Effects on participation and biodiversity of reforming the implementation of agri-environmental schemes in the Netherlands

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Abstract
To prevent further biodiversity loss as a result of intensive agricultural practices, Agri-Environmental Schemes (AES) have been implemented on European farmland. Unfortunately these AES have not always been effective in terms of biodiversity and farmer participation. In an effort to improve the AES system, the Dutch government switched from an individual application system to a collective application system for AES payments in 2016. The goal of this paper is to analyse the effects of introducing this collective application system in terms of farmer participation and biodiversity. We construct a multi-objective mathematical programming model in which farmers maximise utility. Farmers are linked through their common effect on biodiversity. In the collective application system payments are only available when the biodiversity in the region is above a certain threshold. Simulation results show no difference in farmer participation and biodiversity between the individual application system and the collective application system in our baseline scenario. Farmers in our sample attach high weights to biodiversity, therefore the biodiversity level is above the threshold and AES payments are available in both application systems. In a scenario where farmers attach smaller weights to biodiversity, farmer participation and biodiversity are much lower in the collective application system for AES.

Key words: agri-environmental schemes, mathematical programming, biodiversity, contracts
JEL codes: Q15, Q57

1. Introduction

Agricultural intensification has resulted in a loss of biodiversity within Europe (Stoate et al., 2001). To prevent further biodiversity loss, Agri-Environmental Schemes (AES, sometimes also referred to as Agri-Environmental Climate Schemes) have been implemented on European farmland (van Dijk et al., 2015). AES offer payments to farmers that modify their farming practice to obtain environmental benefits (Kleijn and Sutherland, 2003). Sufficient farmer participation is vital and will make it much more likely that the aims of the AES programmes are achieved (Lastra-Bravo et al., 2015). Unfortunately, participation of farmers in AES is often low, resulting in inadequate conservation areas and poor biodiversity results (Kuhfuss et al., 2016; Mckenzie et al., 2013; Whittingham, 2007). These disappointing results combined with the high costs of AES schemes (Kleijn and Sutherland, 2003) have motivated policymakers to try and improve the AES system.

To this effect the 2014 EU Rural Development Regulation (Regulation (EU) No 1305/2013, Article 28) was introduced, which made it possible to apply for AES as a group, but left the option for individual farm applications as well. The Dutch government took this a step further and changed the implementation of the Dutch AES system to allow only joint applications by farmer collectives from 2016 onwards. Only if the farmer collective can offer sufficient nature conservation its application will be approved and payment will become available. If the promised nature conservation is not realized, the payment to the collective will be penalized or withdrawn (Ministry of Economic Affairs, 2016). The collective system is believed to result in a more effective and efficient realisation of nature conservation goals, with lower execution costs, and a better and more sustainable participation of farmers (Portaal Natuur en Landschap, 2016). However, it is possible that farmers who in first instance receive AES payments will no longer be able to obtain these payments due to insufficient participation of their neighbours in the collective AES system. In the regions where this is the case we might encounter a shift towards low farmer participation and biodiversity loss.

Land use systems can be viewed as a coupled human environment systems, characterised by interactions and feedbacks between socio-economic elements such as farming methods and biophysical components such as biodiversity (Schouten et al., 2013; Mitchell et al., 2015). Developing policies for land use systems can be challenging due to the fact that land use systems exhibit many characteristics of a complex system, with nonlinear cause-effect responses. The result is that sometimes the system shows no response to a policy measure, while at other times a small policy change causes an abrupt change with a cascade of unanticipated side effects. Therefore this complex character should be taken into account when analysing policy measures such as the change in the AES system. Central elements of complex systems are feedbacks, which should be incorporated in land use models to accomplish integration of the social and biophysical system (Verburg, 2006). In both the individual AES and collective AES application system there is a feedback via biodiversity. Biodiversity in the region depends on conservation measures taken by farmers, but the amount of conservation measures also depends on the level of biodiversity in the region. In the collective AES system an additional feedback is introduced via the availability of maintenance payments.

The goal of this paper is to analyse whether the shift from an individual to collective application for agri-environmental contracts is effective in terms of farmer participation and biodiversity. Our case study area contains typical landscapes of hedgerows that separate farm parcels. Biodiversity depends on the farmers' efforts to maintain hedgerows (Boer, 2003). However, maintaining hedgerows is costly. Therefore AES payments are offered to compensate farmers who maintain these elements properly. Farmers can choose not to maintain the hedgerows, but they are not allowed to remove the trees. Farmer participation is measured by the number of farmers in the AES. To measure biodiversity we calculate a biodiversity score, based on three example species. These three species are characterised by different sized key areas that are needed to maintain a sustainable population. We incorporate feedback mechanisms in a multi-objective mathematical programming model in which farmers maximise utility and where famers' utility is influenced by the choices made by other farmers. Farmers are linked through their mutual effect on biodiversity and agri-environmental payments. Section 2 discusses the theoretical framework and the model used. The case study area is described in section 3 and the data are described in section 4. How we measure effectiveness is explained in section 5 and the experimental design is presented in section 6. The results are included in section 7 and finally section 8 concludes.

