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On production costs of biodiversity zones on arable land and in forests adjacent to fields

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Abstract

Biological diversity in agricultural environments has decreased as a result of intensified farming and monoculture. In the European Union, the measures of agri-environment support schemes aim at responding to this decrease, but novel and cost-effective measures to safeguard and conserve biological diversity are required.

This study compares costs and income losses incurred to a private landowner from biodiversity zones established on the border of a field and on the border of a forest adjacent to a field. The purpose of the biodiversity zone located in a forest abutting to a field is also to increase the diversity of species in the agricultural environment and to produce meadow-like habitats particularly suitable for pollinator insects offering ecosystem services to humans.

A biodiversity zone on the border of a field refers to a 25-m wide zone covered by perennial grasses. No pesticides or fertilisation are allowed on the biodiversity zone and the zone must be mowed annually. An alternative for the biodiversity zone established on a field is a biodiversity zone established in the border of a forest. This zone is also 25-m wide and it consists of a 5-m wide meadow-like treeless part and a 20-m wide transitional zone. The 5-metre wide zone closest to the field is immediately deforested and kept treeless with clearings repeated every 6-7 years. The 20-metre wide transitional zone deeper in the woods is thinned to the basal area of 8 m^2/ha and the trees of the transitional zone are managed with light selection fellings every 20 years.

Establishing and managing biodiversity zones incur extra costs and income losses. The zones decrease the landowner’s net income streams, since land previously used solely for agriculture (or forestry) is transferred to the joint production of crops and environmental benefits (or wood and environmental benefits). The production costs of biodiversity zones are calculated by subtracting the present values of net income streams of biodiversity zones from the present values of net incomes received of the corresponding fields and forests managed according to current practices and recommendations.

There was large variation in the amount of private costs and income losses caused by the biodiversity zones established in southern Finland. The costs of biodiversity zones on arable land depend on the productivity of the field and the price of crop originally cultivated. In forests, the variation in the production costs of pollinator habitats resulted from soil productivity as well as the structure and volume of trees at the starting point.

Currently, as the world market price of grain is low, it may often be viable for the landowner to establish biodiversity zones on the field rather than in the forest. In addition, biodiversity zones established on the field are also more easily returned to production than those established in the forest.

Key words: agri-environmental measures; biological diversity; forestry: production cost; public good

JEL classification: Q15, Q23, Q57

1. Introduction

Agricultural intensification i.e. increased mechanisation and farm size, simplification of crop rotations and loss of non-crop features are seen as the main causes of farmland biodiversity losses in Europe (Benton et al. 2003; Stoate et al., 2001). A considerable adverse effect caused by the intensification of agricultural production is the weakening of the living conditions of species important to the sustainability of agricultural production and the biological diversity, such as pollinator insects producing ecosystem services.

A private landowner does not usually have an incentive to perform measures enhancing biological diversity unless the government intervenes in the operations of markets. This is due to the fact that there is no market for biological diversity, since biodiversity is a public-type good the benefits of which come to everyone without pay and costs are left for their producers to pay. The government may change this setting with its actions. It can enforce citizens to pay (as taxes or other charges) on production of environmental goods and services and compensate (e.g. via agri-environmental payments) farmers for performing actions enhancing environmental quality.

Indeed, the agri-environment support scheme is a key policy instrument in preserving biodiversity on arable lands in the European Union. Still, at least in Finland, most agri-environmental measures are targeted at decreasing nutrient loads from fields to waterways. According to monitoring studies on the effects of the agri-environment support scheme, the current measures as a whole are inadequate and their effects are sometimes conflicting in relation to the conservation of biological diversity (Kuussaari et al., 2008). Furthermore, the measures of the agri-environment support scheme are stigmatised by inefficiency in relation to the amount of money spent on agri-environmental payments (Grönroos et al., 2007; Kuussaari et al., 2008). Therefore, it is important to know the production costs and the values of the public goods in order to be able to develop efficient policy measures (Wätzold and Schwerdtner, 2005).

This study compares the costs of two biodiversity measures from the viewpoint of a private landowner. The measures considered are a 25-m wide biodiversity zone established on the border of a field and a 25-m wide biodiversity zone established on the border of a forest abutting to a field. The purpose of the latter measure is also to increase the diversity of species in the agricultural environment and to produce meadow-like habitats particularly suitable for pollinator insects on the borders of forests abutting to fields.

To the best of our knowledge, the above mentioned test setting has not been analysed before. This set-up is particularly interesting in Finland, since we have plenty of forests but only short supply of fields[1]. Many Finnish farmers are also forest owners.

Biodiversity zones cause landowners income losses, because part of land used earlier for crop or wood production is now mainly devoted to the production of biodiversity goods and services. Furthermore, biodiversity zones require regular management which incurs annual costs to landowners. The hypothesis is that a rational landowner adopts the measure if agri-environment payments fully compensate the costs and income losses caused by the measure. Comparing the cost effects of alternative measures yields information for policy-makers on the level of required compensation. Furthermore, the aim of the study is to examine whether the biodiversity zones established in forests are less expensive than those established on fields. The effectiveness of

