OECD Workshop

on the

Evaluation of Agri-environmental Policies

20-22 June 2011
The Johann Heinrich von Thünen Institute,
Bundesallee 50, 38116 Braunschweig, Germany

Monday, 20 June

Session 3b : 16h30-18h00

Follow-up Study on the Impacts of Agri-environmental Measures in Finland

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ABSTRACT

Since 1995 the agri-environmental policy has centred around the agri-environmental payments part-financed by the EU. Through the measures under this it has been possible to influence the relationship between agriculture and the environment. The present agri-environmental scheme is included in the Rural Development Programme for Mainland Finland (2007–2013), which both as such and through the legislation it is based on requires the follow-up of the impacts of the measures. One element in this work is the follow-up study on the impacts of agri-environmental measures (MYTVAS 3) implemented in 2008-2013.

The aim of the MYTVAS 3 follow-up study is to find out how the agri-environmental payments and various measures have influenced the state of the agricultural environment, how the payments have influenced the preconditions for farming activities and how the agri-environmental programme should be developed in order to improve its effectiveness. Key focus in the follow-up is on the impacts of agri-environmental payments on water loading and biological diversity.

As regards their primary impacts, measures with the highest potential for reducing nutrient loading on waters are the basic measures concerning fertilisation of arable crops and nature management fields and additional measures concerning plant cover and fertilisation. The best measures to enhance biodiversity in the agricultural environment are found among the contracts concerning special measures (management of traditional biotopes, promoting biological and landscape diversity, organic production, raising local breeds, cultivation of local crops) and non-productive investments (establishment of constructed wetlands, restoration of traditional biotopes).

The follow-up results show that, measured by nutrient balances, the nutrient loading potential of agriculture has been decreasing for the part of both nitrogen and, in particular, phosphorus. Primarily the reduction in nutrient loading potential has been due to the decrease in the use of artificial fertilisers. Instead, there are indications to the effect that leaching of nutrients of manure from clustered animal production units is becoming a more serious problem. This is why focus should be on measures which increase the utilisation of nutrients contained in animal manure as well as reduce the amounts of nutrients that end up in the manure.

The greatest threat to biodiversity derives from the trend in the landscape structure, where the most typical feature is the decrease in open or semi-open areas excluded from intensive agricultural use. The results of the follow-up study concerning special measures show, however, that locally biodiversity benefits have been achieved in areas where the measures have been implemented to a sufficient extent (traditional biotopes, wetlands, riparian zones, green fallow/nature management fields). This is why it is particularly important to ensure that, on the scale of open arable areas, sufficient proportional shares of areas excluded from intensive arable farming would be maintained in all farming areas.

As a general conclusion we can say that, due to the considerable regional variation in the state of farming environments and needs of the society, there is a need to adjust and customise the objectives, measures and support levels of the agri-environmental programme more according to the regions, production sectors and individual farms. To achieve this, all farms included in the agri-environmental programme should have a farm-specific environmental management plan that specifies the nature values and most significant environmental risks of the farm.

Key words: Agriculture, agri-environmental measures, biodiversity, environmental protection, erosion, fertilisation, follow-up of impacts, manure, nitrogen, nutrient balance, nutrient loading, nutrients, phosphorus, water protection.

1. INTRODUCTION

Modern societies direct various kinds of expectations to farming. Apart from producing food stuffs, agriculture should contribute to, for instance, the maintenance of managed and open landscapes, environmental quality and rural viability. Obviously, agricultural nutrient loading and greenhouse gas emissions have an impact on the quality of the agricultural environment. Biological diversity, in turn, interacts closely with agricultural production techniques, cultivation methods and land use. In developed countries, the significance of agri-environmental commodities and services as a joint-product of farming has been growing in the past twenty years and the importance of the public good aspect shows no sign of fading. For these reasons, it is essential that the relationship between agriculture and the environment is properly examined and various impacts of applied policy measures are cautiously followed up.

Since 1995 the Finnish agri-environmental policy has centred around the agri-environment measures part-financed by the EU. The present agri-environment scheme is included in the Rural Development Programme for Mainland Finland (2007–2013), which both as such and through the legislation that it is based on requires the follow-up of the impacts of the measures. One element in this work is the follow-up study on the impacts of agri-environment measures (so called MYTVAS 3) implemented in 2008-2013 and mainly financed by the Finnish Ministry of Agriculture and Forestry and partly by the Finnish Ministry of the Environment. The study is conducted by a consortium that is coordinated by the MTT Agrifood Research Finland (MTT) and, together with MTT, is comprised of the Finnish Environment Institute (SYKE), University of Helsinki (HY) and Finnish Game and Fisheries Research Institute (RKTL).

The aim of the MYTVAS 3 follow-up study is to find out how the agri-environmental measures have influenced the state of the agricultural environment, how the measures have influenced the preconditions for farming activities and how the agri-environmental programme should be developed in order to improve its effectiveness. Key focus in the follow-up is on the impacts of agri-environmental measures on nutrient loading to waterways and biological diversity.

The main objective of this paper is to summarize preliminary key results of the MYTVAS 3 follow-up study and, based on them, to assess the effectiveness of the agri-environmental measures. In addition, the purpose is to describe at a general level the content of the current Finnish agri-environmental scheme. Finally, the idea is to discuss about the possible policy implications of the observations and conclusions made.

However, when assessing the results presented or making recommendations for new or re-designed measures, it should be born in mind that the follow-up data may indicate that something has taken place but not necessarily the exact cause of the event. It is not always possible to show that certain trends would specifically be the outcome of the present agri-environmental programme and the application of measures under it. The time lag between a measure and observed impact is often long and the cause-effect relations are complex or partly unknown. In addition, the other aspects of agricultural policy and changes on the market influence the state of the agricultural environment either directly or indirectly.

