LIFE04 ENV/FI/000299

Report on the results of the survey of nutrient load from different equine areas

Håkan JANSSON, Aaro NÄRVÄNEN, Paula PERÄLÄ and Helena JANSSON

MTT Agrifood Research, Finland

Abstract

Equine areas with different use were tested for their nutrient load status. In the first face surface soil samples (0 – 2 cm) were taken from areas of different equine use. In the second face surface soil samples taken from 0 –2 cm were compared to the sampling depth 0 – 20 cm usually used in field sampling. In the third face sampling was carried out to the depth of one meter. In the fourth face artificial rain simulation studies were carried out using samples from surface soils.

The surface soil samples (0 – 2 cm) showed that the highest phosphorus contents could be found in areas where horses most frequently defecate or are given hay or silage. The lowest contents were found in areas with a low frequency or short history of equine use. In steep areas this method probably underestimate the load. Also in paddocks, where there is a throughflow of water the topsoil phosphorus content may underestimate the phosphorus load.

The extractable phosphorus contents in surface soil samples (0 – 2 cm) in comparison to deeper soil samples (0 – 20 cm) were on the average three times higher in the surface soil samples.

The deep sampling showed that the highest extractable soil phosphorus in equine areas would be find in the surface soil. The highest total nitrogen was also found in the topsoil layer as well as the highest nitrate contents. The highest soil ammonium contents were found in the 40 – 60 cm layer.

From the artificial rain treatment the surface flow water was collected. When comparing the extractable phosphorus content from the paddock surface soil with the dissolved reactive phosphorus contents from the rain simulation it could be seen that the correlation coefficient was high (r2 = 0,85). This means that in equine areas the low cost analyses of extractable phosphorus contents of the topsoil is a good indicator in predicting phosphorus load.

In the rain simulation test the runoff waters from two run-in stable areas were 6,81 and 2,58 mg/l dissolved reactive phosphorus (DRP) respectively. Typically for a critical phosphorus equine source area the DRP contents are high compared to the total phosphorus (8,85 and 4,00 mg/l P respectively) contents. Thus in the equine area waters the phosphorus contents can be as high as in untreated domestic wastewater. Typically the nitrogen contents (4,55 and 4,59 mg N/l respectively) are of the level found in runoff water from field areas.

As the number of horses increases with more than 1% every year the phosphorus load from the Finnish equine industry will increase at the same rate if nothing is done to reduce the load per horse.

Index words: horse, critical source areas, paddocks, yards

Introduction

Horses are social animals and prefer to live in close contact with conspecifics. Horses are adapted to moving over long distances every day and to spend most of their time on food consumption. These natural behaviour patterns need to be consireded in order to optimise welfare in stabling systems for domestic horses. Altough the ways in which horses are used differ considerably, all horses have the same basic needs regarding locomotion, social contact and comfort behaviour. Sondergaard et al. recommend that horses spend at least 3-4 hours per day in paddock, but if the horse is exercised, the time in paddock can be reduced. The daily time in paddocks should , however, never be less than one hour, since there are other aspects of being released in paddocks which cannot be met by forced exercise, i.e. the freedom of movement and access to physical contact with other horses (Sondergaard et.al.,2004).

In an English survey concerning abnormal behaviour, McGreevy et al. (1995) found that horses are less likely to develop abnormal behaviour the less time they spend in the stable.

Schatzmann (1998) found that horses do not prefer to stay outside if the entire outdoor area is muddy. Thus, it is important to make sure that this is not the case.

Equine industry and history

In Finland we now have about 70 000 horses. In the official registers the number of horses in 2005 was 61 000 (Suomen Hippos, 2005). The number of horses has been increasing during the last years for more than 1000 horses per year. The number of horses has earlier been much higher. In 1950 the number of horses in Finland was as high as 408 800. In those days horses were used in agricultural and forestry work and were not kept year-round in paddocks.

Pikkarainen (2005) made a survey study from 70 stables in South Western Finland (Häme). At these stables were kept 828 horses. The horses were kept in paddocks for 7,2 hours on the average. On the average the size of these horse paddocks were $1100m^2$. From the same report it can be seen that on the average in the same paddock there were kept 1.9 horses. When these figures are applied to whole Finland it can be estimated that we have about 37 000 horse paddocks. As our increase in horse number is about 1000 these horses will need additional 500 paddocks.

Mud

Mud problem has been defined as a serious problem for especially small acreage horse landholders. It has been noted that: most people realise that rainwater plus exposed soils equals mud. What many people do not realise, however, is that this combination can also lead to water pollution (Blickle et al., 2003). When soil and manure has mixed with water to make mud, it can easily be carried into nearby streams or lakes. Sediment can smother trout and salmon eggs, destroy habitat for insects (a food source for fish) and cover prime spawning areas (Blickle et al., 2003). In high-traffic areas (such as paddocks or stall entryways), horse hooves loosen topsoil and compact the soil below. As the soil becomes more and more compacted with the constant pounding of heavy horse hooves, rainwater is not able to percolate through the soil and instead pools on top, mixing with the loose topsoil to create mud (Blickle et al., 2003). Also in Finland the problem with high traffic domestic animal areas has been noted. In a trial with different stage of cattle trampling Pietola et., al (2003) measured an infiltration rate decrease from 7 cm h^1 to 1 cm h^1 in a trampled area. On a sandy soil the same figure was a decrease from 15 cm h^1 to 3 cm h^1.

In the USA the problems on environment problems on horse farms are well known and horse farms are advised in the best management practices in horse keeping on farm level (Stephenson et al., 2003). The best manage practices include mud management, the use of buffer strips, and installing rain gutters.

Phosphorus

Phosphorus is the nutrient, limiting algae growth in most of the lakes and rivers in Finland and therefore a reduction of phosphorus load should be carried out if algae blooms are a problem. In the Baltic Sea a reduction of both phosphorus and nitrogen has earlier been considered to be needed to reduce algae growth but recently also research papers where phosphorus has been pointed out to initially be the limiting nutrient has been published. It has been calculated that a reduction of nitrogen by 50% to the Baltic Sea would be four times as expensive as a similar reduction of phosphorus and today countries in the Baltic Sea catchment area report already some success in reducing loads of phosphorus, but little for nitrogen. Thus the expensive measures against nitrogen load should be used in reducing phosphorus, instead of nitrogen (see Jansson and Närvänen, 2005).

When studying the ditch sediment in different agricultural and forest areas Jansson et al. (2000) noticed high phosphorus content in runoff waters from horse stable areas. These high water phosphorus contents were reflected as high extractable contents of phosphorus in ditch sediments where this water flowed. In pasture areas it has been shown that phosphorus in the overland flow is in dissolved reactive form (DRP). It follows that remedial strategies that rely on physically trapping phosphorus entrained in overland flow (i. e. buffer strips and riparian zones) are unlikely to be effective (Nash 2002).

In a study comparing two methods Dougherty et al. (2004) of measuring runoff P concentrations from large plots (1250 m^2) with low intensity simulated rainfall (8 mm/hr) and small plots (1.5 m^2) with high intensity simulated rainfall (80 mm/hr). Measurements were made on two occasions and over a range of soil P concentrations. There was a highly significant effect of the method of measuring runoff P concentration. Runoff P concentrations from the small plots were approximately half of those derived from large plots.

In a study on nutrient loads from pastures Jansson and Tuhkanen (2003) compared runoff concentrations in artificial rain from different critical source areas of phosphorus load on pastures and other field areas to soil extractable contents. The extractable phosphorus in uppermost layer (0-2 cm) proved to be a good indicator of the critical source area. The paddocks in Sweden are also reported as a source of phosphorus. In late autumns and early springs the vegetation is to a large extent destroyed as the horses are kept there under wet conditions for many hours every day. The grass cover will be worn away (Steineck et al. 2000).

Hollinger and Cornish (2000) monitored farms with various land uses. In their study the 4 hectare of semi-improved pasture grazed by cattle and horses (hobby farm) they measured very low phosphorus and“normal” nitrogen content in the flow water. A 44 ha of intensive, irrigated dairy pasture had 6,4 kg/ha phosphorus load and the phosphorus load per hectare from the hobby farm was only 0,8 kg/ha.

In a study in the catchment area to the Bridgeport Reservoir, California, USA the conclusions were that it was most likely that excreta and urine from cattle and horses grazing in the valley increased the total phosphorus, phosphate phosphorus and faecal coliform bacteria. Phosphate phosphorus was almost quadrupled (Horne et., al, 2003).

Jansson and Närvänen (2005) tested a promising chemical treatment using ferric sulphate to water from a horse stable area. When using an amount of 0,06 mg/l of ferric sulphate solution (11.5 w/w iron) they measured a reduction of 95 % in dissolved reactive phosphorus in the settled solution.

Ma et., al (2001) identified two zones in a small catchment area in Morrow Lake Watershed, Michigan, USA with high phosphorus sediment. Of these one was due to a feedlot for 30 horses.

Algal blooms

In Finland in 1995 Pietiläinen reported that phosphorus is the major nutrient limiting algae growth in Finnish lakes. Also globally phosphorus has been reported as limiting factor in the majority of cases (Ongley, 1996)

In the past a reduction of both phosphorus and nitrogen was considered to be needed to reduce algae growth in the Baltic Sea. However during last years increasingly the opinion has been presented that the expensive measures against nitrogen output (for example in agriculture), imposed by authorities in order to diminish eutrophication in the coastal waters, are doomed to failure as evidently phosphorus is initially the limiting nutrient (e.g. Söderström, 1996).

Those species of blue-green algae that usually form the blooming in the Baltic Sea, the toxic Nodularia and the non-toxic Aphanizomenon, satisfy their nitrogen need by fixing dissolved atmospheric nitrogen from water. The growth of these species is thus dependent on the availability of phosphorus in the water. The concentration of plant-available phosphorus is thus a crucial factor that determines the extent of blue-green algae blooming in summer (SYKE, 2004).

The authorities in European countries like Finland, Sweden, Russia, Estonia, Latvia, Lithuania, Poland, Belarus, Denmark and Germany in which large areas situate in the badly polluted Baltic Sea catchment area know quite well the need for a reduction in agricultural phosphorus load. Still they do not necessarily know that within the agricultural sector you find critically high phosphorus source areas like equine areas (Jansson et., al, 2000).

Material and methods

The equine trial reported here consists of a trial with four faces. In the first face we collected soil surface samples from thirty sites in Ypäjä in SW Finland. In the second face we compared surface and topsoil samples taken from equine areas in Jokioinen in SW Finland. In the third face we collected soil samples to a dept of one meter now also from sites in Ypäjä and Jokioinen and in the fourth face we collected soil samples for artificial rain treatment from these both areas. The first face was carried out as a project partly financed by the Ministry of Environment and executed at the MTT. A short report from this face has been published in Finnish 2002 (Jansson et al.). The second and third face was partly financed by Häme Environmenal Centre, coordinated by Agropolis Oy and executed at MTT and the report is published in Finnish on the websites of this project (http://www.equinelife.fi/files/ymp_juoksutarhat.pdf). The fourth face has been fully carried out as a part of this project. For comparison and background information also these other faces are reported here.

Soil sampling

In the first face the soil sampling was carried out in Ypäjä. Thirty soil samples were taken from the surface layer (0-2 cm).

In the second face soil sampling from 17 sites of equine critical source areas were carried out with a sampling depth of one meter. These samples were taken at the Ypäjä Equine College and Equine Research of MTT Agrifood Research. Sampling was also carried out at a stable with a well-documented nutrient load history (starting in 1994) in the catchment area of the lake Rehtijärvi as well as at a newly established stable in Kuuma. To get information between the upper soil layers the surface (0-2 cm) soil layer in an equine site was compared to the normal (0-20 cm) field sampling depth at twelve sites. In the fourth face 27 samples were taken for a rain simulation study from paddocks of a largely varying use. As rain simulation samples surface (0 – 5 cm) samples were used. The soil samples were cut to fit into forms with a diameter of 24 cm. After the rain simulation treatment of these soils the top layer (0 – 2 cm) was used for soil testing.