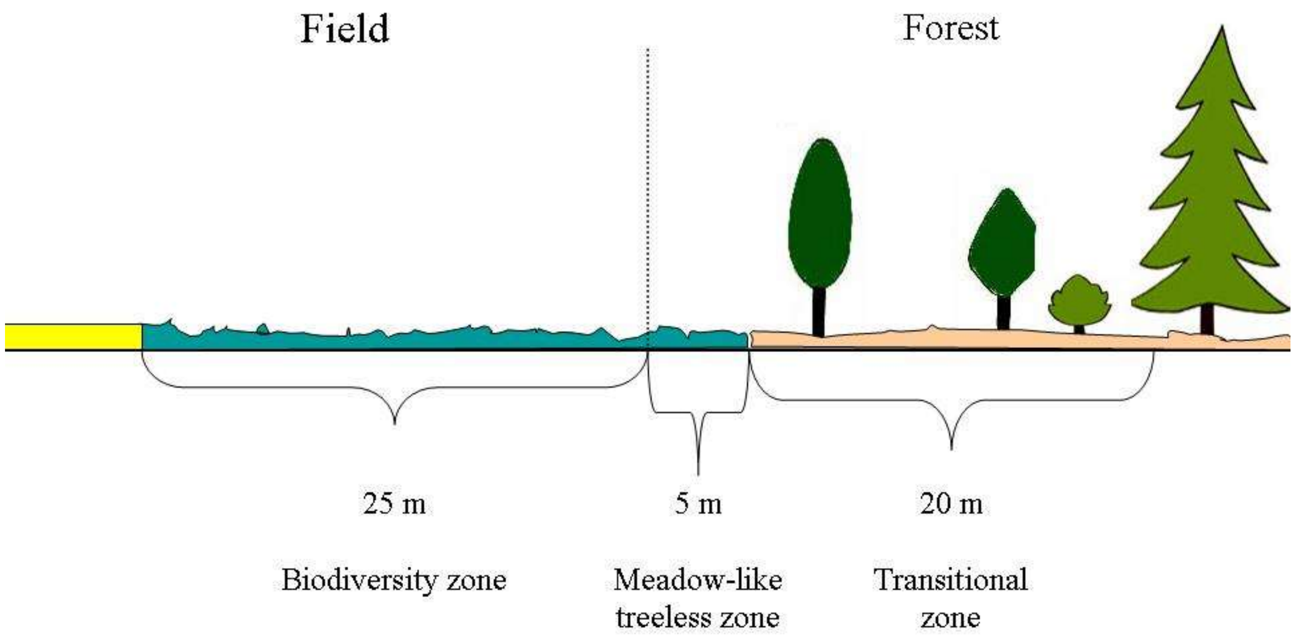
[1] The share of agricultural land is about 9% of the total land area and the share of forestry land is approximately 87% of the total land area of Finland (Finnish Statistical Yearbook of Forestry, 2009).

biodiversity zones is outside the scope of this paper, but it will be studied in detail from the viewpoint of pollinator insects in another project coming out later. At this point we briefly analyse another externality i.e. forest shading. This is because biodiversity zones in forests adjacent to fields let through more solar radiation and increase the yield of the field plot.

2. Material and methods

This study compares the costs and income losses incurred to a private landowner from biodiversity zones established on the border of a field and on the border of a forest abutting to a field. It is assumed that a rational landowner complies with the requirements of good agricultural and environmental conditions and the recommendations of forest management as well as maximises the present value of net income streams obtained from the field and forest hectares. Establishing and managing biodiversity zones incur extra costs and income losses and thus decrease the landowner’s net income streams, since land previously used solely for agriculture (or forestry) is transferred to the joint production of crops and environmental benefits (or wood and environmental benefits). The landowner’s costs and income losses can be calculated by subtracting the present values of net income streams of biodiversity zones from the present values of net incomes received of the corresponding fields and forests managed according to current recommendations.

Fig. 1 Biodiversity zones established on the border of a field and on the border of a forest



Biodiversity zones established on a field border and on a forest border are depicted in Fig. 1. The objective of both biodiversity zones is to conserve the biological diversity of farmland species and increase the amount of semi-natural habitats for pollinator insects providing valuable ecosystem services. To evaluate the costs, altogether 30 test plots were established in Jokioinen and Vihti in southern Finland.

2.1 Biodiversity zone on field

A biodiversity zone on the border of a field refers to a 25-m wide zone covered by perennial grasses or meadow plants (Fig. 1). The establishment costs of the biodiversity zone depend on the crop originally cultivated on the field. If the biodiversity zone is established on a cereal field, founding costs consist of tilling, sowing and seeds. Instead, if the biodiversity zone is set up on a grass parcel, there will be no establishment costs. In addition, it is assumed that, once established, the biodiversity zone will be kept on the field plot in future. Hence, the establishment expenses have to be paid only once.

In the profit margin calculations, no establishment costs were assumed for animal farms. Instead, it was assumed that the establishment of a biodiversity zone would cost €157.70 per hectare for crop farms.

No pesticides or fertilisation are allowed on the biodiversity zone. This restriction decreases the variable costs of biodiversity zones compared to conventional crop production.

Plants on the biodiversity zone must be mown annually. The timing of the mowing must take into account the living conditions of wild birds and mammals such that mowing will not be performed too early in the summer (before 1 August). To impoverish the biodiversity zone of nutrients, the plants mown must be cleared from the biodiversity zone and they can be used in agricultural production as animal feed. Hence, the management of biodiversity zones incurs annual costs, but some income may also be received if the mown plants can be used as silage or dry hay.

In the profit margin calculations, it was assumed that animal farms are able to utilise the hay harvest received from biodiversity zones, the yield of which is assumed 20 per cent of the normal silage yield. Instead, the harvest received from the biodiversity zone is assumed to be of no value on crop farms.

In addition, it was assumed in the profit margin calculations that single farm and natural handicap payments are also paid for the biodiversity zone established on the field. However, the assumption is that agri-environmental payments are only paid for the crop originally grown and not for biodiversity zones, since we try to evaluate the amount of agri-environmental payment required to make the farmer indifferent to choosing between the conventional good management of the field and the biodiversity zone.

The agricultural supports differs between test plots, since the test plots in Vihti situated within the support area A and those in Jokioinen are situated within the support area B. Furthermore, animal farms receive higher support than crop farms.

In addition to net income received from the biodiversity zone, the quantity of income losses caused by the biodiversity zone established on the field depends on opportunity costs i.e. the productivity of the field and the price of crops originally cultivated. The test plots feed barley yield estimates are based on yield records and expert[2] evaluations.

First, the prices of crops and inputs were assumed to be on the level of 2010. Then, the price of feed barley was altered. Variable costs and labour costs were evaluated using the data of Tuottopehtori e-service (ProAgria Keskusten Liitto, 2010) and machine-work costs and statistical contracting prices reported by TTS tutkimus (Palva, 2009) were utilised.