3. THE CURRENT FINNISH AGRI-ENVIRONMENTAL PROGRAMME AND THE MONITORING OF IMPACTS

The objective of the current Finnish agri-environmental programme is to enable sustainable agricultural and horticultural production so that the environmental burden caused by production is reduced from its current level. Agri-environmental payments help to diminish the negative environmental impact of agriculture, secure the biodiversity of agricultural environment and the cultural landscape in rural areas, and maintain the preconditions for agricultural production even in the long term. The burden on the environment and particularly on surface and ground water is diminished by increasing the use of plant nutrients, decreasing the risks caused by the use of pesticides, ensuring the biodiversity of the agricultural environment, and caring for the fauna, the flora and the rural landscape. Objectives also include a reduction in the erosion of arable land, an increase in the diversity of soil fauna and the amount of humus and the maintenance of the productivity of soil or its increase.

Structure and measures of the Finnish agri-environmental programme

The Finnish agri-environmental programme consists of basic measures, additional measures and special measures. Payments vary according to measures and assisted regions. The purpose of basic measures is a systematic monitoring of farming and its environmental protection, the fertilisation of field crops and horticultural plants according to the fertility of the soil and the needs of the plant species in question, the reservation of wider headlands and an establishment of broader set-aside margins by water channels than what is provided for in the water law as well as the care for biodiversity and the maintenance of landscapes. The basic measures are obligatory for all farmers who participate in the agri-environmental programme.

In addition to basic measures, the agri-environmental programme includes a number of more demanding additional measures that are optional to farmers depending on the assisted region in question. There are additional measures for both regular field crops and horticultural plants. Additional measures include reduced fertilisation, adjustment of nitrogenous fertilisers for field crops, enhanced vegetal cover on arable land during winter, cultivation of catch crops, observation of nutrient levels, diversification of farming, extensive grassland production and the application of manure during the growing season.

The compensation for basic and additional measures is paid for the farm's entire arable land area eligible for agri-environmental payments, provided that both cross-compliance requirements and minimum requirements are complied with. The minimum requirements include the maximum limits for nitrogenous and phosphate fertilisers as well as the conditions for the use of plant protection products.

Special measures are measures with a particularly significant impact on the quality of the agricultural environment. These measures can concern, for example, the establishment of a buffer zone or a creation of a multi-functional wetland, field cropping on underground water basins, treatment methods of runoff waters, organic production, raising of native breeds, farming of original plant species or management of traditional biotopes. The compensation paid in the context of special measures is linked to area or animal unit. It is also possible to include non-arable land in some agreements.

The participation of farmers in the agri-environmental programme is extensive. In March 2010, about 58,100 farms, or 90 percent of all farms (64,000), were committed to the basic agri-environmental measures defined for the programming period 2007-2013. About 70 percent of these farms were cropping farms and 30 percent were livestock farms, and their committed area totalled 2,112,000 hectares (about 92 percent of the total cultivated arable land of 2,296,000 ha). In 2009, the total payment for basic measures was EUR 220 million and the total payment for additional measures was EUR 72 million. The total amount of compensation paid in the context of special measures was EUR 48 million in 2009. In other words, the grand total of agri-environmental payments was about EUR 340 million.

Monitoring of impacts

The purpose of the MYTVAS 3 follow-up study is to continue the efforts of previous follow-up studies. The object of the first MYTVAS follow-up study (MYTVAS 1), commenced in 1995, was to study the impact that the various measures associated with agri-environmental programme had on the environment and the environmental burden caused by agriculture. The MYTVAS 1 study was complemented with a project during which the financial significance of agri-environmental payments was monitored.

The final report (Palva et al. 2001) of the MYTVAS 1 study that took place between 1995 and 1999 concluded that the use of nitrogenous and phosphate fertilisers decreased and was, in most cases, approaching the (then) baselines defined for agri-environmental payments. However, the amount of phosphate fertilisers was not yet adjusted precisely enough to correspond to the fertility of the soil. The leaching of nitric nitrogen was estimated to have decreased by 4 to 15 per cent in different areas, which was mainly attributed to a decrease in the amount of nitrogenous fertilisers and livestock manure applied on the land. Furthermore, it was estimated that the leaching of phosphorus erosion was diminished by 5 to 13 per cent mainly due to the introduction of reduced tillage and spring ploughing. On the contrary, soluble phosphorus levels persisted or rose slightly, principally because the diminished set-aside obligation in 1994 led to a decrease in the use of the procedure known as green fallowing and an increase in the cultivation of cereals.

A financial analysis revealed that the importance of GAEPS support (General Agri-Environmental Protection Scheme) for the total income of Finnish farmers was significant in all assisted regions, types of farming and farm size categories. It was estimated that 62 percent of the GAEPS support was spent on the costs caused by the agri-environmental measures, and 38 percent remained as a financial incentive. Therefore, it was concluded that the termination of the agri-environmental programme would mean serious financial difficulties for the majority of farms, unless a new, corresponding scheme was initiated (Koikkalainen et al. 1999).

In the MYTVAS 2 follow-up study (2000-2006), the impact on water bodies and biodiversity was analysed in two separate reports. The final report on the impact on water bodies (Turtola and Lemola 2008) concluded on a general level that a more effective reduction of the burden caused on water bodies would require the reallocation of future measures on the areas where the burden is greatest, and the priority should particularly be on diminishing the burden in the livestock production areas in the south-western and western Finland.