Soil analyses

For assessment of the phosphorus load in the studied areas, soil AAAc-extraction method was used (0.5 M ammonium acetate, 0.5 M acetic acid, pH 4.65). In addition to soil extractable phosphorus also other soil properties were determined as soil pH, electrical conductivity and extractable magnesium, potassium, calcium and sodium. The phosphorus contents in the topsoils of paddocks were classified using the field soil classes in use in the Finnish Agri-Environmental Program and compared to samples from areas, where the phosphorus load has been measured. The soil texture was determined by hand as is done in Finland in the routine soil testing. The extractable soil nitrate and ammonium nitrogen were determined using the same method as described by Esala (1992).

Rain simulation and water analyses

The above 27 soil samples were kept under artificial rain with an intensity of 21 mm/h. The raindrops were formed at a height of 104 cm from the samples. For water analysis the surface flow water was collected into bottles. Three bottles of runoff water was collected from every treated soil sample. In the first bottle the first runoff water period was collected and in the second and in the third bottle we collected the runoff from the following runoff periods. The water samples were analysed for dissolved reactive and total phosphorus as described by Uusi-Kämppä and Yläranta (1996).

Results and discussion

Surface soils

The results in the first face of this project show that the highest extractable soil contents were found in equine areas where the horses were regularly fed with hay or in areas where the horses defecate. The run-in stable areas were also high in phosphorus. When interpreting these results using the seven interpreting classes in use for field soils it can be seen that almost 50 % of the samples fell into the highest class, and according to this classification alarmingly high. The lowest phosphorus contents in this study were found in areas of minor equine use. However also in some areas with quite high equine use the phosphorus content in the sampled top soil layer (0 – 2 cm) was not especially high according to the classification. In these cases the explanation seemed to be that most of these sites were erosion affected and the sampled layer was unaffected soil from layers exposed by erosion (see Appendix 1).

In the surface samples (0-2 cm) from different paddock areas, with a regularly replaced surface layer, were in total 1.8 ha. Despite the fact that the surfaces have been replaced frequently, in most cases every year, the topsoil showed high or extremely high content of soluble phosphorus. Paddock areas used by horses in run-in stables (cold loose holding of horses during winter months) were also all extremely high in AAAc-extractable phosphorus. In ungrassed areas of larger paddocks the contents of extractable phosphorus varied largely. In these areas the environmentally most difficult problems i.e. steep slopes susceptible to erosion and areas, where surface waters flowed through the critical source area were found. Often a use of a tractor for cleaning was not possible, as the critical source areas were stony or wet. The trees needed to reduce the erosion were often gnawed by the horses and dying.

Compared to the paddocks the other equine areas studied were relatively low in phosphorus (Appendix 1). The extractable phosphorus from the trotting course was however of the level of Finnish fields. The field phosphorus level in Finland, however is high enough to be a big contributor to the dissolved reactive phosphorus (DRP) load. In Finland a typical field water DRP content is 0.13 mg/l and amount 0.4 kg/ha per year. DRP is directly available for algae growth and therefore the reductions in DRP should be an essential part of the phosphorus to be removed. A removal of only particle phosphorus from our field waters can end up in an increasing secchi depth and more light and higher amount of blue-green algae in our lakes and rivers (Jansson and Närvänen, 2005).

Surface soils compared to topsoils

In the second face the surface layer (0-2 cm) was compared to the normal studied topsoil layer (0-20 cm). As can be seen in appendices 1a and 1b that soil pH in the surface layer (0-2 cm) does not differ from the topsoil (0-20 cm) pH. Electric conductivity in the surface layer is much higher than in the topsoil layer. The electric conductivity in soil showed a strong positive correlation with the acid ammonium acetate extractable soil phosphorus in these soils. In the topsoils and the surface soils the correlation coefficients were as high as 0,92 and 0.86 respectively (Fig 1). Also the extractable potassium content is much higher in the upper layer but the difference in extractable calcium contents are small. On the average the magnesium contents are equally high in these studied layers but when comparing the paddock areas you can see that in these areas the magnesium content is about twice as high in the upper surface layer compared to the topsoil. The most dramatic differences could be noted in case of the soil extractable phosphorus contents. On the average the surface layer was three times as high as the topsoil layer. In the most muddy paddock was also noted the highest extractable phosphorus. In this paddock the difference between the layers in the phosphorus contents were not however as distincted. This may be due to the fact that almost all the topsoil layer are mixed by the horse hooves.

Although a high electric soil conductivity in equestrian areas also indicate a high soil phosphorus it was not so in all the studied areas. In the study carried out in the first face including the surface soils from thirty sites the places with the two highest electric conductivity (the racetrack and the dressage arena) are not exceptionally high in phosphorus. The explanation is that in these areas for dust prevention salt and usually magnesium chloride is used and this will raise the electric conductivity but not the phosphorus content of soil (see appendix 1).

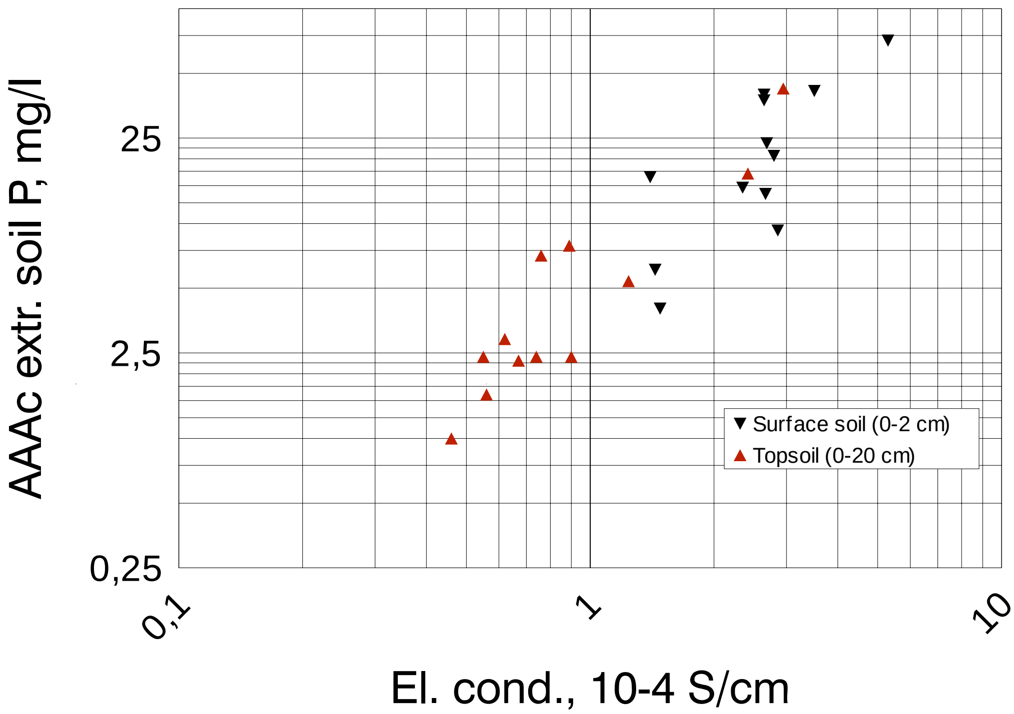

Figure 1. Electrical conductivity in comparison to acid ammonium acetate (pH, 4,65) extractable phosphorus in different soil layers of paddocks.

Soil layers

Soil pH

The soil pH in the studied paddocks (see Fig. 2 and Appendix 3) is much higher compared to the Finnish mean pH content in field topsoils. The highest pH values exceeded pH 7. This is a very high figure for Finnish conditions as in a survey on pH in Finnish soils there were only 5 % of the soils higher than pH 6,65 (Mäkelä-Kurtto et. al 2002).

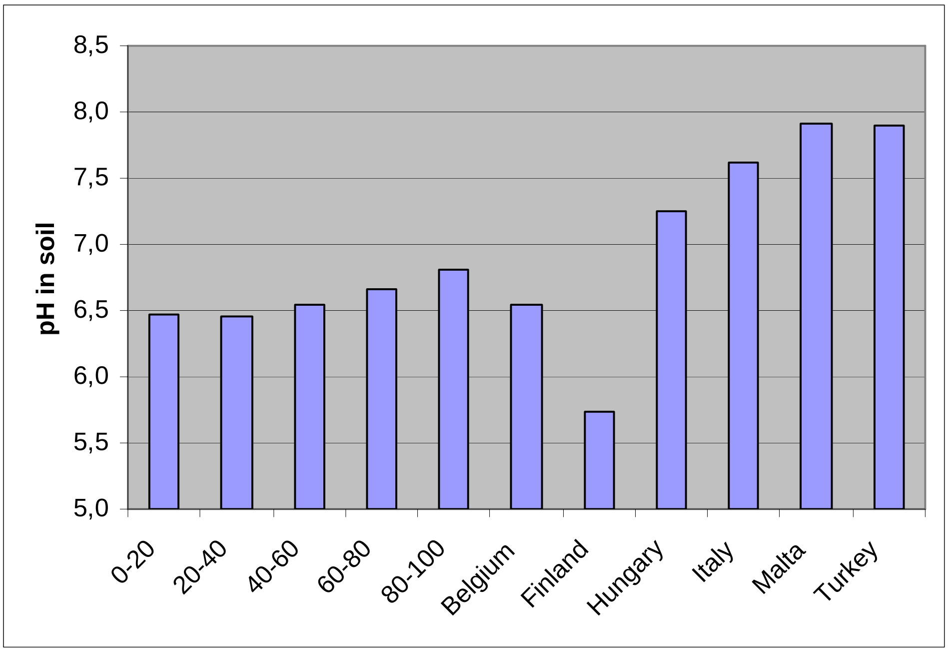

Figure 2. Average pH in soil layers of paddocks. For comparison the average contents reported by Sillanpää (1982) of top soils from fields in six EU-countries and in one candidate country are shown

Electrical conductivity

When compared to soils in many other European countries the electrical conductivitiy values in this study are low (Fig 3. The Finnish mean content reported by Mäkelä-Kurtto (2002) is equally low. The Finnish mean reported by Sillanpää from wheat growing fields in southern and middle parts of Finland is somewhat higher.

