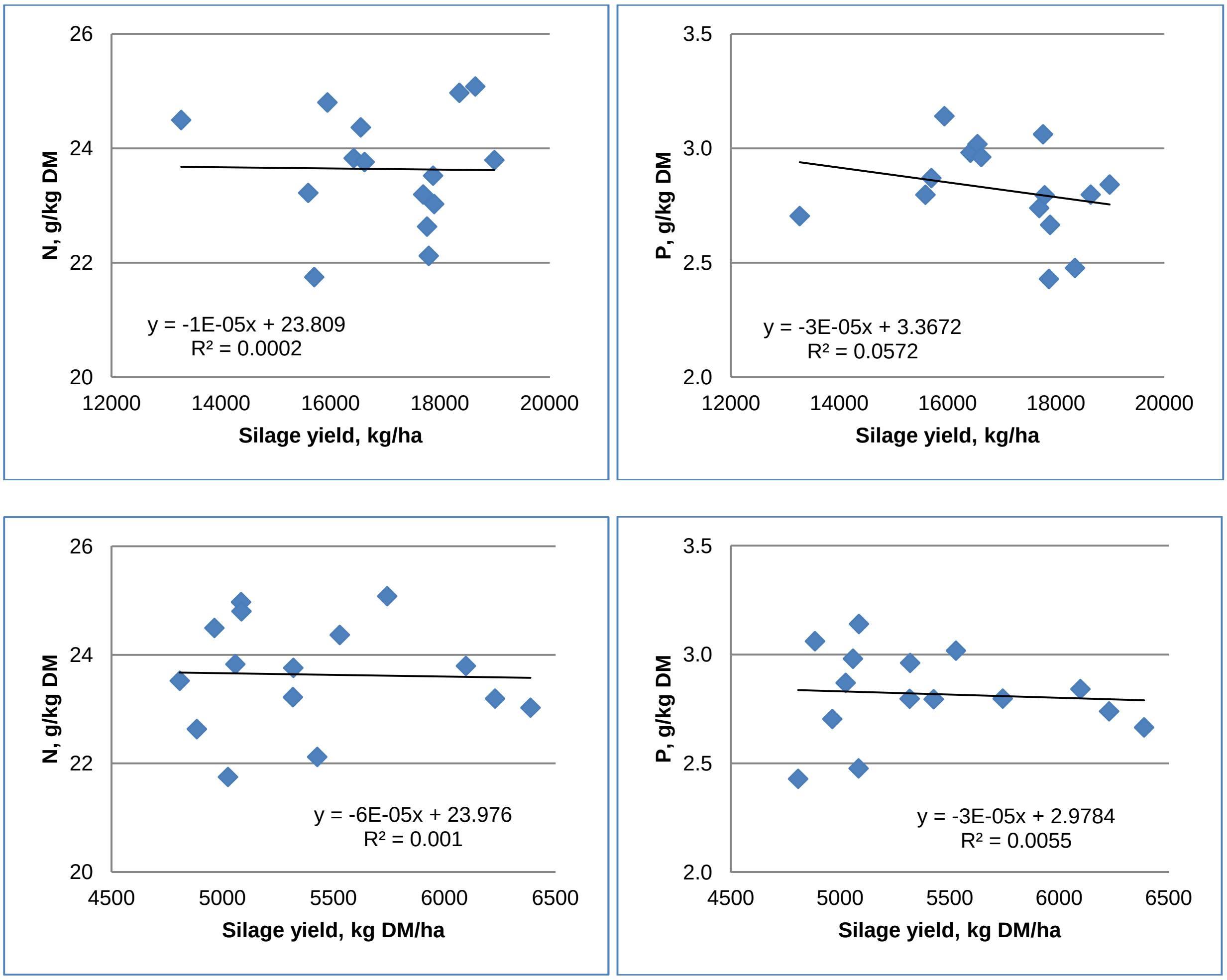

Figure 18. Correlations between silage yield (kg fresh matter in the top and kg dry matter(DM) in the bottom per hectare) and its nitrogen (N) and phosphorus (P) concentrations on annual basis (years 1998–2012).