The final report on biodiversity impact (Kuussaari et al. 2008) reached the following two main conclusions: firstly, the impact of the agri-environmental measures had been positive, even if it was not able to stop the impoverishment of the agricultural environment, and secondly, the most important biodiversity-promoting measure contained in special measures was considered to be the management of traditional biotopes. The report concluded that the structure of the agri-environmental programme should be reformed, particularly with respect to obligatory basic and additional measures, and that agri-environmental measures should be complemented with new, more effective biodiversity conservation methods.

The results and conclusions of previous MYTVAS follow-up studies reflect the changes that have taken place in agri-environmental measures, agricultural environmental policy and general agricultural policy. Initially, the agri-environmental programme was also a method of securing farmers' income when the EU membership in the beginning of 1995 destroyed overnight the cornerstone of national agricultural policy, that is, the price support system that rested on strong border protection (Aakkula et al. 2006). After that, the demands concerning the environmental impact of the agri-environmental programme have been incrementally increased. By now, the agri-environmental programme in particular and agricultural environmental policy in general is expected to have a significant effect on the environment.

3. NUTRIENT LOADING AND ITS IMPACTS ON WATER QUALITY

Today, a major goal of national water protection policy in Finland is in controlling agricultural nutrient losses as crop production and animal husbandry comprise the largest source of nutrients into surface waters. Phosphorus (P) is transported from fields in dissolved form and as attached to eroded soil particles. Transport of this particulate phosphorus is regulated e.g. by soil texture, slope and vegetation cover, whereas transport of dissolved phosphorus is governed by soil phosphorus status, and methods and amounts of fertilization and manure spreading. Nitrogen (N) is mainly in easily soluble form, and its losses are regulated mainly by methods and amounts of fertilization and manure spreading. Soil contains large amounts of organically-bound nitrogen, so transfer is also regulated by decay of organic matter.

Maximum fertilization rates for different crops are set in the basic measures of the agri-environmental programme. In special measures, there are additional options to reduce fertilization. Further, manure use and handling are controlled by the nitrate directive and agri-environmental programme (basic, additional and special measures). Erosion control measures in agri-environmental programme include wintertime vegetation cover and reduced tillage. In addition, constructed wetlands and buffer zones (15 m wide) defined in special measures serve this purpose.

In the MYTVAS 3 study, nutrient loading to the surface waters were followed by using two methods. First, we have followed development of selected indicators (nutrient balances and soil test P value) of nutrient load. Second, we have calculated trends in nutrient fluxes from agricultural rivers based on observed discharge and nutrient concentration. Changes in indicators and river nutrient fluxes were compared to changes in agricultural practices and water protection methods by regression analysis (Penttilä et al. 2006). To distinguish effects caused by agri-environmental measures from those caused by other, partly independent factors, we also included changes in climate and land use in the analysis.

While implementing the agri-environmental measures on fields, the total area of cultivated fields has been changing due to other factors, like changes in CAP policy and market prices. Further, changing climate is assumed to increase nutrient load by increasing runoff and temperature. So far, no increasing trend in annual or seasonal runoff has been detected (Korhonen 2007). On the other hand, increase in annual temperature is detected (Tuomenvirta 2004), which may have increased soil organic matter decomposition.

Changes in indicators: nutrient balances and soil phosphorus status

In the MYTVAS 3 study, development of areal nutrient balances and soil phosphorus status (soil test P value) serve as indicators of nutrient loading from fields (Uusitalo 2004, Rankinen et al. 2007). Fertilization and yield uptake are the main factors influencing nutrient balances. National and areal nitrogen and phosphorus balances were calculated for the period 1990-2009. Use of commercial fertilizers has decreased considerably in Finland in 1990-2006. In 1990, nitrogen use was 112 kg/ha and phosphorus use 30.7 kg/ha. In 2007-2009, the average nitrogen use was 73 kg/ha and that of phosphorus only 7 kg/ha.

Both nitrogen and phosphorus balances have been decreasing since 1990 (Figure 1), mainly due to decrease in commercial fertilizer use. In recent years the yield uptake has also increased in southern Finland. At the same time, there has been a change in crops; since 1995 the area of cereals has steadily increased. Moreover, during 1990-1994 the area of fallow was highest due to obligatory set-aside intended to reduce overproduction.

Nutrient balances decreased most in the Vuoksi catchment. Nutrient balances were highest in the areas of high domestic animal density. In the Bothnian Bay drainage basin both nitrogen and phosphorus balances were above the mean of Finland. Even though total number of domestic animals is steadily decreasing in Finland, animal husbandry is intensifying in south-western and western Finland. In some areas nutrients in manure alone were sufficient to cover crop need. The highest amount of phosphorus in manure was applied in the Bothnian Bay catchment (about 11 kg/ha). Nitrogen balance was higher than the average in the Archipelago Sea catchment. This is the only area where decrease in commercial N fertilizer use is not seen since 1995.

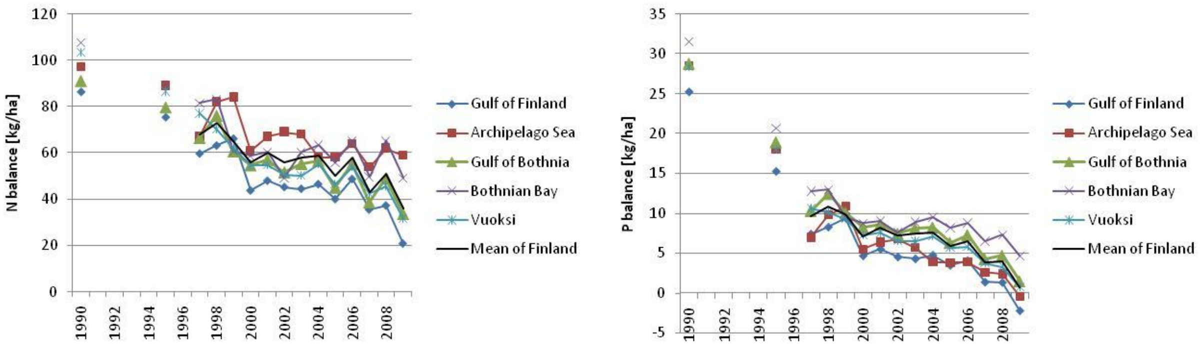

Figure 1. Change in nutrient balances in Finland a) nitrogen, b) phosphorus.