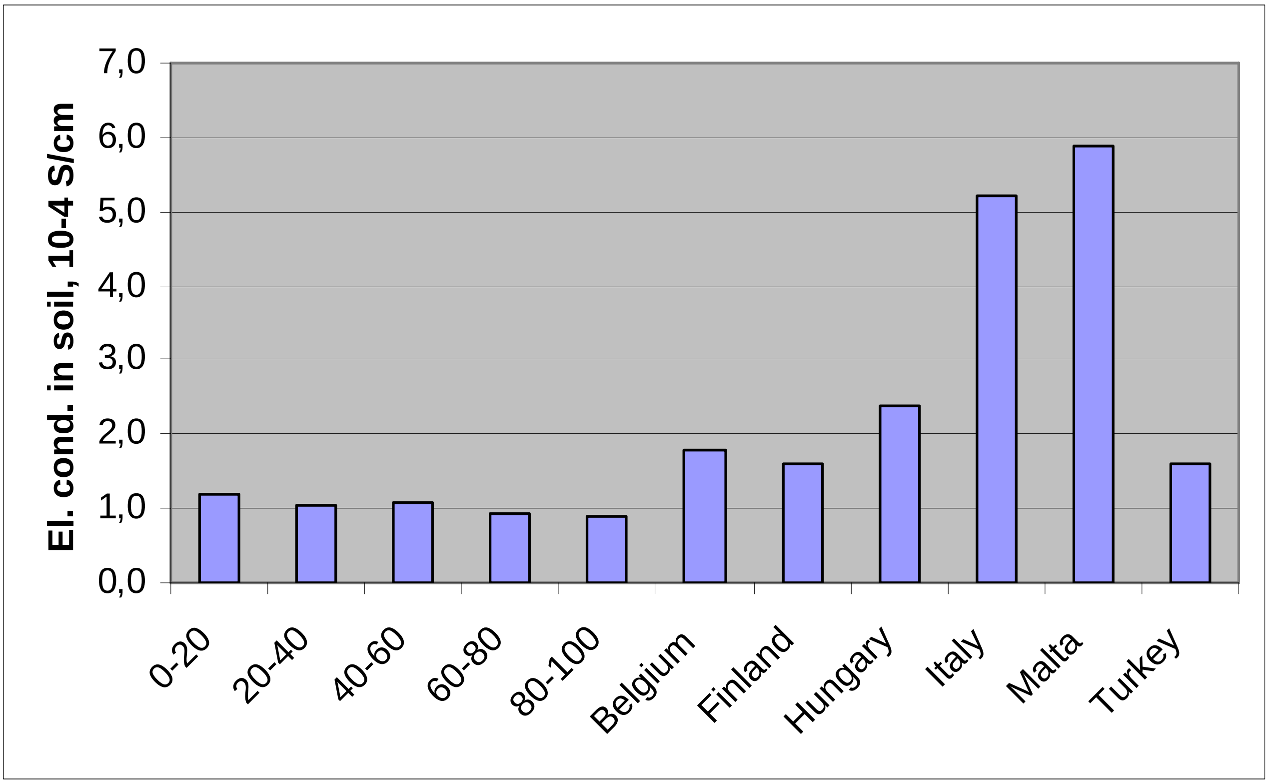

Figure 3. Average electrical conductivities in soil layers of paddocks. For comparison the average contents reported by Sillanpää (1982) of top soils from fields in six EU-countries and in one candidate country are shown

Organic carbon

In Fig 4 it can be seen that the organic carbon content in the first two upper layer of paddocks is lower than the Finnish means for top soils of fields reported by Sillanpää (1982) and Mäkelä-Kurtto (2002). In Finland the organic carbon content increase when moving north in our fields and when comparing with top soils from the same region the difference is not so pronounced as when comparing with the whole Finland (Sippola and Tares, 1978). When comparing the organic carbon contents of these two upper layers to top soils in other EU-countries it can be seen that the content is higher.

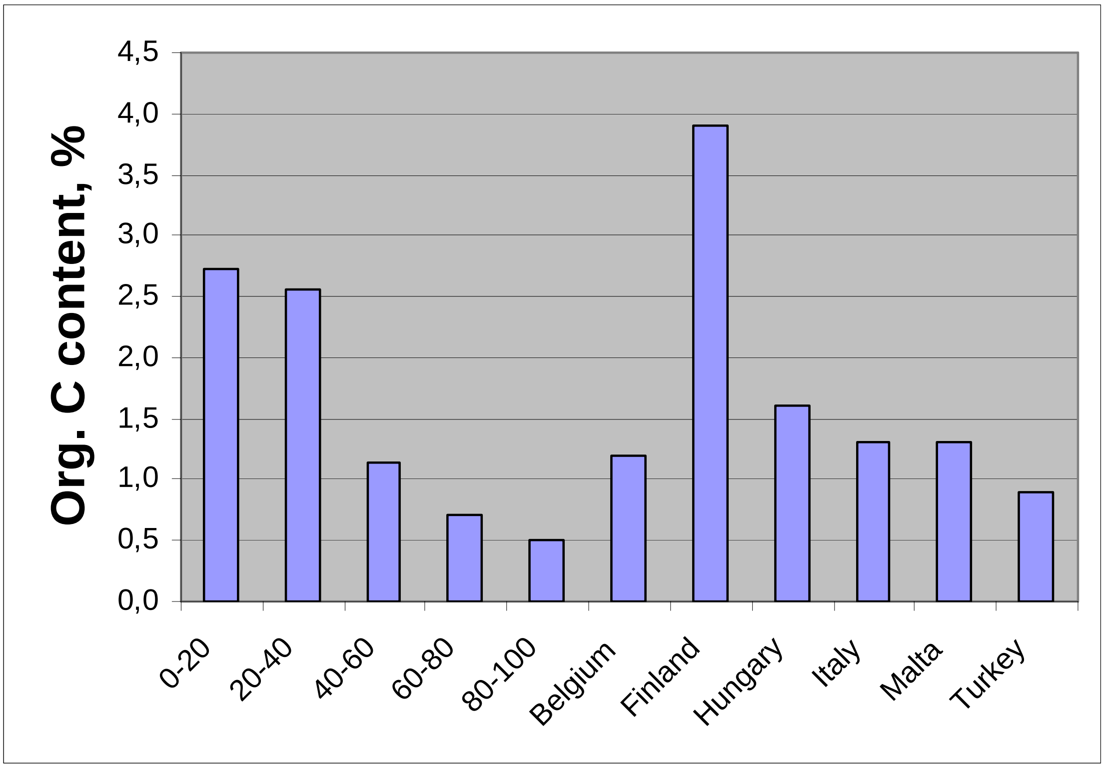

Fig 4. Organic carbon contents in soil layers of paddocks. For comparison the average contents reported by Sillanpää (1982) of top soils from fields in six EU-countries and in one candidate country are shown

Soil total nitrogen

In Fig 5 it can be seen that the average total nitrogen contents are highest in the upper soil layers of paddocks. Compared to field areas in Europe the topsoil contents in this study (0 – 20 cm) are at a level normally found in the topsoil of European fields. Compared to topsoils of fields in Finland the total nitrogen of paddocks is in the same layer (0 – 20 cm) much lower. In Finland we have large organic field soil areas (Sippola and Tares, 1978) but the paddocks are preferably established on course mineral soils, where the risk that the paddock turn to a muddy area is lower.

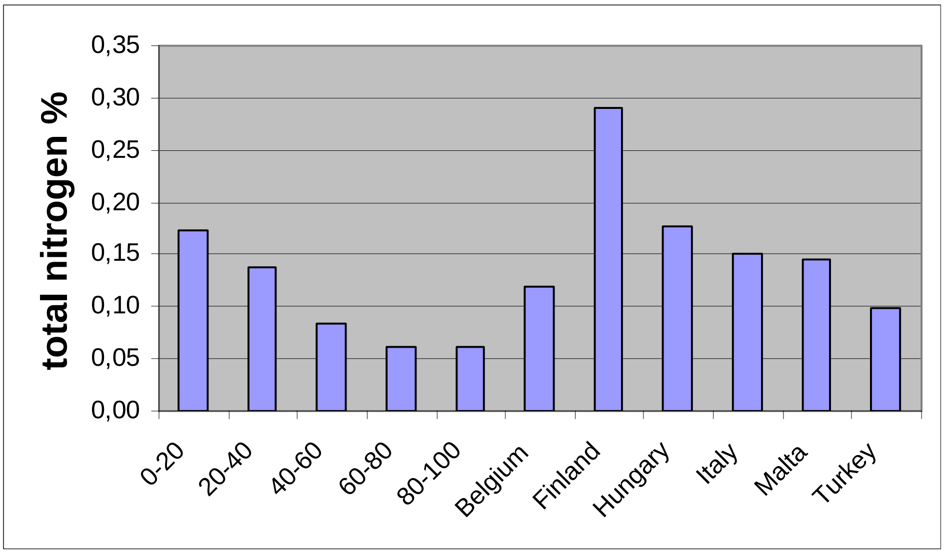

Fig. 5. Total nitrogen in soil layers of paddocks. For comparison the average contents reported by Sillanpää (1982) of top soils from fields in six EU-countries and in one candidate country are shown.

Soil total phosphorus

The topsoil content in this study (Fig. 6) are lower than the upper layers reported from pastures and of the same level as reported for cultivated soils but are much higher than reported from forest soils (Andrews 2004).

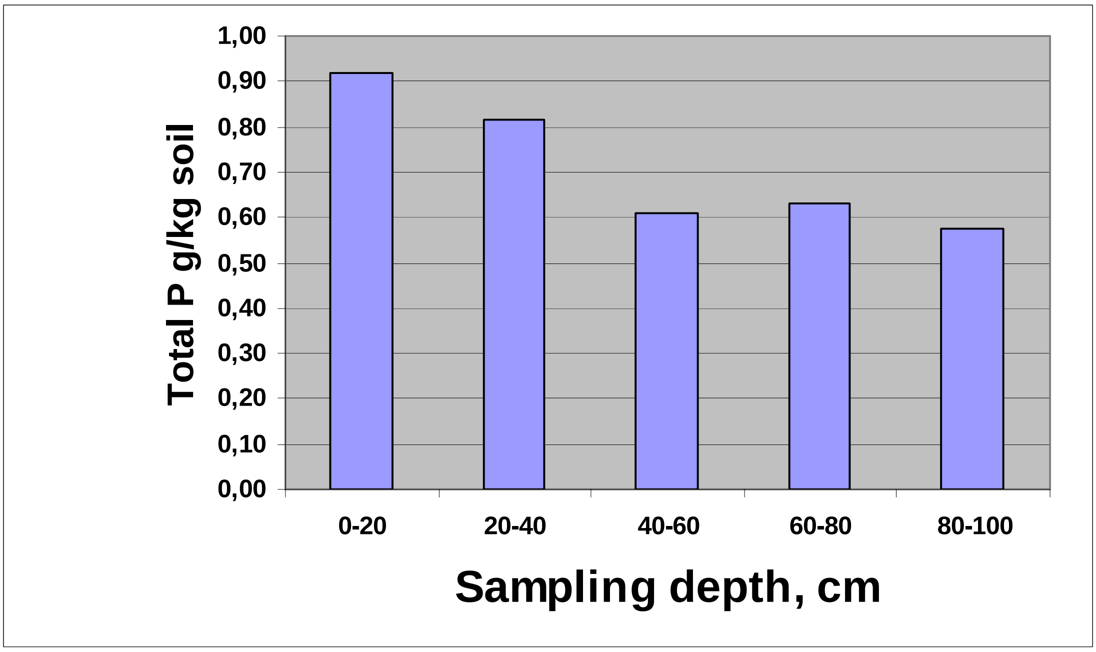

Fig. 6. Average total phosphorus in soil layers of paddocks.

Soil ammonium and nitrate nitrogen

The soil ammonium content were highest in the soil layer 40 – 60 cm (Fig 7). Together with the average small amount of nitrate nitrogen in these paddocks this mineral nitrogen level would not be enough for a full yield of a field crop like cauliflower and this crop would respond to an additional N (Rahn et al., 1998).

The soil nitrate average contents are highest in the topsoil (Fig 6) but also these contents can be interpreted as low and the only sample site with a high nitrate content (Reid and Stewart, 2004) was the site from the (critical source) area, where horses are fed with hey or silage under the open sky during the winter period.