The total costs and income losses incurred by biodiversity zones established on field plots of different quality were computed by first calculating the present values of profit margin in feed barley production for crop and animal farms. For simplicity, no crop rotation was assumed. Then, a biodiversity zone to be managed annually was established on a field plot. The quantity of costs and income losses incurred by the biodiversity zone can be computed by subtracting the present value of the net income stream received of the biodiversity zone from the present value of the net income stream received of the crop production. The discount rate of 3% was used in the calculations.

2.2 Biodiversity zone in forest

An alternative for the biodiversity zone established on a field is a biodiversity zone established in a forest (Fig. 1) abutting to a field. This zone is also 25-m wide and it consists of a 5-m wide meadow-like treeless part and a 20-m wide transitional zone.

To evaluate the costs and income losses incurred by biodiversity zones established in forests abutting to fields, the total of 30 test plots were established in southern Finland. Inventories of their tree stands were made in the summer of 2009. Measurement data was utilised as initial states in the simulations. Fellings and management were simulated by means of SIMO simulator (http://www.simo-project.org/). For each test plot, two different chains of managing forests were simulated.

In the first simulation, it was assumed that no biodiversity zones are established and that the test plots are managed according to the prevailing practice in Finland (i.e. forest management practice recommendations given by Forestry Development Centre Tapio). In the second simulation, it was assumed that the 5-metre wide zone closest to the field is immediately deforested and kept treeless with clearings repeated every 6-7 years. The 20-metre wide transitional zone deeper in the woods is thinned to the basal area of about 8 m^2/ha. The trees of the transitional zone are managed by light selection fellings every 20 years. In the light selection fellings, trees are removed from all age classes, the emphasis being on tall trees. The aim is to have tree stands with mixed trees of varying ages with a large share of broad-leaved trees.

The costs and income losses of biodiversity zones were calculated by subtracting the present value of net income streams obtained as a result of clearings and light selection fellings from the present value of net income streams obtained as a result of the management recommendations by Tapio.

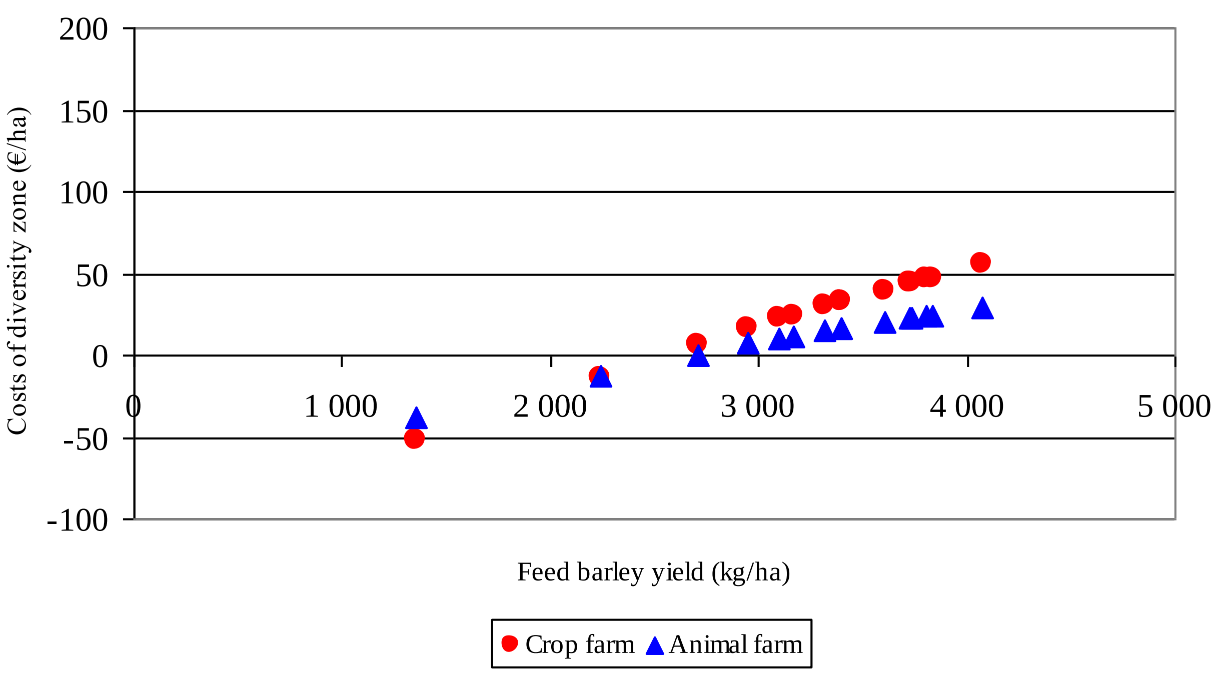
[2] Farm manager Ari Turtola, MTT, 15 March 2010.

3. Results

3.1 Biodiversity zones on fields

The costs of biodiversity zones established on fields were evaluated by means of profit margin calculations on crop and animal farms when the price of feed barley is assumed to be €100 per ton (i.e. on the current level) and €125 per ton (near the long time average). The results of these calculations are shown in Figures 2 and 3. The annual net costs per hectare of producing biodiversity benefits on field test plots vary from €-52 to €55 (Fig. 2) and from €-18 to €157 (Fig. 3). The average per hectare costs are €18 and €88, respectively. The discount rate of 3% was used in the calculations.