Effect of decreasing phosphorus balance is gradually reflected to soil test P values which were decreasing, except in the Archipelago sea catchment, where the mean values were higher than elsewhere (Figure 2). In regression analysis there were positive correlation between soil test P values and areal percentage of high-value crops, which usually have high fertilization levels. Another positive relationship existed between soil-test P and the amount of manure spread on the fields.

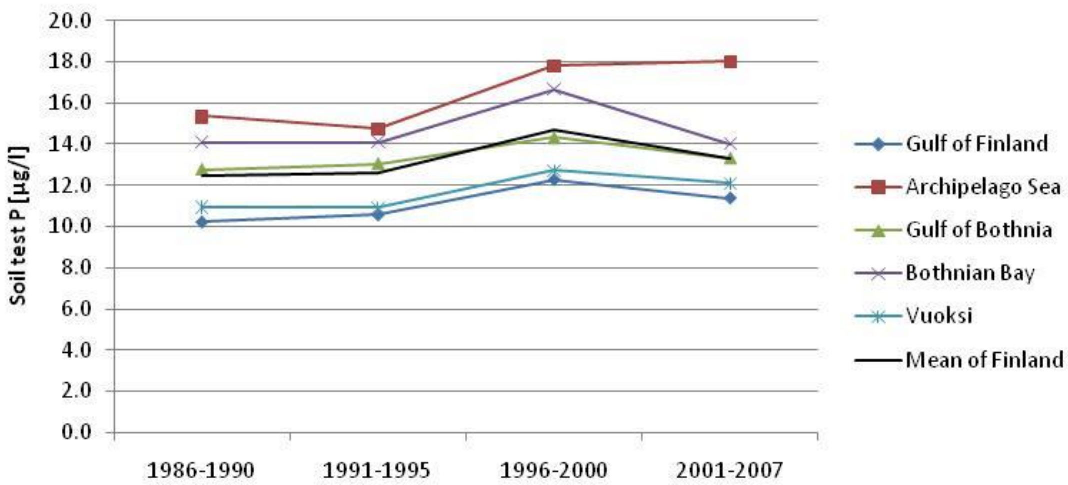

Figure 2. Change in soil test P values in Finland.

Changes in nutrient fluxes from rivers

We studied nutrient (N and P) loading and changes in land use and agriculture in 22 rivers discharging into the Baltic Sea. Areas of river basins ranged from 357 to 4923 km^2, field percentage from 1.3 to 42.8 and lake percentage from 0.2 to 12.9. The remaining areas in the basins were mainly forests. Daily discharge and the concentrations of total phosphorus and total nitrogen were taken from the data base of the Finnish Environmental Institute. We divided the samples in four sets representing the periods 1985-1989 (I), 1990-1994 (II), 1995-1999 (III) and 2000-2006 (IV). Periods I and II served ad background for the first and second agri-environmental programme periods (1995-1999 and 2000-2006, respectively). Nutrient concentrations were simulated by a regression model (Wartiovaara 1975; Sjöblom 2008). Daily nutrient loads were calculated from simulated concentration and observed discharge.

The highest nutrient load (t/a) occurred in the large rivers discharging into the Bothnian Bay. Specific tot-P load (kg/km2/a) was clearly highest from the river basins with high proportion of fields flowing to the Archipelago Sea. Specific tot-N load (kg/km2/a) from these river basins was also high (Figure 3).

a) b)

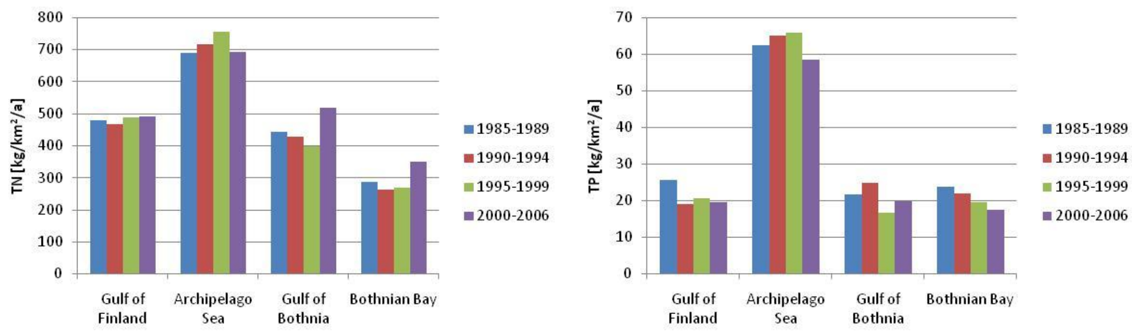

Figure 3. Specific nutrient loads in drainage basins a) total nitrogen, b) total phosphorus.

To calculate trends in agricultural nutrient loads we equalized the effect of discharge and removed the effects of municipal and industrial waste waters, waste waters from scattered settlements, and nutrient loads from forest treatment areas. Remaining nutrient flux originated mainly from agricultural areas. During 1985–2006, there was a decrease in phosphorus loads (on an average 17%) but an increase in nitrogen loads (27%). No decrease in phosphorus loads was found in the rivers discharging into the Archipelago Sea (Figure 4). Increase in nitrogen load was highest in drainage basin of Bothnian Bay. The results were in accordance with the trend analysis by Ekholm et al. (2007).