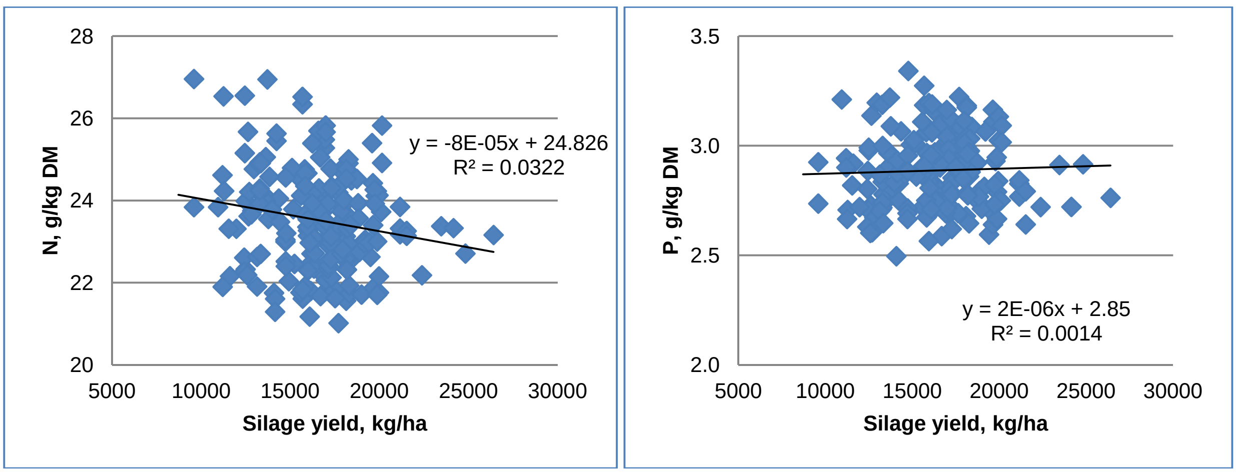

Figure 19. Correlations between silage yield (kg fresh matter/ha) and its nitrogen (N) and phosphorus (P) concentrations on regional basis over years 2002–2012 (n=197).

Increasing N fertilization increases both grass yield and N concentration (Korhonen et al. 2005), but on the other hand, good growing conditions (adequate water and radiation) promote high DM accumulation which results in dilution of N in the plant biomass. These two phenomena affect the correlation of grass yield and N concentration in opposite ways and may explain the lack of correlation in the data set.

The yield data used in the current analysis is collected in a very rough basis. Further, as farmers aim at reducing the annual variation in silage yield, management decisions such as fertilization for regrowth and number of cuts taken per year may vary from year to year in order to smooth the annual variation in the yield. These actions may also obscure the correlations between the DM yield and N and P concentrations in field data.

3.3.8 Error sources when estimating nutrient amount of the grass silage yield

The amount of nutrients removed from a certain field is a multiplication of yield (kg), DM content (g/kg) and nutrient content (g/kg DM). Measuring the grass yield on-farm is not a simple task. The yield typically varies between plots due to the differences in soil and management, e.g. in Tila-Artturi-project (www.mtt.fi/artturi) the measured plot yields varied from 600 to 14100 feed units/ha within three years in 15 farms.

The yield is measured on fresh matter basis and then multiplied by the DM concentration. DM concentration of harvested grass material may vary from less than 200 to 400 g/kg within one day in good prewilting conditions. To assess DM concentration the silage has to be sampled representatively which may be difficult. Difficulties may arise from large size of the silo or due to variability between bales for baled silage. Further, DM concentration of a sample is prone to changes during storage before analysing. Further, if the silage has been harvested unwilted, effluent losses during ensiling may reduce nutrient content during ensiling thus distorting nutrient balances.

Deviations due to inadequate yield measurements and unrepresentative sampling may cause larger deviations to nutrient balances of grass fields than N and P contents of the silage as the range in annual variation of N content was within 22.0 – 25.1 g/kg DM and in P content within 2.43 – 3.15 g/kg DM.