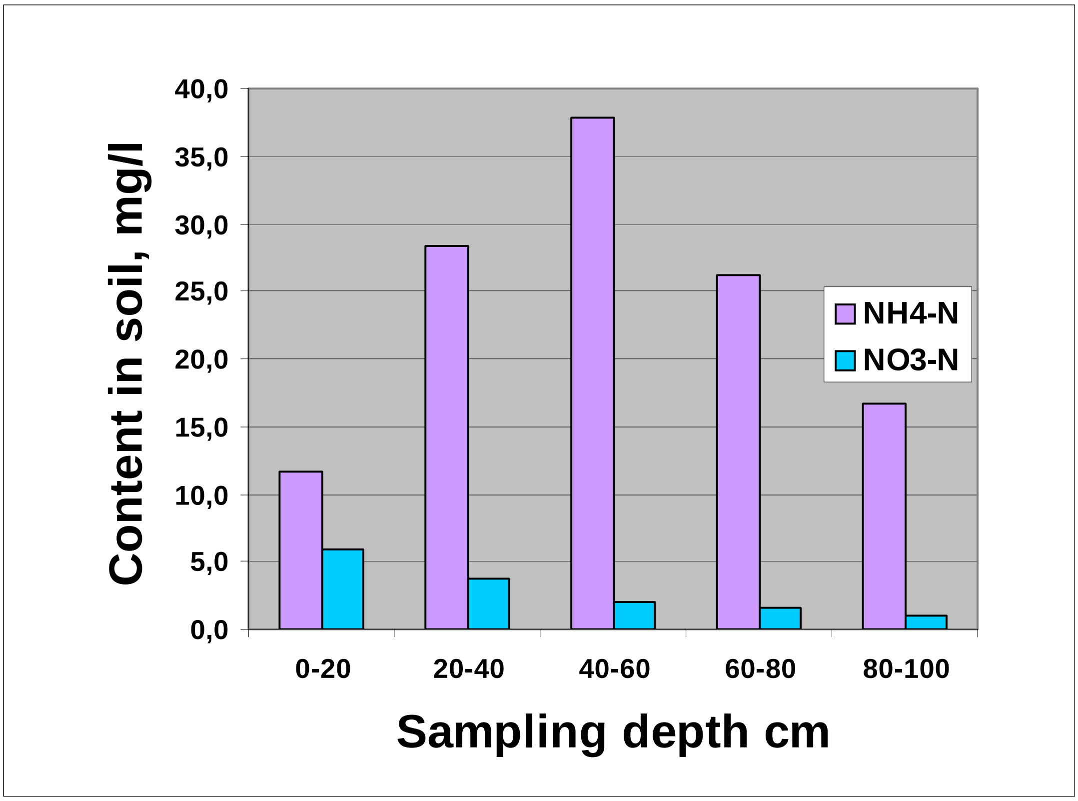

Fig. 7. Average extractable soil ammonium and nitrate nitrogen in soil layers of paddocks.

Acid ammonium acetate extractable calcium

Compared to the calcium contents reported for course mineal field soils in Finland (Sippola and Tares, 1978) the topsoils in this study (Fig 8) are equally high. The highest calcium measured from the soil layers sampled (Appendix 3) is from the same paddock in Ypäjä, where also the highest soil pH (7,99) was measured. The highest extractable calcium was measured from the lowest (80 – 100 cm) layer but the highest pH was measured from the 20 – 40 cm layer. The area in the paddock from where this sample profile was taken is used for feeding of horses with hey or silage under the open sky.

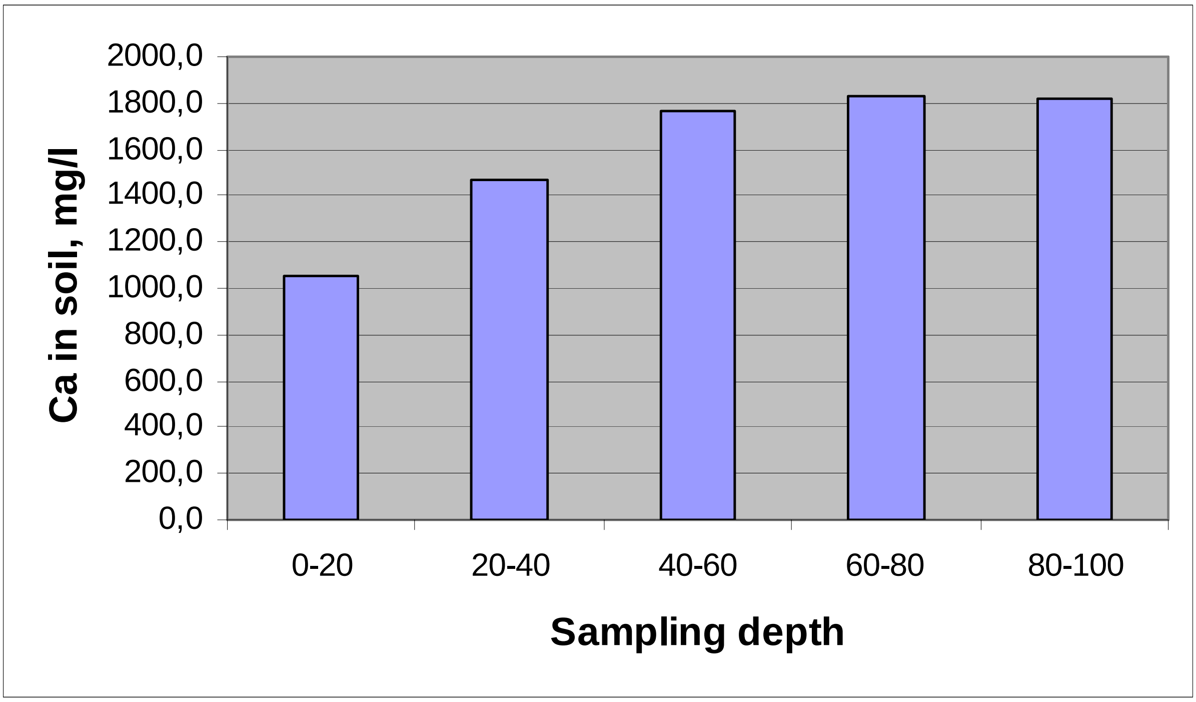

Fig. 8. Average extractable soil calcium in soil layers of paddocks.

Acid ammonium acetate extractable potassium

Of the five paddocks layers studied the highest extractable potassium contents were found in the upper layer (Fig. 9). Compared to field topsoils in Finland the contents in the topsoils in this study are much higher – the average contents reported by Mäkelä-Kurtto et al., is only 111 mg/l soil and the maximum content in her study (805 mg K/l soil) is exceeded by topsoils in this study at two sites (Appendix 3).

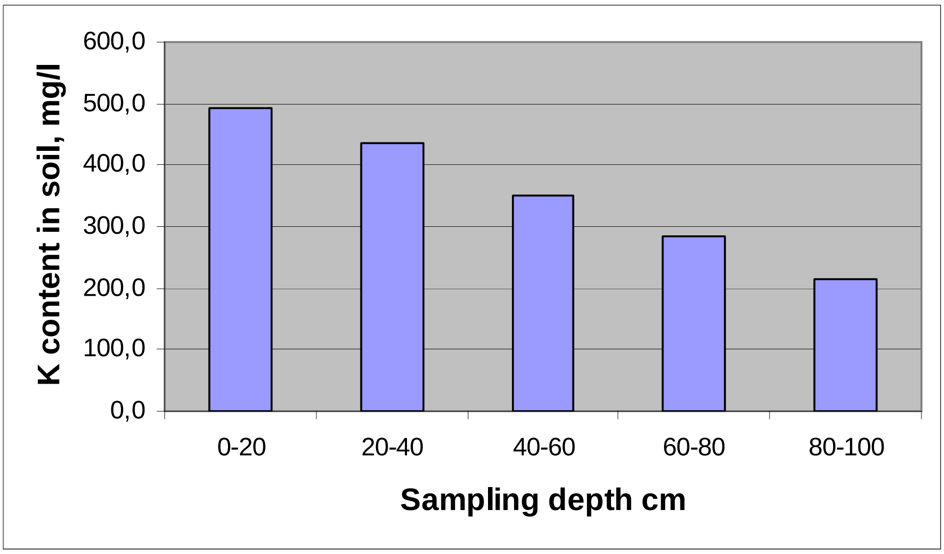

Fig. 9. Average extractable soil potassium in soil layers of paddocks.

Acid ammonium acetate extractable magnesium

Also in case of magnesium higher contents were found in the topsoil (0 – 20 cm) layer (Appendix 3) compared to those reported by Mäkelä-Kurtto (2002). In the lower layers the extractable magnesium contents are much higher (Fig. 10).

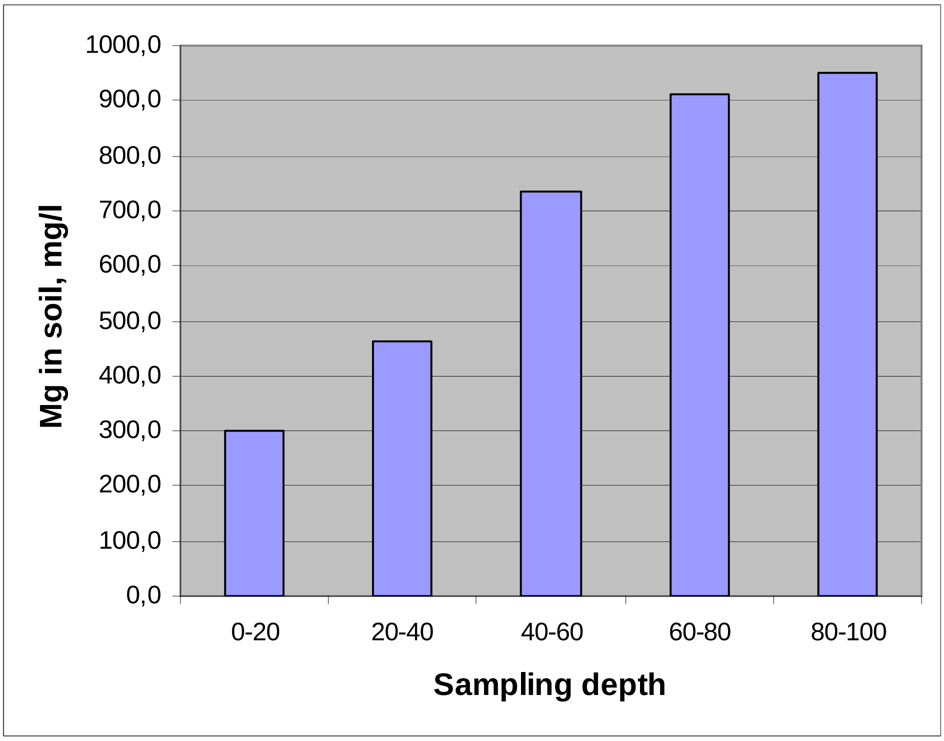

Fig. 10. Average extractable soil magnesium in soil layers of paddocks.

Acid ammonium acetate extractable phosphorus

When comparing the acid ammonium acetate extractable phosphorus (AAAc) in the paddocks sampled it can be seen that the soil layers are very different (Fig 11) and high AAAc extractable phosphorus is typical in the topsoil (0 – 20 cm) layer. However it should be kept in mind that much higher AAAc extractable contents are found in the surface soil (0 – 2 cm), where the content in paddocks can be as much as seven times as high as in the topsoil (see Appendices 1a and 1b).

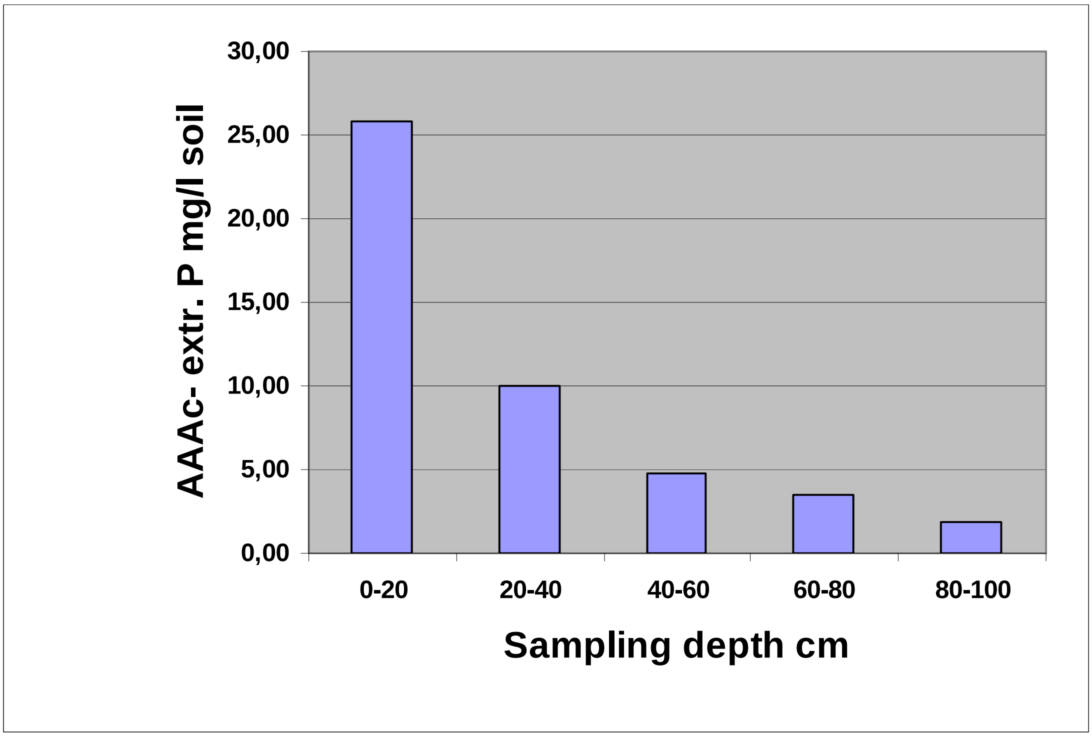

Figure 11. Average acid ammonium acetate (pH, 4,65) extractable phosphorus in different soil layers of paddocks.