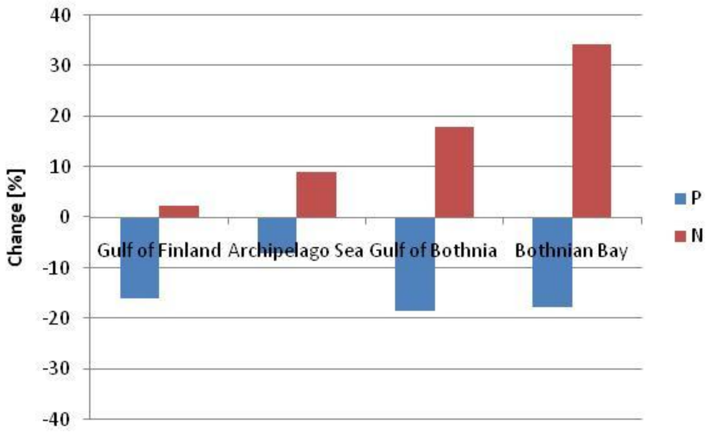

Figure 4. Change in nutrient loads from agriculture.

Field area, lake percentage and runoff had the highest impact on annual nutrient loads, so these were standardized before studying the effect of other factors. Despite these phosphorus load was explained by the soil test P value and nitrogen load by the percentage of organic fields and the amount of nitrogen added in manure. Area of fallows is related to decrease in nutrient load. Area of grass is related to decrease in phosphorus load only in drainage area of Gulf of Finland and Archipelago Sea, but otherwise increase in nutrient loads.

Nitrogen load to the Bothnian Bay and the Gulf of Bothnia was explained by nitrogen balance but that to the Archipelago Sea and the Gulf of Finland only by yield uptake of nitrogen.

Decrease in phosphorus load was mainly explained by increased area of fallows during some periods (1990-1994), and decrease in soil test P value. Grass cultivation may have served as erosion protection method in erosion prone fields in drainage basin of Archipelago Sea. Increase in nitrogen load seems to be due to a recent increase in field area and intensification of animal husbandry. Further, observed increase in temperature may have increased nitrogen load. On the other hand, most of the study catchment located in the drainage basins of the Archipelago Sea and the Bothnian Bay, where N balances stayed above the average of Finland.

Archipelago Sea is sensitive sea area, and nutrient loading from Finland has highest impact. Nitrogen load increased to the Bothnian Bay which is phosphorus limited and effect is not seen there as deterioration of water quality. On the other hand excess in nitrogen may be transferred to southern areas of Baltic Sea, which are partly nitrogen limited.

6. BIODIVERSITY IMPACTS

Two types of studies have been conducted within the MYTVAS 3 project in order to examine the biodiversity impacts of the agri-environment scheme, monitoring of the trends in farmland biodiversity and case studies evaluating the impacts of specific agri-environmental measures.

Monitoring of farmland biodiversity

Monitoring of farmland biodiversity has focused on five indicators which complement each other: arable weeds, vascular plants and butterflies of open semi-natural habitats, farmland birds and landscape structure. Below we briefly describe the approaches used to monitor these indicators and summarize the main observed trends.

Diversity of arable weeds of Finnish agricultural landscapes has been surveyed four times in about ten-year intervals in 1961-1964, 1982-1984, 1997-1999 and 2007-2009 (Salonen and Hyvönen 2010). Each of these surveys has sampled 300-700 field parcels in 150-300 farms located in different parts of southern Finland. The last survey indicated a slight decrease in average weed species richness compared to the previous survey ten years earlier: in organic fields a decrease from the average of 24 to 21 species/field parcel and from 16 to 12 species in conventional spring barley fields. The arable weed indicator (Hyvönen and Huusela-Veistola 2008) showed that despite of a slight increase in average weed densities the index values of weeds for seed-eating birds and herbivore insects had decreased, whereas at the same time the index values of weeds for pollinator insects had continued to slightly increase (Figure 5).

The other four farmland biodiversity indicators have been monitored within a common study design which is based on a set of 58 agricultural landscapes distributed within four geographic areas in southern Finland. Landscape structure of the 1 km^2 study landscapes has been monitored since 1990, whereas vascular plants, butterflies and farmland birds have been monitored since 2001.

Somewhat differing trends have been observed in different indicators. In landscape structure the long-continued simplifying and generally negative trend for biodiversity still continued during 1990-2005. This was seen in on average decreasing coverage of semi-natural habitats such as semi-natural grasslands and field margins in all studied geographical regions due to further agricultural intensification and ceasing of traditional management of semi-natural grasslands (Kivinen et al. 2008). The slight impoverishment of plant communities in field margins detected during 2001-2010 (Helenius et al. 2010) was probably related to the long-term negative trend in landscape structure. Also in butterflies the trend was on average slightly negative: one half of the species decreasing, whereas one third of the species increasing during 2001-2010 (Heliölä and Kuussaari 2010). In contrast to plants and butterflies, in farmland birds the observed trends were generally positive. The long-continued impoverishment of farmland bird communities had stopped, and species of forest-field ecotones and farmyards had on average increased during the last ten years (Tiainen et al. 2010). Farmland birds had probably benefited from the relatively high area of rotational fallows and long-term set-asides during the study period.