3.4 The effect of measured concentrations on national balances

3.4.1 Nitrogen

Cereals with the highest cultivation areas, barley, oats and spring wheat; and silage grass have the largest effect on total crop N uptake results (Table 16). For these crops the variation due to the annually measured N concentrations lead to following differences: spring wheat -1887 – 188, barley -2111–5729, oats -2236–1982 and silage 1718–8687 tonnes of N. From these crops silage grass was the only one where constant N concentration was always higher than the measured annual N concentrations. The highest differences of N uptake were observed in 2008, 2009 and 2012. In all these years, cereal yields were reasonably high and most likely N supply from soil and fertilisers did not keep protein contents in normal levels. When these differences were scaled against total agricultural area of Finland, it shows considerable overestimation of crop N uptake in these years when constant values are used, with 5.7 or 7.2 kg/ha. Thus using measured N values would decrease total crop removal which would lead to an increase of the Finnish national N balance surplus compared to the current estimation which uses constant values.

3.4.2 Phosphorus

Barley and spring wheat were the crops, whose P uptake was most overestimated with constant P concentrations (Table 17). In case of spring wheat, measured P concentrations lead to 116–741 tonnes lower crop P uptake compared to constant values. As barley is the most cultivated cereal, its effect on P uptake ranged widely, from -104 to 1802 tonnes of P. Silage grass did not affect annual P uptakes so much as N uptakes. When scaling P uptakes against agricultural area (Table 17), the highest overestimations of crop P uptakes with constant values were 0.9 to 1.4 kg/ha. Using measured P values in P balance calculations would most likely decrease the total crop P removal and thus Finnish national P balance surplus would be increased compared to the current estimation with constant values.

The estimated cost of one grain P analysis done by Evira was 45–50€. Thus analysis of for example 150 cereal grain samples would result in a cost of approximately 6750–7500 € per year.

Table 16. The annual differences between crop N uptakes with constant and measured N concentrations.

Tonnes of Nitrogen in yield											
Constant	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Spring wheat	8906	10330	11361	13921	11436	11823	12892	15152	11703	14850	14385
Winter wheat	2006	2788	3908	1061	1485	3657	2063	1509	2096	4088	2494
Winter rye	1112	1108	949	493	774	1319	925	634	1042	1190	975
Barley	30205	29487	29961	36532	34259	34473	36978	37715	23282	26416	27465
Oats	27841	23938	18722	20054	19323	21859	21705	19940	14484	19718	19196
Grass silage	54127	54969	61511	54701	40361	65806	63542	63004	63926	58152	58511
Measured											
Spring wheat	10793	11970	12325	14449	11926	13216	13349	14964	13484	17928	14669
Winter wheat	1570	2464	3167	784	1152	2808	1615	1171	1682	3491	1806
Winter rye	1130	1187	964	458	747	1264	871	559	959	1199	880
Barley	30946	31599	28873	34267	33197	32896	31249	32633	23160	26198	24989
Oats	29522	26174	18513	19735	20433	22064	19723	18529	15065	20535	17676
Grass silage	51590	53252	54303	50855	38627	61179	54855	57097	57434	53063	50100
Difference : constant – measured value											
Spring wheat	-1887	-1640	-964	-528	-490	-1393	-457	188	-1780	-3078	-285
Winter wheat	436	323	741	277	333	849	447	338	414	597	688
Winter rye	-18	-80	-15	35	28	55	54	75	83	-10	95
Barley	-741	-2112	1088	2265	1062	1577	5729	5082	122	217	2476
Oats	-1681	-2236	209	319	-1111	-205	1982	1410	-581	-817	1520
Grass silage	2537	1718	7208	3846	1734	4627	8687	5907	6493	5088	8411
Total Difference	-1355	-4027	8268	6214	1557	5510	16443	12999	4750	1999	12906
Agricultural Area, ha	2236000	2243900	2251500	2272100	2298700	2293300	2294400	2294300	2290400	2294300	2283700
Crop N uptake, kg/ha	**-0.6**	**-1.8**	**3.7**	**2.7**	**0.7**	**2.4**	**7.2**	**5.7**	**2.1**	**0.9**	**5.7**

Table 17. The annual differences between crop P uptakes with constant and measured P concentrations.