Fig. 2 Annual net per hectare costs of biodiversity zones on field when price of feed barley is €100 per ton

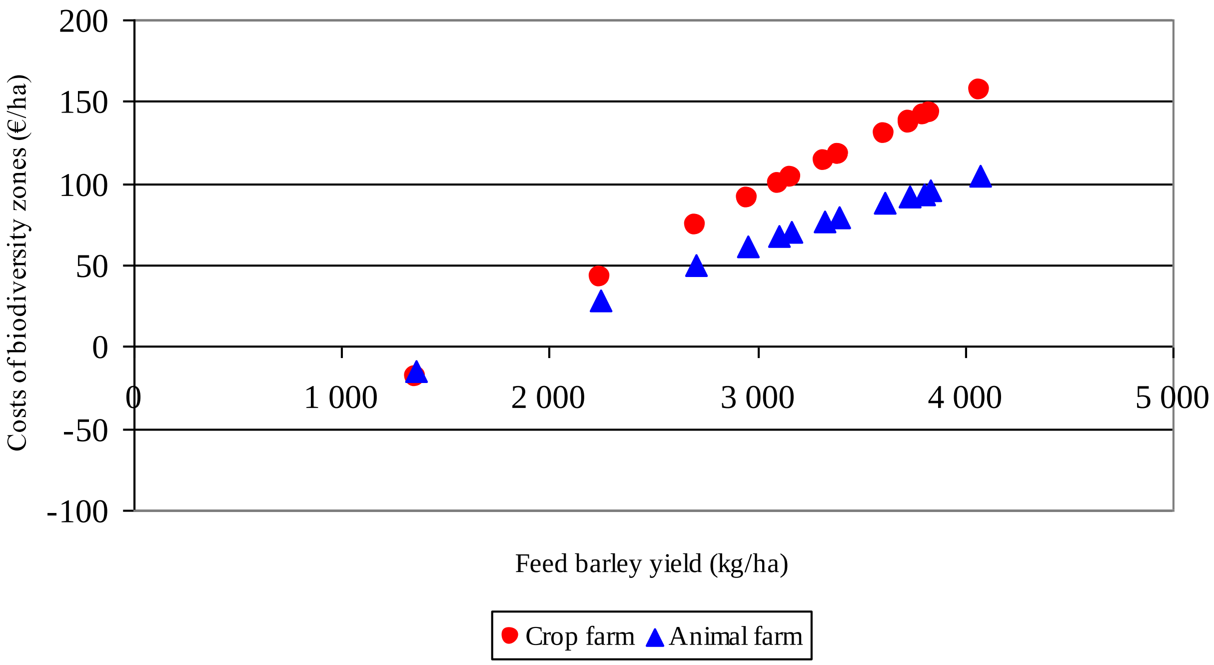


Figures 2 and 3 also indicate that when the quality of arable land (measured via feed barley yields) is poor and/or the price of feed barley is low, some farms would be better off if they establish biodiversity zones on poor quality land and produce environmental benefits on them instead of feed barley. The production costs of biodiversity zones are negative, because the costs of biodiversity zones are smaller than in grain production, and when harvest incomes are small, cost savings make the production of biodiversity benefits more profitable than barley production even without agri-environmental support payments.

As the quality of arable land improves, both farms require compensation in order to establish biodiversity zones. Crop farms need larger support than animal farms, mainly because (according to the assumption made) the animal farm can utilise the yield provided by the biodiversity zone.

Hence, the opportunity cost of crop farms increase steeper than the opportunity costs of animal farms as the quality of arable land improves or the price of feed barley rises.

Fig. 3 Annual net per hectare costs of biodiversity zones when price of feed barley is €125 per ton



The feed barley yield is the most important explanatory variable when explaining the variation in cost of biodiversity zones on field. Simple statistical analysis reveals that, as the price of feed barley €100 per hectare, the average per hectare cost of biodiversity zone increases €32 when feed barley yield increases 1,000 kg/ha. Furthermore, biodiversity zones can be established and maintained annually on average €14/ha cheaper on animal farms than on crop farms. The corresponding figures when the price of the feed barley is €125 per ton are €54/ha and €35/ha.

3.2 Biodiversity zones in forests

The annual net costs per hectare of producing biodiversity benefits on forest test plots vary from €51 to €229. The average was €115/ha. The discount rate of 3% was used in the calculations. The roundwood assortment prices used are shown in Table 1. They have been quite stable in Finland during the past 30 years.

Table 1. Roundwood assortment prices (€/m^3)

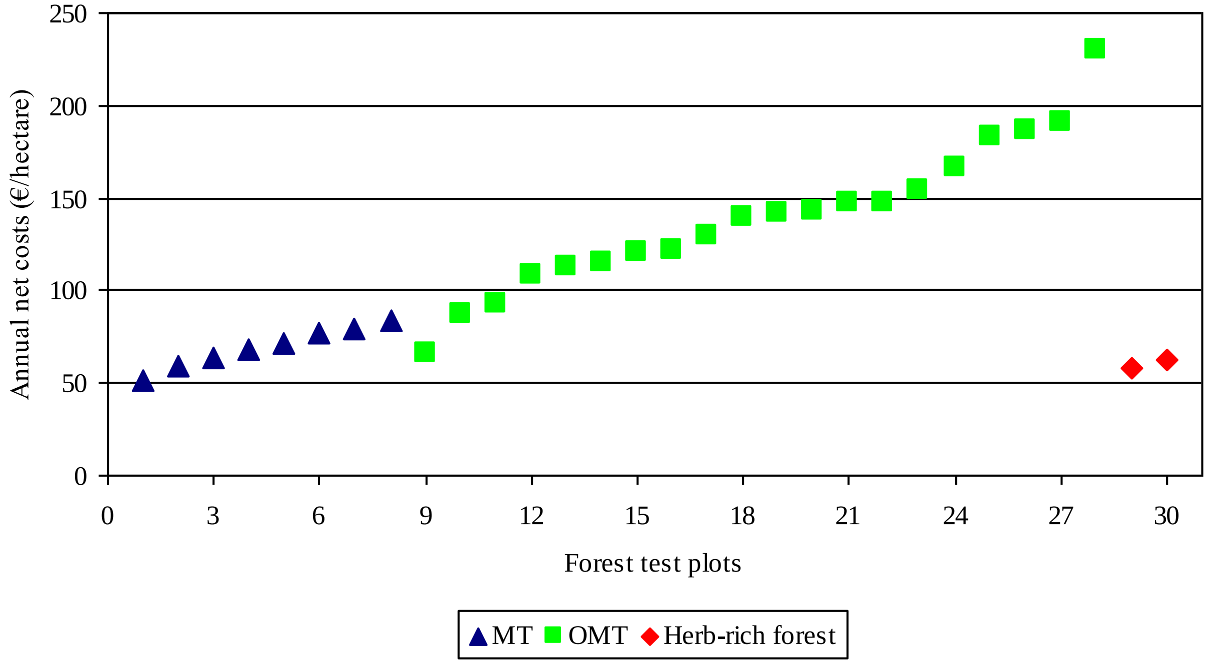
	€/m^3
Pine logs	55
Pine pulp	17
Spruce logs	55
Spruce pulp	25
Birch logs	43
Birch pulp	15
Other wood species	10