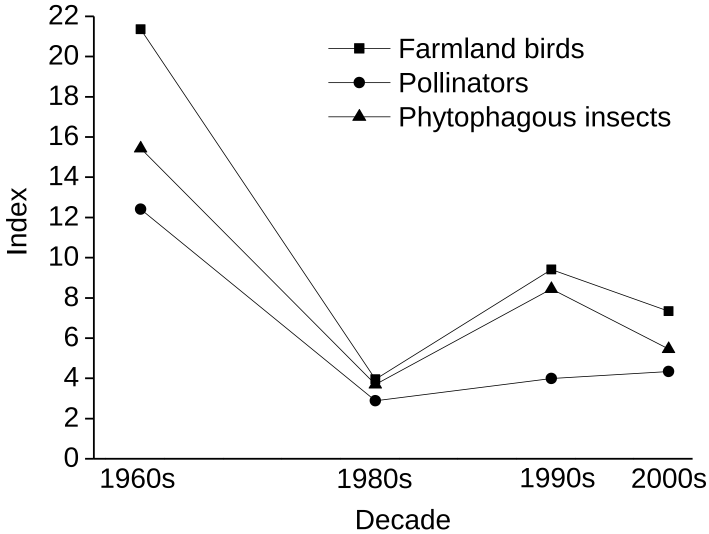

Figure 5. Development of the Finnish arable weed indicator during 1960-2010 (Hyvönen and Huusela-Veistola 2008, Salonen and Hyvönen 2010).

Case studies on the impacts of specific measures

During 2007-2009 three case studies were conducted to evaluate biodiversity impacts of specific Finnish agri-environment measures. The main findings of these studies are briefly summarized below.

Constructed wetlands

The aim of the construction of wetlands in the Finnish agri-environment scheme is both to reduce nutrient loading on waters and to promote maintenance of biodiversity. A total of 19 constructed wetlands were studied in Uusimaa district in southern Finland in summer 2008 in order to evaluate the significance of this special measure for wetland biodiversity (Heliölä et al. 2010a). Dragonflies were studied as an indicator group for species dependent on small-scale wetlands.

The results showed that this measure clearly benefits wetland biodiversity and they can be summarized as three main findings (Heliölä et al. 2010a). First, dragonflies were significantly more species-rich and abundant in the constructed wetlands than in other potential dragonfly habitats typically existing in the studied agricultural landscapes (i.e. different kinds of ditches; Figure 6).

Second, the environmental variable best explaining the variation in species richness and abundance of dragonflies was the coverage of water plants with floating leaves. It correlated positively with dragonfly species richness and abundance together with the permanence of water, whereas muddiness of water showed a negative correlation with dragonfly occurrence. Third, and as the most important applied result, the size of the wetland did not correlate with species richness of dragonflies. This means that even small constructed wetlands can have a high species richness of dragonflies. This finding suggests that economic support would be well-justified also for small constructed wetlands which do not have the capacity to significantly reduce nutrient loading.

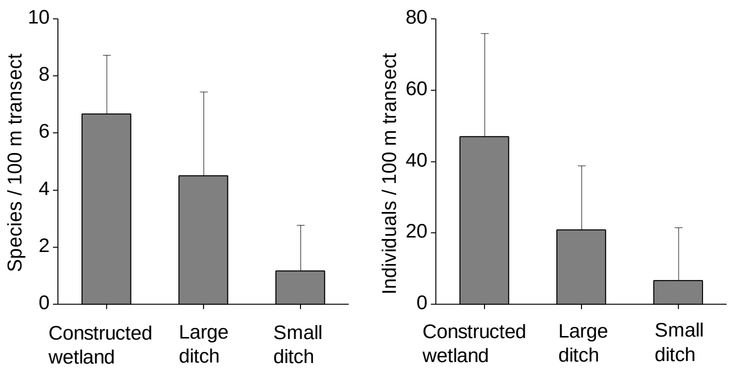

Figure 6. Average species richness (+ standard error) and abundance of dragonflies in constructed wetlands and in the compared habitats, large and small ditches (Heliölä et al. 2010a).

Buffer zones

The aim of establishing >15 m wide buffer zones along waterways is primarily to reduce nutrient loading on waters but also to promote maintenance of biodiversity. The effects of buffer zones on biodiversity were studied in a case study of 21 buffer zones of differing age in southern Finland in summer 2009 (Heliölä et al. 2010b). Vascular plants and day-active Lepidoptera (butterflies and moths) were studied as biodiversity indicators. Their species richness in buffer zones was compared to other linear uncultivated semi-natural habitats available in the study landscapes, i.e. forest edges and field margins, and particularly the field margin between the studied buffer zone and the neighboring waterway.

There were two main results (Heliölä et al. 2010b). First, the average species richness of both plants and Lepidoptera was lower in the buffer zones than in the neighboring old field margins and other uncultivated semi-natural habitats within the study landscapes. Second, species richness of both study groups increased with the time elapsed after the buffer zone establishment (Figure 7).

Plant species richness increased linearly until it reached the level of species richness observed in the neighboring buffer zones in ca. 10-year old buffer zones after which the increase leveled off. In Lepidoptera both species richness and abundance increased linearly throughout the studied buffer zone age classes. Also butterfly species richness reached the level of the neighboring field margins in ca. 10 years. Lepidopteran richness was also positively affected by nectar plant abundance and vegetation height. The results indicate that wide buffer zones can significantly promote farmland biodiversity, if they are kept in the same locations at least for 10 years.