Tonnes of Phosphorus in yield											
Constant	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Spring wheat	1873	2172	2389	2927	2405	2486	2711	3186	2461	3123	3025
Barley	6131	5985	6081	7415	6954	6997	7505	7655	4726	5362	5575
Oats	5354	4603	3600	3857	3716	4204	4174	3835	2785	3792	3691
Grass silage	6132	6227	6968	6197	4572	7455	7198	7137	7242	6587	6628
Measured											
Spring wheat	1757	1845	1976	2326	1664	2154	2303	2677	2155	3017	2788
Barley	6235	5970	5635	6341	5152	6191	6393	6591	4408	4929	5186
Oats	5432	4279	3379	3499	3262	3921	3838	3719	2921	4060	3647
Grass silage	6385	6742	7353	6325	4257	7300	6925	6743	6667	6360	6628
Difference: constant – measured value											
Spring wheat	116	328	413	601	741	332	408	509	306	105	237
Barley	-104	15	446	1074	1802	806	1113	1064	317	433	389
Oats	-78	325	221	357	454	282	336	116	-136	-269	44
Grass silage	-254	-515	-384	-128	315	154	273	394	574	227	0
Total difference	-320	152	695	1904	3312	1575	2130	2082	1062	496	670
Agricultural area, ha	2236000	2243900	2251500	2272100	2298700	2293300	2294400	2294300	2290400	2294300	2283700
Crop P uptake kg/ha	**-0.1**	**0.1**	**0.3**	**0.8**	**1.4**	**0.7**	**0.9**	**0.9**	**0.5**	**0.2**	**0.3**

4 Conclusions

Measured N and P concentrations resulted in different N and P balances both in field and national level compared to constant concentrations from the Feed Tables. For cereals, crop N uptake by constant values was underestimated for spring wheat and oats but overestimated for barley. P uptake by constant values was overestimated in all studied cereals, barley, oats and spring wheat. Based on Evira data set, the Feed Table constant values should be updated. Annual variation of NP concentrations and NP uptake were statistically significant for the studied cereals. Regional variation of N concentration was statistically significant for spring wheat and barley. Regional variation of P concentration was most relevant for barley. The interaction between regions and years was significant for N and P concentrations of spring wheat. The regional variation of N and P concentrations in Finnish farm silages seems to be very small. The annual variation was however somewhat greater.

The annual uncertainty in crop N removal was from -2 to 7 kg/ha. In Finland, the national N balance surplus is now close to 50 kg/ha and thus the largest errors in surplus caused by uncertainty in annual crop N removal can be close to 15%. In Finland, the national P surplus has recently been close to 5 kg/ha and the annual uncertainty of crop P removal, -0.1–1.4 kg/ha was at highest 28% from the national P balance surplus.

When using the measured NP concentrations in nutrient balance calculations, they provide considerable differences against the constant values and also show clear annual variation. Thus it is recommended that NP concentrations of main crops would be followed and used in nutrient balance calculations. While in Finland the existing cereal quality monitoring includes N concentration measurements, it should be accompanied by smaller subset of P analysis. The existing silage grass quality sampling by Valio Ltd. collects an adequate data from NP concentrations. If these data will be public also in future, NP concentrations can be transferred from there for nutrient balance calculations rather easily. Estimating grass dry matter yields accurately enough is probably a greater challenge for calculating nutrient balances than measuring the concentrations of N and P.

Acknowledgements

We wish to express our sincere gratitude to Valio Ltd. for providing the access to their farm silage data set which was essential to be able to conduct this analysis for grasses. We also like to thank Finnish Food Safety Authority Evira for their co-operation in the use of Grain quality monitoring data and grain samples. We are thankful for the European Commission and Eurostat for financing this research activity in their grant scheme “Pilot studies on estimating the content of Nitrogen and Phosphorus in agricultural products.”