Effect of soil productivity

The single most important regressor of the production costs of diversity benefits on forest test plots is soil productivity. In a poor habitat, similar to arable land, establishing a biodiversity zone and producing diversity benefits are not as expensive as in a good habitat, because the return acquired from a forest growing in a poor habitat remains smaller than in a good habitat irrespective of management. Instead, in a good habitat, the difference between the present values of net income streams acquired between the Tapio recommendations and clearings and light selection fellings increases and, at the same time, the opportunity cost of producing diversity benefits also increases.

In Fig. 4, forest test plots are grouped by habitat type to illustrate annual net costs per hectare. The difference of the annual present values of net income streams between the Tapio recommendations and clearings and light selection fellings is on the average €139 per ha in habitats of Oxalis-Myrtillus type (OMT) and on the average €69 per ha in habitats of Myrtillus type (MT). The difference between the averages is statistically significant. Since only two of the habitats were herb-rich forests, it was not possible to evaluate their effect on the production costs of diversity benefits reliably.

Fig. 4 Annual net per hectare costs of biodiversity zones in forest test plots according to habitat types



Regression model

The quantity of the difference in the present values of annual net income streams per hectare between the Tapio recommendations and clearings and light selection fellings can be explained with a regression model in which explanatory variables consist of a dummy variable MT formed of the site class variable, a dummy variable FFM measuring the final felling maturity of the test plot and a continuous variable V measuring the volume of tree stand of the test plot at the start situation.

Variable MT is given value 1 if the habitat is of the MT type. Otherwise (habitat is herb-rich forest or OMT), the variable is given value 0. Variable FFM is given value 1 if the final felling can be immediately performed in the test plot according to the Tapio recommendations[3]. If the first final felling cannot be performed until a few years have passed, variable FFM is given value 0.

Eight of the thirty habitats were MT habitats and final felling could be immediately performed on the tree stand of ten test plots according to the Tapio recommendations. The per-hectare volumes of the tree stand in the test plots varied from 26 m^3 to 411 m^3 and their average was 250 m^3/hectare.

The estimation results are given in Table 2.

[3] The primary basis for regeneration maturity is the largeness of tree stand (diameter of stand). If the stand does not reach the minimum of the regeneration-maturity diameter e.g. due to its treatment history, it can be regenerated based on its age.

Table 2. Regression model

Dependent variable Difference in present values of annual per-hectare net income streams between Tapio recommendations and clearings and light selection fellings					
Explanatory variables	Unstandardised coefficients Coefficient	 Standard error	Standardised coefficients	*t*	Sig.
MT	-69.738	11.669	-0.666	-5.977	0.000
FFM	57.656	10.886	0.587	5.296	0.000
V	-0.191	0.056	-0.397	-3.412	0.002
Constant	162.367	15.513		10.466	0.000
Adj $R^2 = 0.68$	n = 30	$F_{3,26} = 21.389$	DW = 1.683		

The regression model explains about two thirds of the variation in the costs of biodiversity zones established in the forest test plots. Based on the estimation results, it is best to establish the biodiversity zones on habitats with poorer soil. A zone established in an MT-type forest is about €70 cheaper calculated per hectare per year than a biodiversity zone established on a better habitat (OMT or herb-rich forest).

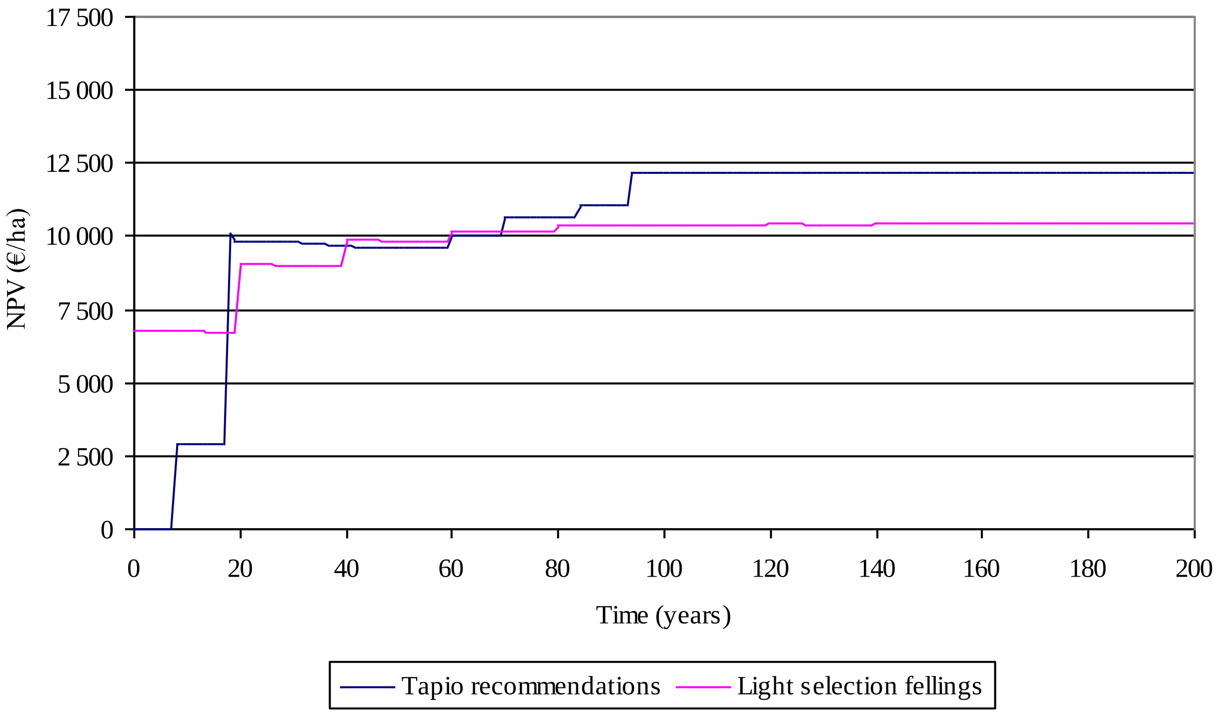
The estimation results also suggest that it is better to establish biodiversity zones in such forests which are not yet mature for final felling but still have a large volume of tree stand. According to Table 2, biodiversity zones established in forests mature enough for final felling are annually on the average €58 per hectare more expensive to forest owner than zones established in such forests where the first final felling is performed in some later years according to the Tapio recommendations. In addition, an increase of the volume of per-hectare tree stand with one cubic metre decreases the annual hectare costs of the biodiversity zone with about €0.20 *ceteris paribus*.