Acid ammonium acetate extractable sulphur

The extractable soil sulphur contents in the upper layer (Fig. 12) is only about half the content reported in a large (n = 720) study of Finnish field soils (Mäkelä-Kurtto et al., 2002).

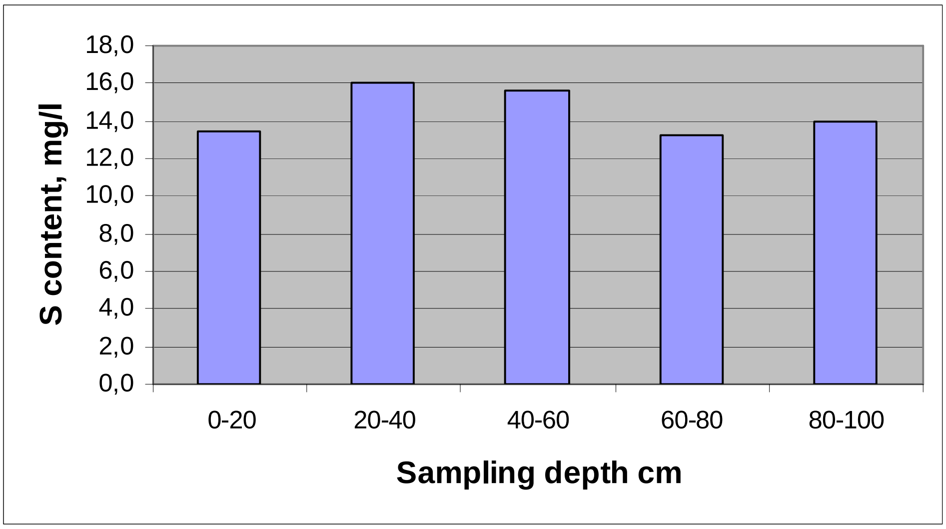

Figure 12. Average acid ammonium acetate (pH, 4,65) extractable sulphur in different soil layers of paddocks.

Acid ammonium acetate extractable sodium

The average acid ammonium acetate extractable soil contents in the 0 – 20 cm layer of paddocks (see Fig. 13) in this study were slightly higher than in a large survey reported by Sippola and Tares (1978).

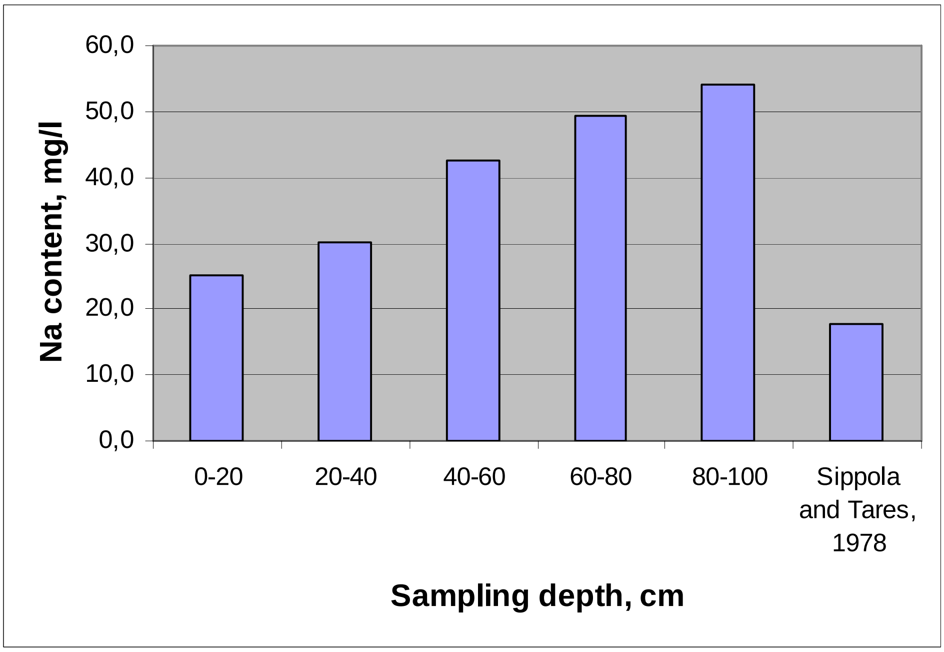

Figure 13. Average acid ammonium acetate (pH, 4,65) extractable sodium in different soil layers of paddocks. For comparison the average content in Finnish field topsoils reported by Sippola and Tares (1978) is shown.

Rainfall simulation tests

In phase four of this study we took altogether 26 samples from equine areas. These samples were used for rainfall simulation studies. In the rainfall treatment of the soil samples surface flow water was sampled. Altogether three bottles of water was collected per treated soil sample. The second bottle was used for comparison with the soil phosphorus content and in estimating the phosphorus load in different paddocks (Fig. 14).

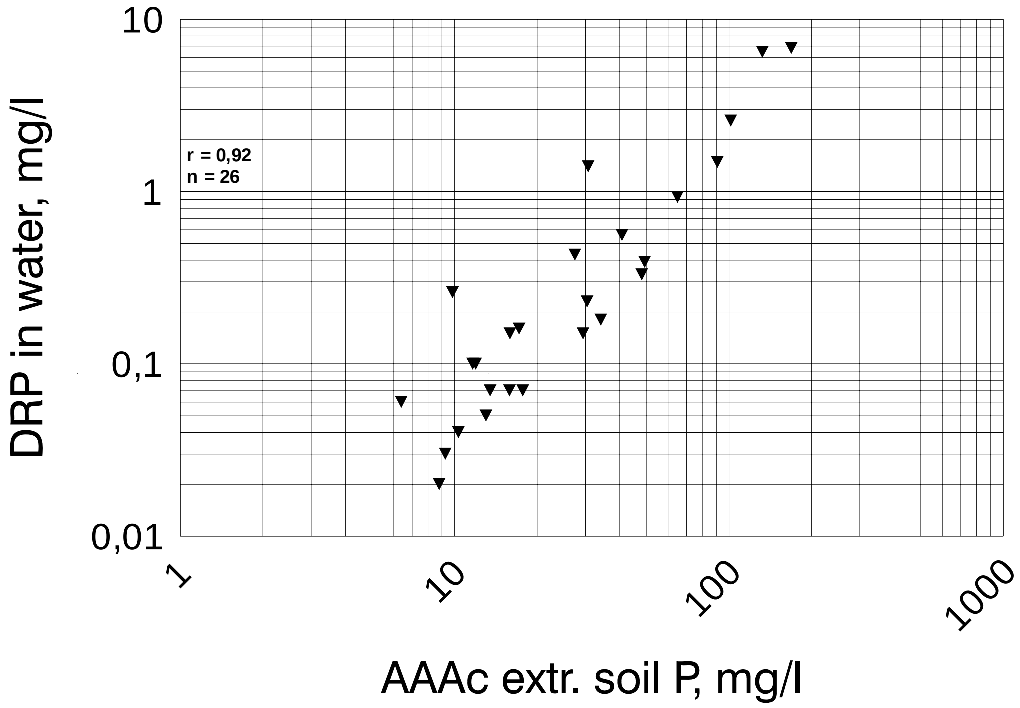

Figure 14. Dissolved reactive phosphorus contents in waters from artificial rain treatment of paddock soil samples as related to AAAc soil extractable soil phosphorus (r = 0,92, n = 26).

As can be seen in figure 14 the maximum AAAc-extractable content found in this face was 169 mg P/l soil. We also analysed the faeces of a horse for AAAc-extractable soil phosphorus and we found 270 mg P/l. As the highest water phosphorus content we have earlier sampled from a puddle in an equine area is 17,3 mg/l dissolved reactive phosphorus. This area was a paddock area, where no change of surface paddock surface material had been carried out for more than twenty years. This content is more than hundred fold the contents reported from Finnish field waters (Rekolainen, 1993). If all our paddocks would be over twenty years without maintenance this high figure would be the case for all our paddock. The load from one hectare of paddock areas would be equally high as the phosphorus load from hundred hectares of field area.

We also made a test using a mixture of fresh horse faeces (50 % by volume) mixed with fine sand. This mixture was tested in the rainfall simulation as other samples but during the rainfall treatment to the surface of the sample 6 grams of Ferix-3 (Biolchim, 2005) was added before the second bottle was filled up. The influence on water quality can be seen in Fig. 14. The treatment influence on water pH on dissolved phosphorus content can be seen in this second bottle.

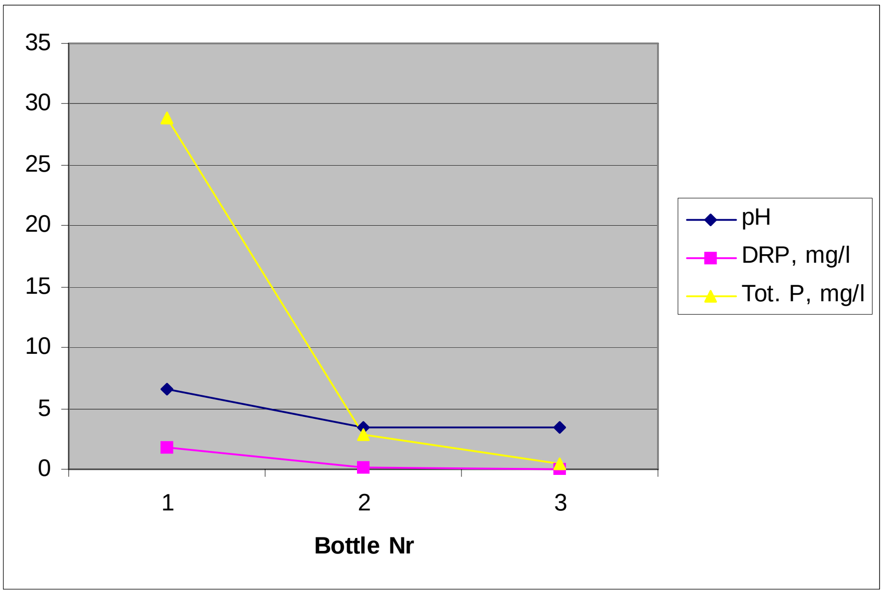

Figure 15. Contents of dissolved reactive phosphorus (DRP), the contents of total phosphorus and pH in surface flow water from an artifical rain treated horse faeces-fine sand mixture. During the rain treatment 6 g (1340 kg/ha) of ferric sulphate (Ferix-3) was added to the surface of mixture between the first and second bottle.

When comparing the total phosphorus contents in soil with the content in the surface water it can be seen that the soil total phosphorus is not a good indicator of the phosphorus load from horse paddocks (Fig 16).