5 References

Huhtanen, P., Nousiainen, J. & Rinne, M. 2006. Recent developments in forage evaluation with special reference to practical applications. Agricultural and Food Science 15: 293–323.

Evira 2013. Finnish grain Quality in 2012. Evira publications 3/2013. Finnish Food Safety Authority.

ISO 20843:2006. Cereals and pulses. Determination of the nitrogen content and calculation of the crude protein content. Kjeldahl method.

Korhonen, M., Rinne, M. & Huhtanen, P. 2005. Effects of soil characteristics and fertilizer application on grass yield and chemical composition including mineral and trace element contents – farm scale studies in Finland during 1995–2004. NJF Seminar no 370, "Essential trace elements for plants, animals and humans", Reykjavik, Iceland, 15–17 August 2005. Available at: http://composit.dimea.se/filebank/files/20050919$091137$fil$6LJMW76K9Dx30sD0KxM6.pdf

Kumpulainen, J. & Paakki, M. 1987. Analytical quality control program used by the trace elements in foods and diets sub-network of the FAO European cooperative network on trace elements. Fresenius J. Anal. Chem. 326:684–689.

Kuoppala, K., Rinne, M., Nousiainen, J. & Huhtanen, P. 2008. The effect of cutting time of grass silage in primary growth and regrowth and the interactions between silage quality and concentrate level on milk production of dairy cows. Livestock Science 116:171-182.

MTT 2014. Feed Tables and Nutrient requirements. Available online at: www.mtt.fi/feedtables.

Nousiainen. J. 2004. Development of tools for the nutritional management of dairy cows on silage-based diets. University of Helsinki, Department of Animal Science. Publications 54. 61 p. + 5 encl. Academic dissertation. Available at: http://ethesis.helsinki.fi/julkaisut/maa/kotie/vk/nousiainen/developm.pdf

ProAgria 2013. Maidontuotannon tulosseminarai 2012. ProTuotos-karjojen rehustus vuonna 2012. https://portal.mtt.fi/portal/page/portal/ProAgria/Tapahtumat/Tulosseminaarit/Tuloksia/rehunkulutus_tuse-lehmat_2012_Huhtamaki_Tuija.pdf

Rinne, M. 2000. Influence of the timing of the harvest of primary grass growth on herbage quality and subsequent digestion and performance in the ruminant animal. University of Helsinki, Department of Animal Science. Publications 54. 42 p. + 5 encl. Academic dissertation. Available at: http://ethesis.helsinki.fi/julkaisut/maa/kotie/vk/rinne.

Rinne, M., Nykänen, A., Nyholm, L., Nousiainen, J. & Vanhatalo, A. 2007. Kehitysrytmi huomioitava apilanurmen korjuussa. Puna-apilaa nurmiin ja ruokintapöydälle. Puna-apila tehokkaasti luomumaidoksi –tutkimushankkeen päätösseminaari 17.4.2007. Toim. A. Vanhatalo & M. Topi-Hulmi Suomen Nurmiyhdistyksen julkaisuja 25: 23–33. Saatavilla Internetissä: https://portal.mtt.fi/portal/page/portal/nurmiyhdistys/Julkaisut/punaapila/rinne.pdf

Rinne, M, Nykänen, A., Kemppainen, J., Nyholm, L. & Nousiainen, J. 2010. Proportion of red clover in forage can be estimated based on calcium concentration. Proc. 1st Nordic Feed Science Conference, Uppsala, Sweden 23–24 June 2010. Swedish University of Agricultural Sciences, Dept. Animal Nutrition and Management, Report 274, pp. 5–9. Available in Internet at: https://arbetsplats.slu.se/sites/huv/Delade%20dokument/NFSC_Proceedings_100617.pdf

Salo, T., Jauhiainen, L. & Peltonen-Sainio, P. 2010. Sadon määrä ja laatu. In Aakkula, J., Manninen, S & Nurro, M. (eds.) 2010. Follow-up study on the impacts of agri-environment measures (MYTVAS 3) – Mid-term report. p. 45–50. Maa- ja metsätalousministeriön julkaisuja 1/2010. (in Finnish). http://www.mmm.fi/attachments/mmm/julkaisut/julkaisusarja/newfolder/5pe9soaAU/Mytvas_netti.pdf

Salo, T., Eskelinen, J., Jauhiainen, L., Kartio, M. 2007a. Reduced fertiliser use and changes in cereal grain weight, test weight and protein content in Finland in 1990–2005. Agricultural and Food Science 16, 4: 407–420.