The finding that it is better to establish biodiversity zones in such forests where the volume of tree stand is large but which are not mature for final felling is due to the fact that a lot of felling income is immediately received from a biodiversity zone established in such a forest from the 5-metre wide zone to be deforested and the 20-metre wide transitional zone which is thinned to the basal area of 8 m^2/ha. Instead, forestry according to the Tapio recommendations will not incur income for the forest owner until a few years after the first final felling. This is clearly visible in Fig. 5 which shows the accrual of the present values of net income in test plot 10.

The habitat type of test plot 10 is myrtillus type (MT). The volume of the tree stand (219 m^3/ha) is initially smaller than the average (250 m^3/ha). The dominant tree species is initially pine. When acted upon the Tapio recommendations, the test plot will be regenerated with spruce. In light selection fellings, the regeneration is natural and the trees are partially determined randomly. In the simulation example, test plot 10 is naturally regenerated with downy birch and aspen.

When acting upon the Tapio recommendations, the first thinning in test plot 10 is performed after 8 years and the first final felling after 18 years. However, light selection fellings immediately incur felling income of about €6,800 per hectare. Hence, establishing a biodiversity zone and performing light selection fellings accrue felling income more quickly to the forest owner.

Fig. 5 Accrual of present values of net incomes on forest test plot 10

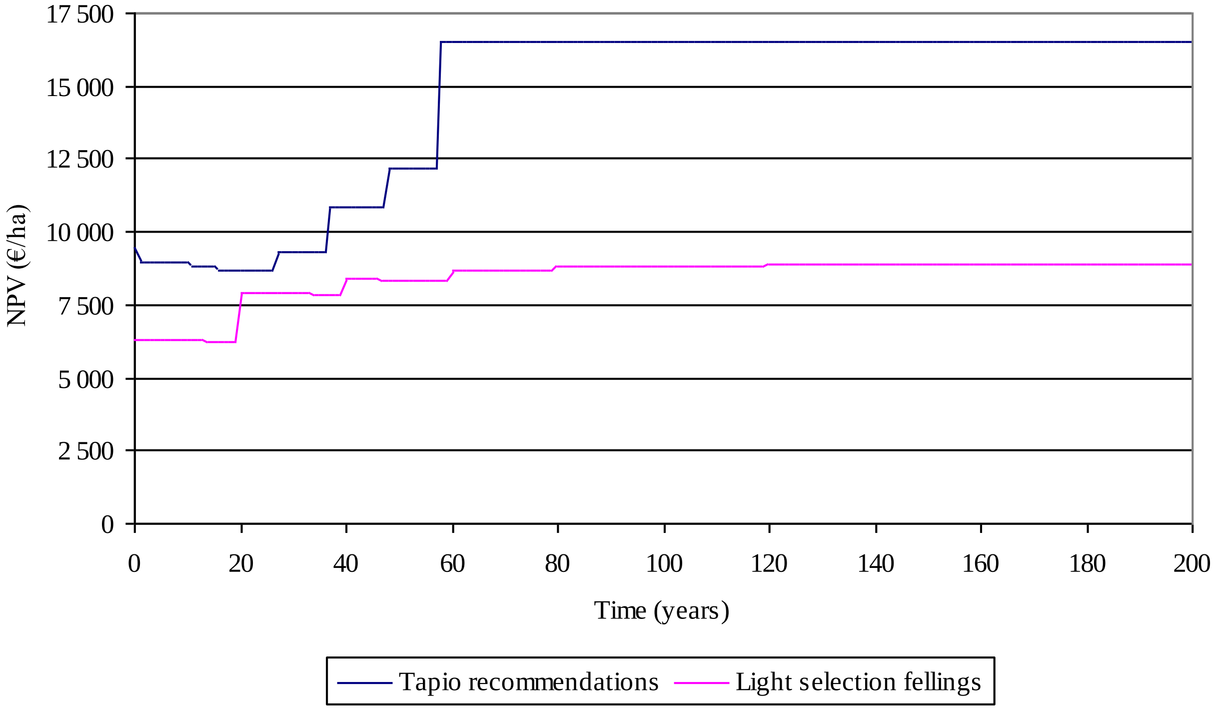


Forestry according to the Tapio recommendations will not incur a lot of net income for the forest owner until after the first final felling. Then, the present value of received net felling income is about €10,000 per ha. The present values of net income were calculated with the discount rate of 3%. It should also be noticed that, when acting upon the Tapio recommendations, no income is received for many years after the final felling, whereas light selection fellings accrue net income evenly at 20-year intervals.

In Fig. 5, the cost incurred of the biodiversity zone to the landowner is the vertical distance between the two curves (Tapio and light selection felling). Even large net income received in the adequately far future will not accrue the present values of the net income from management chains. Instead, they will be fixed at a certain level. The difference of the present values of net income per hectare received in test plot 10 between the Tapio recommendations and light selection fellings was €1,695/ha when the discount rate was 3%.