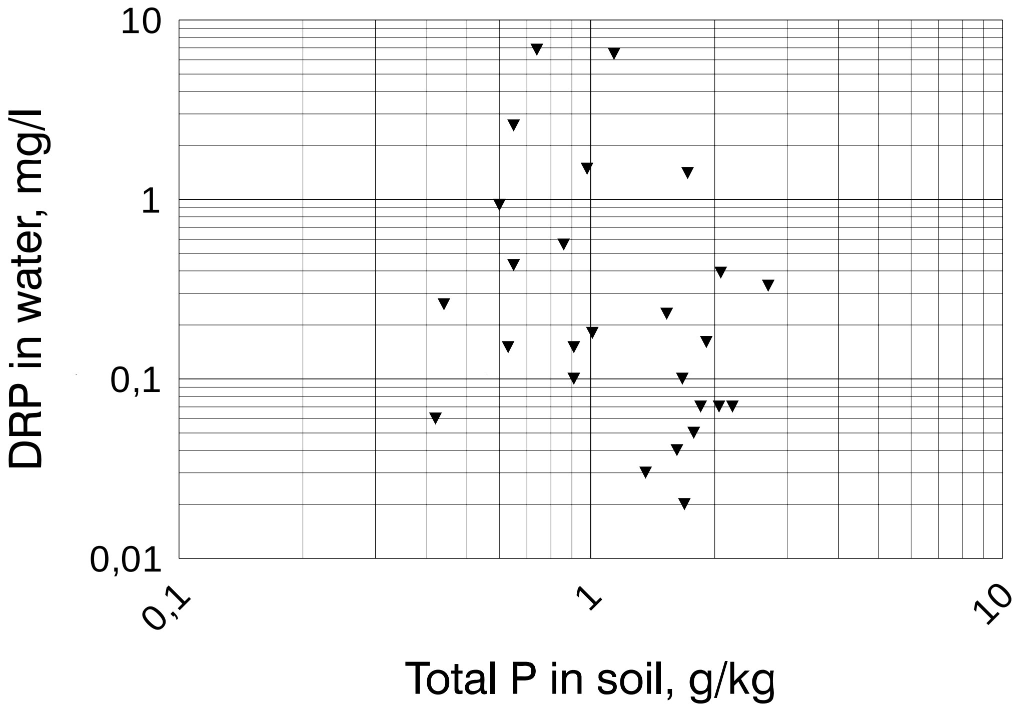

Fig. 16. Dissolved reactive phosphorus contents in waters from artificial rain treatment of paddock soil samples as related to AAAc soil extractable soil phosphorus.

In our equine survey it could be seen that horses on the average are kept for seven ours in paddocks and on the average one paddock is used by two horses. The paddock areas varied largely but was on the average 1100 m^2. As much as 80 % of the horses are kept on pasture in summer (Pikkarainen, 2005). The paddocks had been in use for 5,4 years on the average.

In Sweden the amount of phosphorus in faeces and urine from a horse is reported to vary from 8 to 16 kg phosphorus per year (Steineck et. al, 2000). With varying diets van Doorn et al. (2004) found wide varying but relatively low (0 to 1 g/day) urinary P excretion by mature trotters. The faecal excretion varied from 18 to 37 g/day. From these above figures we can see that a yearly input to our paddocks is

In a study on faecal phosphorus excretion from yearling geldings Heize et. al (2004) found water-soluble phosphorus contents varying from 3,0 to 7,9 g/day. Faecal output of total P, water-soluble P and insoluble P was 8.4, 3.0 and 5.4 g/day, 10.1, 3.9 and 6.9 g/day, 14.9,5.3 and 9.6 g/day, and 19.0, 7.9 and 11.1 g/day, respectively for diets containing whole oats, alfalfa cubes, sweet feed and pelleted concentrate (Heize et. al., 2004). The water-soluble P thus varies between 36 to 42 % of the total P in the faeces.

From the above figures we can see that the inputs of phosphorus into Finnish paddocks is 3 kg of phosphorous in faeces during one year per horse. As on the average two horses use the same paddock we will get an input of 6 kg phosphorus/paddock/year and about 60 kg phosphorus per hectare. As reported by Pikkarainen (2005) the surfaces in paddocks are changed every third year and this will make our paddocks surfaces on the average 1,5 years old and in this period the average AAAc extractable phosphorus has risen to over 50 mg P/l soil as indicated in Appendix 1. This corresponds to a phosphorus content in surface water flow of about 1 mg dissolved reactive P/l (see fig 14). If applied to the whole Finland this means that the dissolved reactive phosphorus load from our horse paddock areas are as high as eight times as those from our field areas.

Conclusions

In Finland the growing horse population is more and more situated in the Baltic Sea Proper catchment area. Also in the other countries with land areas in the catchment area this will be a problem as a fast developing economy will increase the horse population. We can see this growth in the equine industry very clear in a country like Sweden. In Sweden the economy has steadily been growing for a long time and more and more people are interested in equine sports and Sweden has now the highest amount of horses per inhabitants of all EU-countries. Swedish horse population declined from about 720,000 to approximately 84,000. Since then the number has risen again, reaching 220,000 in 2000 (Brasch et al., 2002). As our equine paddock use is probably of the same level the phosphorus load from equine areas in Sweden is 3 – 4 times the load in Finland.

According to the EU Water framework directive we should have a good biological and chemical status in our waterbodies in 2015. This should make us cut down our phosphorus load. The water from equine areas is high in phosphorus and these areas is an increasing problem with our increasing horse population. A reduction in phosphorus contents using chemical treatment has been shown to be cost effective. Therefore in our Finnish Agri-environment Programme the chemical treatment of waters from equine areas should be included. Also the stables outside the Agri-environment Programme should be subsidised by the Finnish Government to carry out these measures.

References

Andrews, S. 2004. Analysis of Attert River Basin Surface and Sub-surface Soil Using a Fingerprinting Technique. Available at the Internet: http://www.clarku.edu/offices/Leir/Linked%20Docs/HONORS-SEBASTIAN-S2004.ppt

Agneta Brasch, A., Dahlin, A., Danell, B., Ericson, P., Eriksson, J. Å., Höggren, M., Jeppsson, S., Linnarsson, E., Rehn, H. Tjälldén, U., and *Stålhammar*, E. M. 2002. Country report on animal genetic resources for food and agriculture in Sweden. Available at the Internet: http://www.nordgen.org/download/svensklandsrapport-eng.doc

Biolchim. 2005. Ferix® 3 Kemira 20 % Fe Granulare. Available at the Internet http://www.biolchim.it/db/Microelementi/Terreno/Ferix3_Kemira20_Fe_G.pdf

Blickle, A. R., Paige, J. and Clark, E. 2003. Healthy horses, clean water. A guide to environmentally friendly horsekeeping. Available at the Internet. Read 11. 5. 2005. http://www.psat.wa.gov/Publications/HORSE_MAN.pdf

van Doorn, D. A., Everts, H. Wouterse, H. and Beynen, A. C. 2004. The apparent digestibility of phytate phosphorus and the influence of supplemental phytase in horses. J. Anim. Sci. 82:1756-1763

Dougherty W. J., Fleming N. K., Cox J. W. and Chittleborough D. J. 2004. Rainfall simulation underestimates runoff phosphorus concentrations from dairy pastures. ISBN 1 920842 26 8 SuperSoil 2004 Published by The Regional Institute Ltd. Available at the internet: http://www.regional.org.au/au/asssi/supersoil2004/s16/oral/1560_doughertyw.htm

Esala, M. 1992. Split application of nitrogen: effects on the protein in spring wheat and fate of (15)N-labelled nitrogen in the soil-plant system. Annales Agriculturae Fenniae 30, 3: Annales Agriculturae Fenniae. Seria Agrogeologia et -chimica 158: 219-309. Diss. : Helsinki : University of Helsinki, 1991.

Hainze M. T. M., Muntifering R. B., Wood C. W., McCall C. A., Wood B. H 2004. Faecal phosphorus excretion from horses fed typical diets with and without added phytase. Animal feed science and technology. 117 (3-4): 265-279.

Hollinger, E. and Cornish, P. 2002. Magnitude and management of diffuse agricultural nutrient pollution. Landscape and ecosystems management, Conference Proceedings, 4-8 November, 2002, Tweed Heads. P190-93.University of Western Sidney, Richmond NSW. Available at the internetIntrenet: http://www.coastal.crc.org.au/coast2coast2002/proceedings/Theme4/Magnitude-management-diffuse-agricultural-nutrient-pollution.pdf

Horne A. J., Roth, J. C., Beutel, M., Barth, R., Elkins, K., Stoller, S., Muneepeerakul, R., Berlin, J., Truitt, J., Huang, S. and Kane, J. 2003. Report on Bridgeport reservoir beneficial. Use impairment: limnology in the summerfall 2000 and comparisons with 1989. Available at the Internet. Read 11. 7. 2005. http://www.waterboards.ca.gov/lahontan/TMDL/Bridgeport/Bridgeport_Reservoir_Year_2000_FINAL_Report_Figures.pdf

Jansson, H., Jansson, H., Vanhamäki, P. 2002. Hevostarhojen maassa runsaasti fosforia. Koetoiminta ja käytäntö 59, 4(16.12.2002): 15. (In Finnish) http://www.mtt.fi/koetoiminta/pdf/mtt-kjak-v59n4s15a.pdf

Jansson, H., Mantylahti, V., Narvanen, A. and Uusitalo, R. 2000. Phosphorus content of ditch sediments as indicator of critical source areas. Agricultural and food science in Finland, 9(3), 2000, pp. 217 – 221. http://www.mtt.fi/afs/pdf/afsf9_217.pdf

Jansson, H. and Närvänen, A. 2005. Reducing the phosphorus load and the algae blooms in Finnish lakes and the Baltic Sea. In: SÖDERLUND, L., SIPPOLA, J., KAMIJO-SÖDERLUND, M. Proceedings SUSDEV-CHINA symposium : sustainable agroecosystem management and development of rural-urban interaction in regions and cities of China. Agrifood Research Reports (2005):68, 190-200. Available at the Internet. Established 27.7.2005 http://www.mtt.fi/met/pdf/met68.pdf

Jansson, H., Tuhkanen, H.-R. 2003. Laitumelta tulevan ravinnekuormituksen vähentäminen. In: Jaana Uusi-Kämppä, Markku Yli-Halla ja Kaarina Grék (toim.). Lypsykarjataloudesta tulevan ympäristökuormituksen vähentäminen. Maa- ja elintarviketalous 25: s. 40-47. (In Finnish with English summary) Available at the Internet: http://www.mtt.fi/met/pdf/met25.pdf

Ma, Y., Bartholic, J., Asher, J., Shi, Y. and Ouyang, D. 2001. NPS assessment model: An example of AGNPS application for watershed erosion and phosphorus sedimentation. Journal of spatial hydrology. Volume 1 no 1.
Available at the internet. http://www.spatialhydrology.com/journal/paper/nps/nps.pdf

McGreevy, P.D., French, N.P. & Nicol, C.J., 1995. The prevelance of abnormal behaviours in dressage, eventing and endurance horses in relation to stabling. Vet. Record. 137, 36-37.

Mäkelä-Kurtto, R., Sippola, J., Grek, K. 2002. Peltomaiden viljavuus ja helppoliukoiset raskasmetallit. In: Risto Uusitalo (toim.) ja Riitta Salo (toim.). Tutkittu maa - turvalliset elintarvikkeet Viljavuustutkimus 50 vuotta -juhlaseminaari, Jokioinen 24.9.2002. Maa- ja elintarviketalous 13: s. 30-46.
Available at the Internet: http://www.mtt.fi/met/pdf/met13.pdf

Nash, D. 2002. Phosphorus transfer from land to water in pasture-based grazing systems. Institute of land and food resources. The university of Melbourne, Parkville 3010. Available at the internet.
http://eprints.unimelb.edu.au/archive/00000752/02/02_Whole.pdf

Ongley, D. O. 1996. Control of water pollution from agriculture - FAO irrigation and drainage paper 55. Food and Agriculture Organization of the United Nations

Pietiläinen, O. P. 1995. Agricultural phosphorus load and phosphorus as a limiting factor for algal growth in Finnish lakes and rivers Workshop "Phosphorus loss from soil to water"
Wexford, Ireland, 1995: 354-356.