2. Theoretical framework and Model description

2.1 Theoretical framework

Resources are limited, and so farmers face limitations in their choices. We take an economic perspective which allows us to determine the best choices given these limitations. Although financial incentives play a role in farmer decisions on nature conservation, farmers do not only apply for AES on the basis of economic profit (van Dijk et al., 2015; Lokhorst et al., 2011). Also farmer motivation to support biodiversity and farmer interactions influence conservation choices and behaviour (Runhaar et al., 2016). Even in the case no subsidy is provided, farmers might be willing to perform conservation measures due to their positive attitude toward wildlife and landscape, perceived social norms, and perceived personal ability (van Dijk et al., 2016). Therefore we apply the multi-criteria decision making (MCDM) paradigm, in which multiple conflicting objectives can be combined (Calker et al., 2006). Farmer decisions in our model depend on several weighted farmer objectives in a utility maximization framework. In doing so we step outside the traditional reductionist economic approaches in which farmer choices are purely based on the profit maximization paradigm, but are still able to model a rational-decision-making process (Jongeneel et al., 2008).

2.2 Conceptual model

Our model describes a landscape made up of nine individual farmer-agents, which decide on the maintenance of hedgerows on their own farming parcels. Although each farmer-agent maximizes his own utility, farmer-agents are connected through their mutual effect on biodiversity and the availability of AES payments.

The farmer-agent model describes a typical farm in the area: a dairy farm producing milk, with the option to maintain hedgerows in return for financial support from the AES program. These hedgerows are located on the farms parcels, and contribute to the biodiversity level in the region if they are maintained. Properly maintaining hedgerows entails some yearly work like checking and some bigger work like pruning or cutting down trees every few years. In practice, farmers tend to alternate the large maintenance work for different hedgerows, ensuring that only a part of the hedgerows need major maintenance every year. Therefore, the model considers just the average amount of work needed every year for maintaining hedgerows. Well-maintained hedgerows create shade resulting in a lower grass or maize production. Although most farmers that are not in the AES scheme do some maintenance work, we assumed that farmers who will not properly maintain their hedgerows have negligible maintenance costs and shade effects.

The farmer's aim is to maximize his utility. Utility depends on several weighted farmer objectives which is captured by an additive utility function. In order to add the utility of the different objectives, the utility values of each objective have to be normalized (Vieira et al., 2016). Farmer objectives and weights have been determined during interviews. We grouped the objectives into the following categories: profit maximization, labour minimization, risk minimization and biodiversity maximization. It is possible that a farmer does not attach a value to an objective. In that case the weight for this objective will be zero.
Profit equals the revenue from milk plus the revenue from selling cows and AES payments minus the costs of farming and the costs of maintaining hedgerows. Labour minimization refers to the minimization labour used on the farm, determined by the amount of labour needed for each task executed on the farm. We measured risk as the variance in milk prices (see e.g. Berentsen et al., 2012; Kaiser and Messer, 2011; Schmit et al., 2001). If a farmer attaches a value to the risk minimization objective, (s)he will be risk averse. Although we realise farmers might feel uncertain about the availability of AES payment in the collective AES system before the contract is agreed, we assumed there is no price risk for the AES payment once the contract is agreed as contracts are concluded for a period of 6 years. Biodiversity is measured by a biodiversity score, depending on three example species (see also the section on biodiversity).

There are two feedbacks in our model, as illustrated in figure x. The feedback through biodiversity takes place in both the individual AES system and the collective AES system. The overall biodiversity level in the region has an effect on the individual farmer decision (arrow 1), the individual farmer decision determines the amount of hedgerows maintained on the farm (arrow 2) which influences the overall biodiversity level (arrow 3). The payment feedback takes place only in the collective AES system. The availability of AES payments depends on sufficient overall biodiversity in the region (arrow 4), the individual farmer decisions depend on the availability of payment (arrow 5), the individual farmer decisions determine the amount of hedgerows maintained on the farm (arrow 2) which has an effect on the overall biodiversity (arrow3).

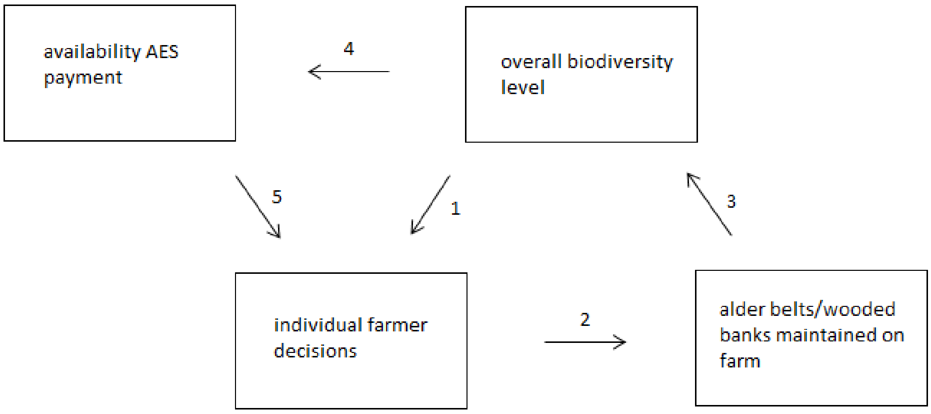


Figure x: Schematic representation of feedbacks in the model

2.3 Measuring effectiveness

Farmer participation

Farmer participation is measured as the number of farmer-agents that maintain hedgerows. We hereby assumed that each farmer-agent maintaining hedgerows does so within the AES scheme.