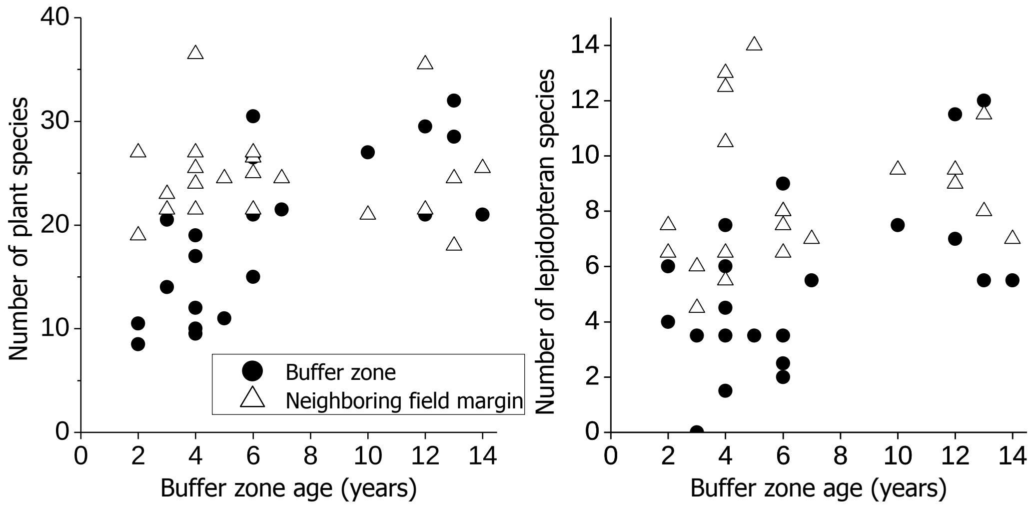

Figure 7. Plant and lepidopteran species richness in the >15 m wide buffer zones plotted against buffer zone age (black dots). Open triangles show the corresponding values for the neighboring uncultivated old field margin (Heliölä et al. 2010b).

Long-term set-asides

Finnish agri-environment scheme promotes establishment of green fallows and set-asides via a measure called environmental fallow which offers economic support for the establishment of varying kinds of green fallows including differently established long-term set-asides. The biodiversity effects of long-term set-asides were studied experimentally in a six-year field experiment during 2003-2008 (Hyvönen et al. 2010, Alanen et al. 2011, Hyvönen and Huusela-Veistola 2011). Here we report how two pollinator groups, bumblebees and day-active Lepidoptera, responded to the succession of set-asides sown with three different seed mixtures: a standard mixture with competitive grasses and red clover and two alternative mixtures based on non-competitive grasses and nectar plants (Alanen et al. 2011). The pollinators were monitored in 24 large treatment plots (50 m x 50 m) and on 10 surrounding field margins.

The responses of the two pollinator groups to set-aside creation were distinctly different (Figure 8; Alanen et al. 2011). Social bees, whose abundance peaked during the first year of set-aside succession, were more abundant on set-asides than on field margins during the entire experiment. In contrast, it took Lepidoptera three years to reach the abundance of the field margins, whereas the corresponding species richness level was not reached.

Both pollinator groups responded positively to the diverse seed mixture with nectar and pollen plants. The preference of the other two seed mixtures was similar in the two groups, the mixture with less competitive grasses generally outperforming the competitive grass mixture. The results indicate that pollinators in agroecosystems can be supported by long-term set-asides. Set-aside establishment by sowing a seed mixture of non-competitive grasses containing nectar and pollen plants is recommendable. It is possible to enhance bumblebees even on short-term set-asides. Lepidopterans, in contrast, responded much more slowly, their occurrence being strongly driven by the availability of larval food plants together with adults´ nectar resources. Supporting lepidopteran diversity therefore requires long-term set-asides of several years.

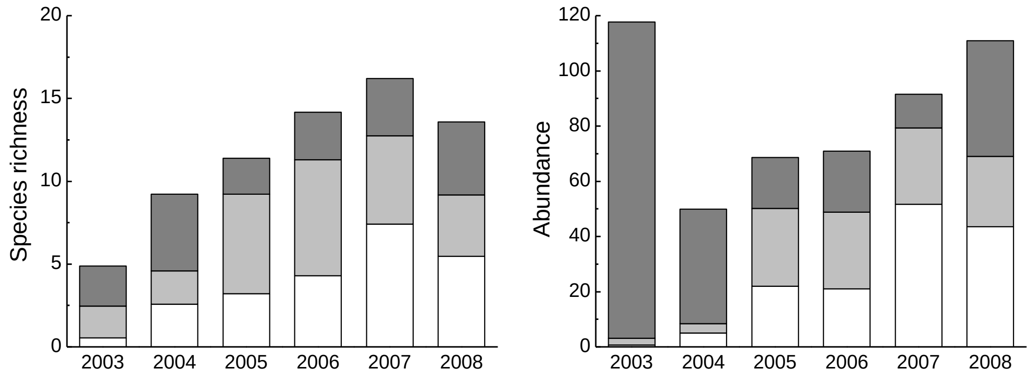

Figure 8. Development of pollinator species richness and abundance in the long-term set-aside experiment during six years after the set-aside establishment (Alanen et al. 2011).

7. SUMMARY, DISCUSSION AND POLICY IMPLICATIONS

Nutrient load

In general, the agricultural nutrient load potential measured in nutrient balances has decreased constantly. The decrease can be attributed primarily to the reduction in the use of artificial fertilisers. There is, however, some evidence that especially clustered livestock production units in some regions pose an increasing problem because of nutrient run-offs from manure. Thus, it is important to develop measures that increase nutrient recycling particularly by making a more efficient use of the nutrients contained in manure.

On the grounds of SYKE's statistical modelling approach based on water quality and flow data, it can be concluded that the flux of phosphorus from river basins to the Baltic Sea decreased during the analysis period (from 1985 to 2006) in all areas except the Archipelago Sea. The result points to the same direction as the development of soil phosphorus status, indicating that the content of readily soluble soil phosphorus had started to decrease in all catchment areas except that of the Archipelago Sea.