Pietola, L., Yli-Halla, M., Horn, R. 2003. Cattle trampling increases risk for surface runoff. In: Oiva Niemeläinen and Mari Topi-Hulmi (eds.). Proceedings of the NJF's 22nd congress 'Nordic Agriculture in Global Perspective', July 1-4, 2003, Turku, Finland. Jokioinen: MTT Agrifood Research Finland, NJF. [p. 30].
http://portal.mtt.fi/pls/portal30/docs/FOLDER/AGRONET/YHTEI SET_HANKKEET/NJF/NJF2003/25.PDF Published 15.9.2003

Pikkarainen, M. 2005. Hevosten hyvinvointi ja lajinmukainen käyttäytyminen sekä niiden toteutuminen Suomalaisilla talleilla (The welfare and the species specific behavior of horses and its implementation at Finnish stables, in Finnsh with English summary). HAMK, Mustiala, Finland. 51 p.

Reid, K. and Stewart, G. 2004. Interpreting a Soil Nitrate Test from Fertilized Ground. Available at the Internet:
http://www.omafra.gov.on.ca/english/crops/field/news/croppest/2004/06cpo04a2.htm

Rekolainen, S. 1993. Assessment and mitigation of agricultural water pollution. Publications of the Water Environment Research Institute. No. 12. Helsinki: National Board of Waters and the Environment. 34 s.

Rahn, C. R., Paterson, C. D. and Vaidyanathan, L. V. 1998. The use of measurements of soil mineral N in understanding the response of crops to fertilizer nitrogen in intensive cropping rotations. *Journal of Agricultural Science, Cambridge* (1998), **130**, 345-356. Available at the Internet:
http://journals.cambridge.org/download.php?file=/AGS/AGS130_03/S002185969800531Xa.pdf&code=c0219c14d408ee27329e7a33e0a9df0e

Steineck, S., Svensson, L., Jacobsson, C., Karlsson, S. and Tersmeden, M. 2000. Hästar – gödselhantering. Institutet för jordbruks- och miljöteknik. Available at the Internet: http://www.jti.slu.se/publikat/teklor/pdf-filer/t82.pdf

Söderström, J. 1996. The significance of observed nutrient concentrations in the discussion about nitrogen and phosphorus as limiting nutrients for the primary carbon flux in coastal water ecosystems. Sarsia 81:81-96 Available at the Internet. http://www.ifm.uib.no/sol/VisAbst.asp?ASEQ=1168

Sillanpää, M. Micronutrients and the nutrient status of soils. A global study. FAO soils bull. 48, 444 p. FAO, Rome

Sippola; J, & Tares, T. 1978. Soluble content of minerals in cultivated soils. Acta Agric. Scand.:28: 11-25

Schatzmann, U., 2000. Winter pasturing of sport horses in Switzerland – an experimental study. Equine Vet. J. Suppl.27, 53.

Sondergaard, E., Clausen, E., Winther Christensen, J. & Shougaard, H. 2004. Housing of horses. Danish recommendations. DIAS report Special Edition. Ministry of Food, Agriculture and Fisheries, Danish Institute of Agricultural Sciences. Plant production, Animal Husbandry and Horticulture. 105 s.ISSN 1397-9892.

Steineck, S., Svensson, L., Jakobsson, C., Karlsson S., and Tersmeden, M. 2000. Hästar – gödselhantering. (Horses and use of the manure, in Swedish). Institutet för jordbruks- och miljöteknik (In Swedish). Available at the internet. http://www.jti.slu.se/publikat/teklor/pdf-filer/t82.pdf

Stephenson, G., Hannaway, D., Blicke, A., Brewer, R., Brewer, L. J., Chaney, M., Livesay, m., and County, B. 2003. Managing small-acreage horse farms for green pastures, clean water, and healthy horses. Oregon state university extension service. Available at the Internet: http://eesc.orst.edu/agcomwebfile/edmat/EC1558.pdf

Suomen Hippos. 2005. The number of horses in Finland during 1910 to 2004. (In Finnish) Available at the Internet. Established 11.1. 2005. Read 26.5. 2005. http://www.hippos.fi/hippos/tilastot/jalostus_ja_kasvatus/hevoskannan_kehitys.php

SYKE (Finnish Environment Institute). 2004. Heavy blue-green algae blooming likely next summer on the Baltic Sea – eutrophication advances in the Finnish ses areas. Available at the Internet. http://www.ymparisto.fi/default.asp?contentid=79900&lan=en

Uusi-Kämppä, J., Yläranta, T. 1996. Effect of buffer strip on controlling erosion and nutrient losses in Southern Finland. In: Mulamoottil, G., Warner, B.G. & McBean, E.A. (Eds.). Wetlands: environmental gradients, boundaries and buffers. Boca Raton: CRC Press/Lewis Publishers. p. 221-235.

Appendix 1.

Sampling site	Nr	Volume weight kg/l	pH H2O	El. cond. 10 -4 S/cm	Ca mg/l soil	K mg/l soil	Mg mg/l soil	P mg/l soil	S mg/l soil	Na mg/l soil	N %	Org. C %	Hu-mus %	C/N
Constructed paddocks, no vegetation														
Western side of stable I	481	1,14	6,76	1,33	608	391	125	50,55	16,9	28,6	0,08	1,56	2,70	19,5
North western side of stable I	482	1,23	6,54	0,85	566	245	118	46,01	12,9	24,7	0,08	1,80	3,11	22,5
Between stables I and II	484	1,04	6,68	0,73	582	399	149	53,15	10,1	16,8	0,09	1,39	2,40	15,4
Paddock with roofed area (stable I)	485	0,55	6,79	1,71	739	315	180	104,13	10,8	29,4	0,18	5,61	9,71	31,2
Equine hospital paddock	486	0,80	6,71	0,78	766	514	183	45,51	10,8	36,8	0,19	4,03	6,97	21,2
Stable III paddock area close	494	0,99	6,78	1,88	437	479	125	46,95	13,1	52,5	0,11	3,29	5,69	29,9
Stable III paddock area close	497	1,03	6,71	0,94	524	498	158	44,69	12,5	50,7	0,13	3,11	5,37	23,9
Stable III paddock area far off	498	0,96	7,02	3,57	518	705	154	43,34	14,9	75,5	0,18	4,39	7,60	24,4
Mean		0,97	6,75	1,47	593	443	149	54,29	12,8	39,4	0,13	3,15	5,44	23,5
Paddocks, not constructed, no vegetation														
South of stable I lower paddock	480	0,95	6,64	2,12	986	604	221	41,73	21,3	60,2	0,32	7,32	12,66	22,9
Stable III paddock area far off	499	0,46	6,66	4,85	714	603	206	93,06	19,6	125,5	0,49	13,81	23,89	28,2
Stable III paddock area far off	500	0,68	6,73	3,24	1281	755	284	36,78	15,3	54,5	0,62	9,85	17,03	15,9
Stable IV paddock (slope)	493	1,09	6,63	1,28	409	302	99	46,63	8,4	41,2	0,08	2,22	3,84	27,8
Mean		0,80	6,67	2,87	848	566	202	54,55	16,2	70,4	0,38	8,30	14,36	23,7
Not established paddocks varying vegetation														
Birch area, defecating area	471	0,83	6,71	2,70	1240	508	331	187,31	10,2	95,2	0,31	5,88	10,18	19,0
Behind the restaurant gate area	472	0,95	6,05	1,14	855	307	176	27,53	15,9	35,7	0,28	3,94	6,82	14,1
Behind the restaurant in middle	473	0,72	5,90	1,55	1976	224	211	23,48	23,2	41,7	0,86	11,44	19,79	13,3
Birch area, feeding area	474	1,02	6,86	3,15	987	750	158	32,31	25,2	48,8	0,27	3,83	6,62	14,2
Karrinmäki area	475	0,81	6,29	1,65	1638	794	301	51,53	20,9	21,5	0,63	8,08	13,98	12,8
Trotting course paddock	489	0,86	6,45	0,89	1391	361	225	25,34	16,3	33,3	0,31	5,15	8,91	16,6
South of stable II and III (slope)	483	0,69	6,33	3,02	1521	773	279	23,16	25,2	69,3	0,51	9,12	15,78	17,9
Päivärinne, feeding area	487	0,50	6,92	5,16	8054	703	468	227,06	22,8	19,8	1,50	21,29	36,83	14,2
Päivärinne, gate area	488	0,78	6,66	3,06	3678	896	242	43,6	29,9	19,4	0,68	9,74	16,38	14,3
Mean		0,80	6,46	2,48	2371	591	266	71,26	21,1	42,7	0,59	8,72	15,03	15,2
Paddocks with run-in sheds														
Run-in shed A	476	0,53	6,78	5,50	1041	1064	295	122,92	32,1	56,6	0,41	9,40	16,72	22,9
Run-in shed B	477	0,78	6,49	2,06	2176	720	458	71,69	22,7	23,9	0,53	7,21	12,47	13,6
Run-in shed C	479	0,78	6,90	5,25	821	1247	257	102,84	29,8	34,2	0,22	4,68	8,10	21,3
Mean		0,70	6,72	4,27	1346	1010	337	99,15	28,2	38,2	0,39	7,10	12,4	19,3
Other equine areas														
Trotting course	490	1,40	6,65	14,30	546	170	1243	11,49	66,7	95,4	0,02	0,54	0,93	27,0
Dressage arena	491	1,18	6,61	5,85	464	74	417	9,16	14,9	21,5	0,03	5,60	9,69	186,7
Driving course	492	1,41	6,46	0,32	302	114	84	6,57	9,4	17,6	0,02	0,47	0,81	23,5
Watering place, pasture	478	0,74	5,60	1,49	1646	473	442	14,29	23,2	93,1	0,65	8,69	15,03	13,4
Waste tip area, covered	495	1,01	6,03	0,96	1317	270	176	8,76	37,5	30,1	0,18	3,32	5,73	18,4
Waste tip area, covered	496	0,96	5,99	0,59	1155	288	161	15,03	8,4	17,3	0,22	4,43	7,66	20,1

Appendix 2a.

Soil general properties and acid ammonium acetate (pH 4,65) extractable contents of calcium, potassium, magnesium and phosphorus of the surface layer (0-2 cm) in different areas of a horse farm.

Soil layer 0-2 cm

sampling site	pH H2O 1:2,5	El. cond 10 -4 S/cm	Ca mg/l soil AAAc-extr	K mg/l soil AAAc-extr	Mg mg/l soil AAAc-extr	P mg/l soil AAAc-extr
Paddock	6,62	5,3	817	933	287	70,8
Paddock	6,13	2,65	1273	703	282	37,36
Paddock	6,11	2,65	1549	613	334	39,71
Paddock	5,88	2,35	1377	364	214	14,67
Free running stable yard	6,1	3,51	810	470	256	41,3
Pasture	6,17	2,8	1492	648	307	20,6
Pasture	5,9	2,67	1685	435	241	13,7
Pasture	5,68	1,44	1825	441	581	6,08
Area formerly used as manure storage	5,91	2,69	1220	296	420	23,6
Pasture	5,8	2,86	1210	602	239	9,27
Exercise road	5,83	1,4	750	195	126	16,4
Pasture	5,74	1,48	1603	453	533	4,01
Average	**6,0**	**2,7**	**1301**	**513**	**318**	**24,8**

Appendix 2b.

Soil general properties and acid ammonium acetate (pH 4,65) extractable contents of calcium, potassium, magnesium and phosphorus of the topsoil layer (0-20 cm) in different areas of a horse farm.

Soil layer 0-20 cm

sampling site	pH H2O 1:2,5	El. cond 10 -4 S/cm	Ca mg/l soil AAAc-extr	K mg/l soil AAAc-extr	Mg mg/l soil AAAc-extr	P mg/l soil AAAc-extr
Paddock	6,6	2,95	561	709	180	42,5
Paddock	5,89	1,24	1041	407	156	5,4
Paddock	5,74	0,76	935	333	147	7,1
Paddock	5,53	0,62	615	84	44	2,9
Free running stable yard	6,12	2,42	982	1021	209	17,1
Pasture	5,72	0,67	1354	315	305	2,3
Pasture	5,73	0,46	1184	135	187	1,0
Pasture	5,74	0,55	1976	279	675	2,4
Area formerly used as manure storage	5,94	0,9	1488	707	916	2,4
Pasture	5,6	0,56	1108	166	198	1,6
Exercise road	5,99	0,89	871	242	96	7,9
Pasture	5,82	0,74	1759	353	557	2,4
Average	**5,9**	**1,1**	**1156**	**396**	**306**	**7,9**

Appendix 3.