Salo, T., Lemola, R. & Esala, M. 2007b. National and regional net nitrogen balances in Finland in 1990–2005. Agricultural and Food Science 16, 4: 366–375.

6 Annexes

Annex 1. Cultivation area of main cereals, grassland, and other crops including fallows with the total utilised agricultural area (UAA) of Finnish regions in 2012. Two regions are combined in this classification compared to the regional division in Fig. 1 p. 12.

	1000 ha							
Regions	Barley	Oats	Spring Wheat	Winter Wheat	Winter rye	Grassland	Others	UAA
Uusimaa	29.7	20.8	44.9	3.9	3.7	21.9	54.7	179.7
Varsinais-Suomi	76.5	36.1	64.8	8.0	4.1	25.2	74.3	288.9
Satakunta	30.9	32.6	15.2	1.2	1.4	18.1	43.2	142.6
Häme	44.1	33.3	20.7	3.6	3.0	28.4	53.2	186.3
Pirkanmaa	25.1	33.3	10.9	2.5	1.8	36.7	50.7	161.0
Kymenlaakso	23.5	23.7	16.7	1.3	1.0	25.9	46.6	138.6
Etelä-Savo and South Karelia	7.8	8.8	1.3	0.1	0.4	29.4	24.2	72.0
Pohjois-Savo	23.8	9.6	1.5	0.2	0.5	69.3	41.5	146.3
North Karelia	7.4	8.4	2.0	0.1	0.6	37.1	29.1	84.6
Central Finland	11.9	14.2	1.7	0.1	0.4	34.3	33.0	95.6
South Ostrobothnia	60.0	43.5	11.0	0.8	1.5	55.2	74.7	246.8
Österbotten and Central Ostrobothnia	60.0	20.1	10.4	0.6	1.4	54.6	46.7	193.7
North Ostrobothnia	46.6	26.7	2.0	0.4	0.5	82.3	64.5	223.0
Kainuu	2.6	1.3	0.1	0.0	0.0	19.1	8.4	31.5
Lapland	0.7	0.2	0.0	0.0	0.0	35.3	7.6	43.7
Åland	0.8	1.3	1.1	0.5	0.2	6.0	3.6	13.4

Annex 2. Description of ARTTURI® Forage analysis

ARTTURI® - rehuanalyysi

Lisää tietoja näytteen otosta, lähettämisestä ja tulosten tulkinnasta:

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Hinnasto 28.4.2014 alkaen

Tutkimus	Tutkittavat näytteet	Tutkimuksen sisältö	Menetelmä	hinta € alv 0 %	hinta € alv 24%
Säilörehuanalyysi	Nurmi -, vihanta-kokovilja- ja maissi-säilörehut	kuiva-aine raakavalkuainen, NDF, D-arvo, sokeri, iNDF, tuhka säilönnällinen laatu (pH, ammoniakkityppi, maitohappo, haihtuvat rasvahapot, liukoinen typpi, laatuarvosana) rehuarvot	lämpökaappi NIR titraus laskenta	16,80	20,83
Säilörehuanalyysi	Apila- ja sinimailas-säilörehut	kuiva-aine raakavalkuainen, NDF, D-arvo, sokeri, iNDF, tuhka säilönnällinen laatu (pH, ammoniakkityppi, maitohappo, haihtuvat rasvahapot, liukoinen typpi, laatuarvosana) rehuarvot Ca, P, K Arvio nurmipalkokasvipitoisuudesta	lämpökaappi NIR titraus laskenta XRF laskenta	17,80	22,07
Säilöheinäanalyysi	Säilötyt, paalatut heinät, kuivat paali-rehut	kuiva-aine raakavalkuainen, NDF, D-arvo, sokeri, iNDF, tuhka rehuarvot	lämpökaappi NIR laskenta	11,00	13,64
Nurmen korjuuaika, säilörehun raaka-aine, laidunruoho	Nurmi-, kokovilja- ja maissirehujen korjuuaika- ja raaka-aine-näytteet	kuiva-aine raakavalkuainen, NDF, D-arvo, sokeri, iNDF, tuhka rehuarvot	lämpökaappi NIR laskenta	11,00	13,64
Nurmen korjuuaika, säilörehun raaka-aine, laidunruoho	Apila- ja sinimailas-rehujen korjuuaika- ja raaka-aine-näytteet	kuiva-aine raakavalkuainen, NDF, D-arvo, sokeri, iNDF, tuhka rehuarvot Ca, P, K Arvio nurmipalkokasvipitoisuudesta	lämpökaappi NIR laskenta XRF laskenta	12,00	14,88
Heinäanalyysi	Kuiva heinä	raakavalkuainen, NDF, D-arvo, sokeri iNDF, tuhka rehuarvot	NIR laskenta	8,20	10,17
Vilja-analyysi	Ohra (jyvät), kaura (jyvät), seosvilja (ohra+kaura, jyvät)	kuiva-aine, raakavalkuainen hehtolitrapaino rehuarvot	NIR punnitus laskenta	8,20	10,17
Säilövilja-analyysi	Hapolla säilötyt jyvät, murske- ja litistesäilötty vilja	kuiva-aine raakavalkuainen, NDF rehuarvot	lämpökaappi NIR laskenta	11,00	13,64
Edellisten lisäksi valittavissa					
Suppea kivennäisanalyysi	Kaikki yllämainitut	Ca, P, K	XRF	7,90	9,80
Kivennäis- ja hivenaine-analyysi	Kaikki yllämainitut	Ca, P, K, Mg, Na, Mn, Fe, Cu, Zn	ICP	25,25	31,31
Näytteen esikäsittely, veloitetaan, mikäli näytteestä on tilattu vain kivennäisanalyysejä		näytteen kuivaaminen ja jauhaminen		2,50	3,10

NIR – lähi-infrapunamenetelmä, kalibroinneissa käytetään kemiallisia referenssimenetelmiä. NIR-kalibroinnit eivät sovellu muille kuin edellä olevassa luettelossa mainituille rehuille. Seuraavalla sivulla on muille rehuille tarkoitetut analyysit, jotka tehdään alihankintana Eurofins Viljavuuspalvelu Oy:ssä.

XRF – röntgenfluoresenssiin perustuva menetelmä, kalibroinnissa käytetään ICP-menetelmällä saatuja tuloksia

ICP – induktiivisesti kytketty plasma – massaspektrometria (näytteet analysoidaan alihankintana Seilab Oy:ssä)

Näytteiden toimitus laboratorioon:

Analyysiin tarvitaan säilö-, nurmi- ja heinärehuja noin 2 litraa näytettä (ARTTURI-pussi täyteen) ja viljaa noin 1 litra. Rehunäyte toimitetaan rehulaboratorioon mieluiten alkuviikosta. Näytepusseja saatekortteineen on saatavissa maitoautoista ja rehulaboratoriosta. Rehu voidaan pakata myös muuhun soveltuvaan muovipussiin. Saatekortin voi tulostaa Artturin nettisivuilta. Saatekortti tulee täyttää huolellisesti. Maidonlähettäjän numero on tärkeä, koska sitä käytetään analyysilaboratoriossa perustietojen hakemiseen ja tallentamiseen. Analyysiä varten on myös tärkeää tietää rehutyyppi eli onko kyseessä säilörehu, heinä vai nurmi.

Rehulaboratorion yhteystiedot:

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MTT TEKEE TIETEESTÄ ELINVOIMAA

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