Forest test plot 7 in Fig. 6 presents the opposite case in which the production of biodiversity zones is expensive. The initial volume of trees (257 m^3/ha) on plot 7 is near the average (250 m^3/ha). The first final felling according to the Tapio regulations is performed immediately. Since we put more weight to money earned today than tomorrow, the first final felling accrues income clearly more than those following that. The second final felling, which according to Tapio regulations comes after 58 years, has also considerable impact to incomes, because habitat type on forest test plot 7 is OMT and thus it’s potential to produce roundwood is better compared to MT type habitat. The vertical distance between Tapio and light selection fellings curve will be €7,647/ha if the discount rate is 3%.

Fig. 6 Accrual of present values of net incomes on forest test plot 7

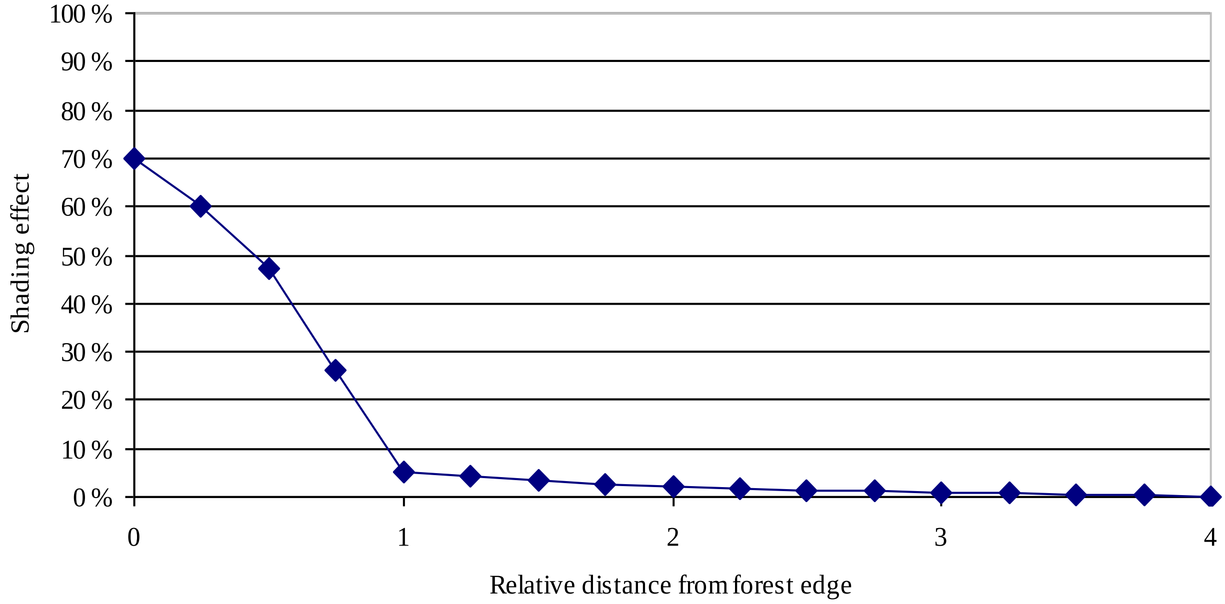


Forest shading and field cultivation

Biodiversity zones in forests adjacent to fields have a positive external effect on field cultivation, because the amount of solar radiation received by the field depends, among other things, on the height and location of the forest border adjacent to the field. The other things defining the magnitude of forest shading are the geographical location (i.e. latitude) of the field, season and time of day.

Fig. 7 depicts the shading effect of a forest south of the field in Vantaa, Finland on June 15. A forest on the south side of the field has typically the greatest impact on the amount of solar radiation received by the field. According to calculations made by Kilpeläinen (1997), its shading effect in Finland can be over 70% at the very edge of the forest. Besides direct solar radiation, the field surface also receives diffuse solar radiation. Hence, the shading effect of a forest edge is never 100%. In addition, the significance of shading decreases quite quickly when receding from the edge of the forest such that the effect almost ceases at the distance of the forest height (at the relative distance of 1 in Fig. 7).

Fig. 7 Average shading effect of forest edge located south of field in Vantaa, Finland on June 15



Source: Kilpeläinen (1997)

The positive external effect of forest biodiversity zone on field cultivation is based the fact that forest border will move 5 metres further from the field when the meadow-like treeless zone is established. In addition, as the result of light selection fellings forest lets more solar radiation through to field.

The results of Kilpeläinen were applied to our field test plots where forest is located at different cardinal points. According to our calculations, biodiversity zones and light selection fellings let on average 4% more solar radiation through to field plots than forests managed according to the Tapio recommendations. Range between field plots was from 2% to 11%.

We utilised expert opinion[4] when evaluating the effect of shading to barley yields in southern Finland and fitted quadratic function to estimates and calculated the effect of shading during rotations under different forest management chains. The more later the first final felling according to the Tapio recommendations will come, the more the field owner gains in terms of barley yields if the forest biodiversity zone is established and the forest is managed with light selection fellings.

As a result of calculations on all field plots, the difference in the value of annual feed barley yields is on average €6 per hectare. In Finland the field owner is often also a forest owner, since farms in Finland are typically quite small family farms. Therefore, the forest owner in most cases may internalise the externality.