A partial explanation could be the relatively extensive farming area of high-value crops (potato, sugar beet, field-scale vegetables) in south-western Finland, combined with the fact that these crops have a considerably higher phosphate fertiliser allowance than herbaceous and cereal plants. Therefore, the reduction of the phosphate fertiliser allowance for special crops should be considered, as the maximum limits for these fertilisers are remarkably high compared to the average amount of phosphorus removed with yields.

On the contrary, nitrogen load increased in almost every modelled river basin, but particularly in Ostrobothnia. Apparently, the principal factors contributing to the rising nitrogen load are a local increase in the amount of arable land, the concentration of livestock production leading to a local growth in the volume of manure, an increase in the surface application of manure in certain areas and the change in the feeding of livestock in the direction which tends to increase the nitrogen content in manure. Another potential explanation is the higher soil temperature, believed to accelerate the decomposition of organic matter. Since the surface application of manure most likely contributes to the fact that the leaching of nitrogen has started to increase, the application of manure by injection during the growth season must be encouraged.

Interpretation of the results is made more difficult by the fact that the changes in nitrogen and phosphorus loads are caused by different reasons, as the behaviour of nitrogen and phosphorus in the soil differs from each other. The employed monitoring data is also problematic in some respects. A reliable definition of the phosphorus level trends determined on the basis of soil samples is made more complicated by the fact that the reliability of the soil samples available during the study period has not stayed on a constant level throughout the years. Furthermore, the interpretability of results from the perspective of the effectiveness of agri-environmental measures is weakened, because the modelling did not account for the analysis of the impact of many key agri-environmental measures, such as low-tillage cultivation, riparian zones and constructed wetlands, as there was no regionally consistent data available for the entire study period.

The key problem with the agricultural nutrient load is the long-term differentiation of livestock production and plant production, which has undermined the practicality of nutrient use. For this reason, there is a need for future measures with which the use of nutrients contained in manure and the recycling of nutrients in general can be improved in a versatile manner. In addition, more attention should be paid on requirements concerning manure application areas and animal density, because they are effective measures to regulate the number of animals in livestock farms and, consequently, the total amount of nutrients transferred through manure.

Biodiversity issues

Most special measures included in the Finnish agri-environmental programme aimed at conserving and increasing biodiversity have been effective as such, but the areas concerned have remained relatively small. The most important problem relates to basic measures which have a limited effectiveness from the perspective of biodiversity. The establishment of environmental fallows is the only basic measure with a significant impact on biodiversity, but even this measure is a voluntary one.

The management of field margins has only slightly increased the amount of open cultivated habitats and the maintenance of biodiversity and landscapes values has remained as an inefficient measure, because it does not include any obligation for a farm to carry out practical biodiversity-enhancing measures. Crop rotation is one measure through which the diversity of field cropping could be promoted.

The most important threat to biodiversity is caused by the development of landscape structure, typically involving a decrease in the area of open or half-open semi-natural areas excluded from actual cultivation. The clearing of field margins and ecological islands located within crop fields, drainage arrangements aimed at increasing arable area and all other rationalisation measures of cultivated areas are reducing of exactly those areas that are the most important from the perspective of the biodiversity of agricultural environment. This poses a clear inconsistency between the objectives of the agri-environmental measures and the agricultural policy in general, because public funds are also employed to support the rationalisation measures of cultivated areas. For this reason, the assessment of biodiversity impacts should also be included when the rationalisation of holdings is planned.

In case it is relevant to increase the size of plots in order to remove technical obstacles to farming caused by ditches etc., removed headlands should be replaced with biodiversity strips or other similar uncultivated areas so that the mix of cultivated and uncultivated areas would remain on a sufficient level within the farmed landscape. With careful planning, it would usually be possible to establish these replacement habitats in locations that are less valuable from the perspective of the arable land use.

In practice, it is difficult to increase the acreage of areas excluded from arable land use, unless basic measures are accompanied by minimum area requirements. A suitable relative share of areas excluded from arable land use should vary between 5 and 20 percent, depending on location, landscape structure, type of farming, type of production and cultivation practices. In this context, particular attention should be paid on the increase of grazing, which is essential from the perspective of biodiversity. Most importantly, the use of natural grazing areas should be increased. The primary measure to achieve this is the special measure for the management of traditional rural biotopes such as semi-natural grasslands.

General observations and recommendations

The results of the follow-up studies show that the development trends in the state of the environment vary according to region. Even if it is not possible to prove in an undisputable manner the impact of agriculture on the development in each region, it is clear that the production structure and, subsequently, the cultivation practices have a critical role. For this reason, the measures and support levels associated with the agri-environmental programme should be increasingly adjusted to the needs of each region, type of farming and individual farm. As this is not easy to achieve, particularly with respect to basic measures, the priority of the agri-environmental payments should be placed on special measures. The tailoring of agri-environmental measures for each farm would require farm-specific environmental management plans that the farmer would draw up together with an authorised expert. The farm-specific environmental management plan would outline the environmental values and risks of the farm and assess the agri-environmental measures that would best promote the conservation of natural values and the management of environmental risks.

The truly successful tailoring of the agri-environmental measures for each farm and region would require farm- and region-specific variation in support levels. A major problem from the perspective of incentives is the fact that EU rules define agri-environmental payments as compensation for the loss of income and additional costs incurred when measures are carried out. Even if a small incentive share would also be allowed, it is not possible to determine the amount of payments on the basis of the environmental gains acquired through the measures. An inevitable result is the lack of cost-effectiveness of agri-environmental measures in producing environmental benefits. Therefore, future steps should be taken to establish a system in which compensation levels could be defined on the basis of the value of the environmental benefits acquired.

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