Soil general properties and nutrient soil contents in 17 paddocks in Ypäjä (Equine College and Equine Research of MTT) and Jokioinen.

			pH	El. cond.	C	N	P	NH4N	NO3N	Ca	K	Mg	P	S	Na
			H2O (1:2,5)	10 -4 S/cm	% of air dry soil	% of air dry soil	g/kg soil (total)	mg/l soil 2 M KCl extr.	mg/l soil 2 M KCl extr.	mg/l soil, AAAc extr.	mg/l soil, AAAc extr.	mg/l soil, AAAc extr.	mg/l soil, AAAc extr.	mg/l soil, AAAc extr.	mg/l soil, AAAc extr.
1	Ypäjä	0-20	5,88	0,75	2,83	0,19	0,67	3,37	1,77	1227	231	256	7,32	19	16,9
		20-40	6,09	0,76	2,98	0,18	0,52	2,55	1,19	1127	139	216	5,2	21,9	22,2
		40-60	6,21	0,35	1,77	0,08	0,39	0,58	0,64	811	81	109	5,99	9	12,6
		60-80	6,23	0,3	0,71	0,03	0,38	0,45	1,72	549	67	47	6,58	6,8	9,8
		80-100	6,22	0,29	0,75	0,02	0,26	0,16	2,05	471	42	40	2,08	8,1	7,8
2	Ypäjä	0-20	6,6	2,03	9,05	0,52	1,55	10,60	2,67	1538	700	338	98,87	17,9	37,6
		20-40	6,59	0,7	3,37	0,2	1,48	16,18	1,32	1913	507	386	16,08	13,7	27,5
		40-60	7	0,69	0,55	0,04	0,53	3,86	1,88	1974	237	624	3,29	9	33,2
		60-80	7,09	0,36	0,41	0,03	0,63	0,33	1,40	2257	210	832	2,25	8	40,5
		80-100	7,25	0,31	0,29	0,02	0,68	0,20	0,55	2086	168	810	1,59	5,8	44,8
3	Ypäjä	0-20	5,98	3,48	4,05	0,28	1,63	16,34	72,38	1700	664	362	23,89	31,9	31,6
		20-40	6,09	2,14	2,15	0,14	1,32	14,75	32,93	1789	333	411	16,68	18,2	30,9
		40-60	6,57	0,76	0,91	0,05	0,64	1,98	8,64	1559	132	462	4,55	10	28,7
		60-80	7,03	0,55	0,54	0,03	0,48	0,59	3,76	1394	89	543	1,57	7,5	28,6
		80-100	7,21	0,45	0,29	0,03	0,53	0,28	2,12	1899	123	979	0,77	10,6	39,1
4	Ypäjä	0-20	7,49	0,84	0,64	0,03	0,51	23,78	1,25	445	505	81	44,67	9,6	21,4
		20-40	7,99	1,91	3,01	0,15	0,67	103,60	0,79	2002	983	149	30,49	16,2	30,9
		40-60	7,84	2,57	2,63	0,18	1	258,30	0,13	2800	1564	150	18,92	20,7	37,3
		60-80	7,05	1,87	2,05	0,15	1,27	277,90	0,11	1879	1191	155	10,22	16,2	33,7
		80-100	7,74	1,29	0,83	0,11	0,41	226,40	0,03	3578	561	825	1,46	13,3	88,7
5	Ypäjä	0-20	6,7	1,01	2,37	0,14	0,64	12,32	0,64	712	544	155	21,95	10,7	14,3
		20-40	6,41	1,18	2,91	0,19	0,85	52,00	5,45	1351	534	255	12,61	21,6	21
		40-60	6,81	1,63	0,89	0,08	0,44	39,33	0,29	2264	307	994	1,5	17,6	45,5
		60-80	6,91	1,3	0,45	0,04	0,47	1,98	0,17	2554	201	1493	0,83	17,6	67,3
		80-100	6,85	1,82	0,33	0,03	0,56	0,87	0,23	2338	209	1542	0,69	16,1	71,2
6	Ypäjä	0-20	6,83	1,3	3,87	0,14	0,68	27,56	0,84	678	513	160	33,98	8,8	23,8
		20-40	6,53	1,85	9,97	0,38	0,88	166,10	0,01	946	948	212	10,91	14,1	34,9
		40-60	6,14	1,67	2,32	0,17	0,76	260,30	0,00	1047	697	250	7,22	18,1	32,7
		60-80	6,48	1,29	1,03	0,1	0,5	135,30	0,12	2234	293	942	1,64	12,4	61,1
		80-100	7,06	1,29	0,53	0,04	0,58	25,29	0,02	2582	201	1182	1,2	8,8	62,4
7	Ypäjä	0-20	6,23	0,51	2,45	0,16	0,53	6,11	1,74	863	238	100	12,36	10,6	8,1
		20-40	5,94	0,41	1,82	0,1	0,4	2,13	3,68	592	130	73	10,25	9	7,8
		40-60	5,91	0,31	1,21	0,06	0,51	0,72	4,80	537	77	57	15,82	8,5	6,5
		60-80	6,03	0,28	0,57	0,02	0,36	0,61	2,78	346	51	30	13,03	6,7	8,6
8	Ypäjä	0-20	7,19	0,73	0,7	0,03	0,78	1,80	1,29	387	545	118	60,83	4,6	30
		80-100	6,34	0,79	0,41	0,03	0,45	0,31	3,10	221	202	32	4,22	24	20,7
9	Ypäjä	0-20	6,84	0,76	0,63	0,04	0,64	2,31	2,29	390	344	100	13,26	7,8	29,6
		40-60	6,21	0,81	0,69	0,04	0,47	4,92	3,94	373	157	77	4,88	16,5	24,2
		60-80	6,34	0,42	0,85	0,1	0,52	6,19	2,19	303	198	65	6,09	11,9	22,6
		80-100	5,48	0,77	1,84	0,12	0,45	9,06	3,27	411	90	60	3,3	26,2	19

Appendix 3. (cont.)

			pH	El. cond.	C	N	P	NH4N	NO3N	Ca	K	Mg	P	S	Na
			H2O (1:2,5)	10 -4 S/cm	% of air dry soil	% of air dry soil	g/kg soil (total)	mg/l soil 2 M KCl extr.	mg/l soil 2 M KCl extr.	mg/l soil, AAAc extr.	mg/l soil, AAAc extr.	mg/l soil, AAAc extr.	mg/l soil, AAAc extr.	mg/l soil, AAAc extr.	mg/l soil, AAAc extr.
10	Ypäjä	0-20	5,59	0,57	4,29	0,3	1,12	3,21	2,40	863	223	112	8,78	16,8	8,7
		20-40	5,64	0,37	2,73	0,18	0,84	2,24	1,89	623	141	79	7,76	18,7	7,4
		40-60	5,79	0,28	1,46	0,09	0,7	1,10	0,92	374	113	53	6,71	16,8	8,7
		60-80	5,81	0,26	1,33	0,08	0,72	1,28	0,76	377	125	51	7,73	16,2	7,7
		80-100	5,86	0,14	0,39	0,02	0,5	0,44	0,57	113	106	19	8,18	11,3	6,7
11	Ypäjä	0-20	6,4	1,03	3,85	0,27	2,06	2,74	2,51	2313	866	390	28,01	14,6	22
		20-40	6,63	0,63	2,38	0,16	1,39	1,67	1,51	2458	504	565	18,31	9,4	22,8
		40-60	6,91	0,69	1,44	0,07	0,71	0,51	0,35	2721	386	1102	2,82	12,4	39,9
		60-80	7,09	1,51	0,52	0,05	0,76	0,53	0,15	2674	316	1394	1,1	13,5	54
		80-100	7,31	1,56	0,44	0,04	0,81	0,63	0,12	2270	274	1364	1,18	12,5	55,8
12	Kuuma	0-20	6,15	2,84	2,64	0,19	0,92	39,57	2,19	1827	808	937	4,92	23,4	57,2
		20-40	6,89	1,73	0,61	0,06	0,63	2,87	0,23	2409	321	1749	0,41	15,6	80,5
		40-60	7,14	1,71	0,36	0,04	0,7	1,02	0,14	2481	288	1906	0,39	17,8	100,3
		60-80	7,19	1,87	0,27	0,04	0,68	0,89	0,37	2251	274	1676	0,44	17,3	89,7
		80-100	7,22	2,01	0,28	0,04	0,73	1,57	0,31	2380	292	1776	0,54	18,5	99,1
13	Jokioinen	0-20	6,21	1,36	1,94	0,13	1,06	3,46	2,98	2391	432	1307	2,44	12,4	63,3
		20-40	6,3	1,12	1,5	0,11	0,94	1,29	3,74	2464	359	1391	1,42	14,5	50,9
		40-60	6,24	1,5	1,06	0,08	0,8	0,96	3,68	2447	354	1480	0,61	15,1	50,4
		60-100	6,38	1,07	0,93	0,07	0,89	0,78	1,91	2391	343	1513	0,76	17,2	55,4
14	Jokioinen	0-20	6,76	0,9	1,37	0,06	0,43	10,24	1,07	364	460	124	17,57	5	15,5
		20-40	6,83	0,37	0,78	0,03	0,32	8,56	0,85	254	331	74	7,99	4,7	12,5
		40-60	6,17	0,48	0,58	0,06	0,55	12,84	0,03	1946	295	1316	0,37	15,6	78,3
		60-80	6,49	0,42	0,36	0,04	0,65	2,90	0,06	2285	272	1732	0,59	3,4	100,1
		80-100	6,86	0,25	0,33	0,04	0,75	0,81	0,01	2101	247	1598	0,55	1,7	92,4
15	Jokioinen	0-20	6,12	0,32	1,1	0,06	0,6	1,62	2,31	478	222	160	8,69	10,2	13
		20-40	5,89	0,44	0,96	0,07	0,61	2,11	2,36	1118	245	659	1,33	19,2	44,9
		40-60	6,11	1,45	0,56	0,06	0,59	5,14	7,94	2141	283	1536	0,35	10,9	88,6
		60-80	6,63	0,95	0,38	0,04	0,74	0,49	5,82	2135	289	1650	0,37	3,7	86,8
		80-100	7,03	0,31	0,33	0,03	0,73	0,48	3,14	1839	246	1470	0,31	3,1	73,1
16	Ypäjä	0-20	6,38	1,09	2,48	0,23	1,02	18,92	0,59	1089	748	235	16,41	17,7	21
		20-40	6,48	1,1	1,87	0,18	0,71	36,15	0,29	1545	593	360	5,8	21,2	28,1
		40-60	6,59	1,17	1,16	0,14	0,49	43,34	0,55	1946	380	667	2,1	24,1	43,8
		60-80	6,74	1,1	0,47	0,09	0,38	2,92	0,15	2650	246	1209	0,34	27,2	60
		80-100	6,67	1,14	0,35	0,08	0,57	1,42	0,05	2786	249	1462	0,38	26,2	69,4
17	Ypäjä	0-20	6,54	0,81	2,09	0,17	0,79	15,37	1,07	557,4	346	163	33,99	8,4	13,5
		20-40	6,51	0,93	1,2	0,13	0,68	63,76	0,24	1394	463	340	3,94	22,9	30
		40-60	7,08	1,03	0,61	0,1	0,48	5,05	0,28	2784	270	992	1,16	27,4	49,6
		60-80	7	1,09	0,44	0,08	0,66	3,08	0,13	3065	365	1244	1,45	26,5	65,9
		80-100	7,01	0,85	0,28	0,07	0,62	3,17	0,03	2287	232	1098	1,04	22,6	61,8