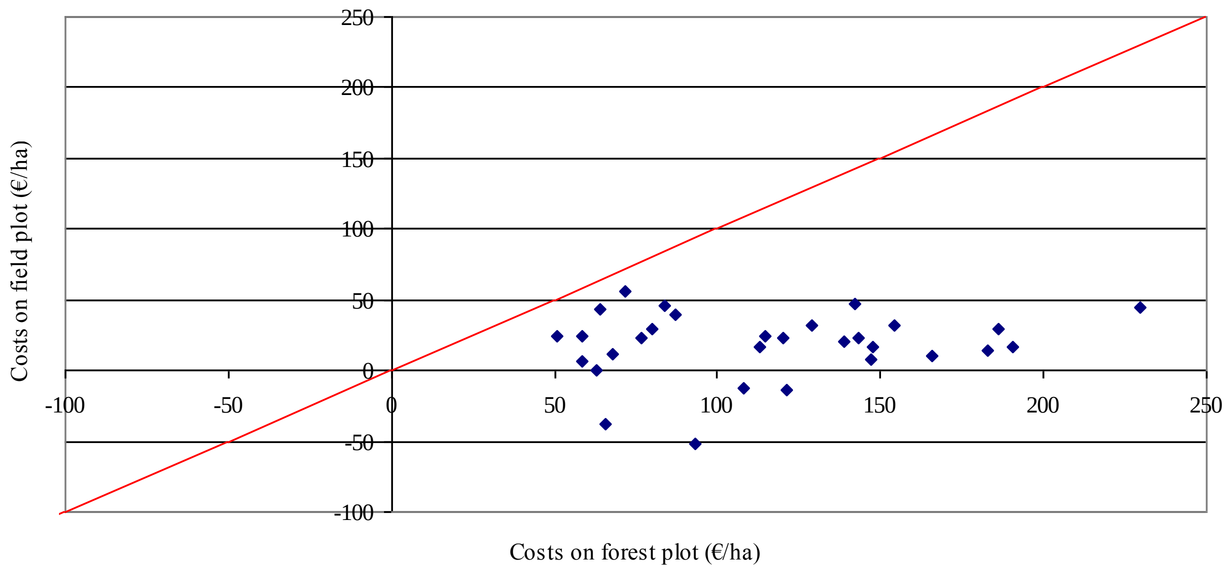
[4] Prof. Reimund Rötter, MTT, 28 April 2010.
12% reduction in barley yield when the share of solar radiation received by the field goes down from 100% to 80% and 30% reduction in barley yield when the share of solar radiation received by the field goes down from 100% to 50%.

4. Conclusions

This paper compared the costs of two biodiversity measures from the viewpoint of a private landowner. Biodiversity zones on the border of a field are already utilised as agri-environmental measures in Finland. Instead, biodiversity zones have not yet been established on the border of a forest abutting to a field, although forest biodiversity zones have a lot of potential in the conservation of farmland biodiversity. In addition to production of biodiversity benefits, forest biodiversity zones adjacent to field typically improve the yields received from field, since they decrease the effect of forest shading on field.

The results from 30 test plots situated in southern Finland indicate that the costs of biodiversity zones on arable land depend on the productivity of the field and the price of original crop and whether the farm is able to utilise plants grown on the biodiversity zone. In forests, the variation in the production costs of biodiversity zones resulted from soil productivity as well as the structure and volume of trees at the starting point.

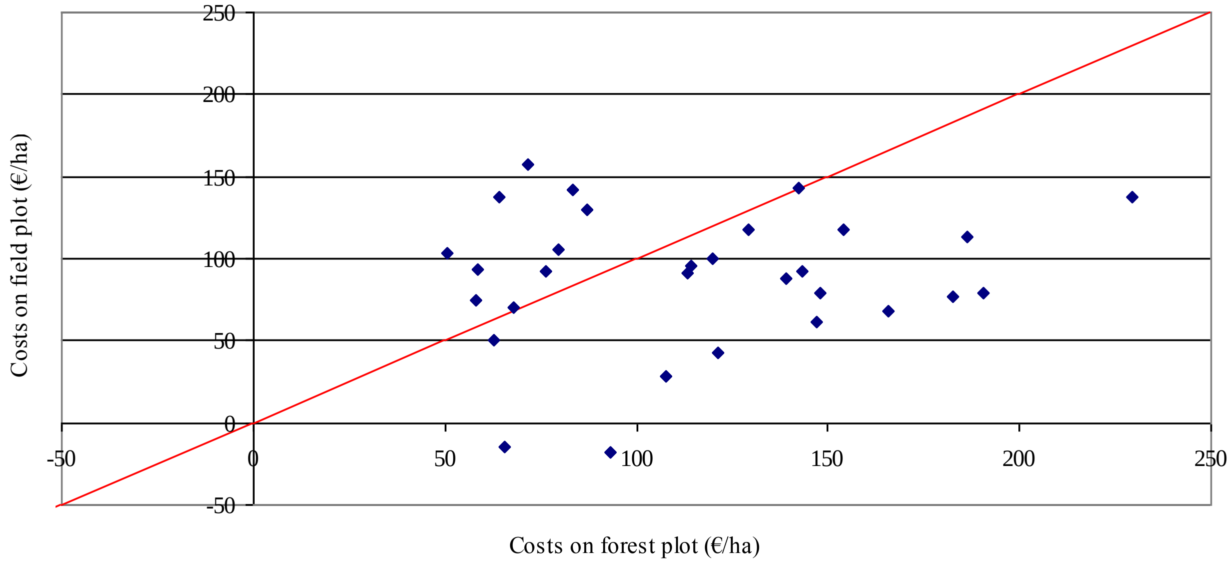
Fig, 8 Annual net hectare costs of biodiversity zones when price of feed barley is €100 per ton



Figures 8 and 9 illustrate that the assumption about the price of crop originally grown on field is crucial when comparing the costs of biodiversity zones. The 45 degree line in Fig. 8 indicates that when the price of feed barley is €100 per ton, the costs in all 30 test plots will be lower if the biodiversity zones are established and maintained on fields instead of forest. On the other hand, as the price of feed barley increases to €125 per ton (Fig. 9), biodiversity production costs in some forest plots of poor productivity soils turn relatively cheaper than those on field plots.

If the price of feed grain is permanently low, it may be viable to continue to establish biodiversity zones on the field rather than in the forest. In addition, biodiversity zones established on the field are more easily returned to production than ones established in the forest, because the growth of forests is slow and the zones do not return quickly to efficient wood production.

Fig. 9 Annual net hectare costs of biodiversity zones when price of feed barley is €125 per ton



Finally, it should be emphasised that our analysis does not yet say anything on the effectiveness and cost-efficiency of the measures compared. Their evaluation requires further studies on the effectiveness of biodiversity zones e.g. on the living conditions and populations of pollinator insects and the value of pollination services they offer. Then, it will be possible to find out whether the diversity benefits can be produced more cost-effectively on the field or in the forest.

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