Biodiversity

To determine the impact of switching from an individual to a collective application system for agri-environmental schemes on biodiversity targets, we needed to estimate the effect of farmer-agent decisions on biodiversity. Biodiversity is a broad concept, and can include numerous animal and plant species. For the purpose of this paper we selected a number of key species characterised by their key area and dispersion capacity, which together represented the biodiversity in the NFW. The minimum or key area of a species is the total amount of habitat area that is needed to maintain a sustainable population of that species (Reijnen et al, 2007). The dispersion capacity of an organism refers to the extent to which it is able to move from one habitat area to another (Reijnen et al., 2001). These habitat areas are the areas where the conditions are such that the species could occur. All maintained hedgerows that are within a distance equal to the dispersion capacity are added to calculate the key area. Key areas and dispersion capacity have also been used to analyse and measure biodiversity by e.g. Grashof-Bokdam et al. (2009), Reijnen et al., (2001), Reijnen et al., (2007), Elands et al. (2005) and Kwakernaak et al. (2015).

In our model we used key areas to define the average area that suffices to maintain a sustainable population of a species. The dispersion capacity is used to determine if the species would be able to move from one hedgerow to the next within this defined area. To analyse the impact of the collective AES system we differentiate between species that have small key areas and species that have larger key areas. In this way we can conclude whether the collective AES system impacts differ for biodiversity that occurs on a small scale and biodiversity that occurs on a larger scale.

False oat-grass (Arrhenatherum elatius) is a plant species that occurs in the hedgerow landscape in the NFW (expert judgement and Floron 2017). This species is an example of a species for which the biodiversity is dependent on a small scale key area. It has a key area of 1000 m^2 and a dispersion capacity of 100 metres. The size of the key area indicates that a sustainable population could not survive on the hedgerows of a single parcel. However, the dispersion capacity suggests that the species could reach the hedgerows on the neighbouring parcels. On average the amount of hedgerows on a parcel plus its neighbouring parcels is sufficient to support a sustainable population of this species when these hedgerows are maintained.

The purple hairstreak (Favonius quercus) is a butterfly that occurs in wooded banks (Vlindernet, 2017). It is an example of a species with a medium scale key area. The key area of this species is 5 ha and the dispersion capacity is 100 m. The key area needed for this species cannot be provided on one farm; however the amount of hedgerows on the farm plus its neighbouring parcels is sufficient to support a sustainable population of this species when these hedgerows are maintained.

The Large-flowered Hemp-nettle (Galeopsis speciosa) is a plantspecies that occurs in the hedgerow landscape (expert judgement and Dijkstra, 2017). It is an example of a species with a large scale key area. The key area of this species is 10 ha. All the hedgerows in the region need to be maintained to support a sustainable population of this species.

For each of the three biodiversity types (small, medium and large scale) we defined the size of the area that is sufficient to support a sustainable population of that biodiversity type (parcel plus neighbouring parcels, farm plus neighbouring parcels, all farms). However, it is possible that only part of the hedgerows in the defined area is maintained. If the ratio of maintained hedgerows to the total amount of hedgerows within this defined area is above a certain threshold the biodiversity level will be high. If the ratio is below the threshold the biodiversity level will drop.

2.4 Mathematical model

In this section we present the general structure of our mathematical model. The exact equations and restrictions are presented in appendix X.
Each farmer-agent maximizes utility as defined in equation 1, subject to the constraints presented in equations 1a-1c.

$$maximize \;\; U = \sum_{n=1}^{N} g_n O_n \left(r_1, \dots, r_Z\right) \qquad (1)$$

Subject to:

$$\sum_{z=1}^{Z} a_{zk} r_z \leq b_k \quad \forall_k \quad [\pi_k] \qquad (1a)$$

$$\sum_{z=1}^{Z} c_{zl} r_z = d_l \qquad \forall_l \tag{1b}$$

$$r_z \geq 0 \qquad \forall_z \tag{1c}$$

Where:
U is utility; g_n is the weight attached to objective n; $O_n(r_z)$ is the normalized value of objective n depending on activity level z; r_z is the level of activity z, b_k is the total availability of a resource k; a_{zk} is the quantity of resource k demanded by activity z; π_k is the shadow price of resource k; d_l is the total available quantity of resource l; c_{zl} is the quantity of resource l demanded by activity z.

The way we define the objectives is presented in equations 2-5.

$$O_1 = \sum_{j=1}^{J} p_j\, y_j - \sum_{m=1}^{M} w_m\, x_m + (p_o - w_o) y_o - w_L(LR - LI) \tag{2}$$

$$O_2 = LR \tag{3}$$

$$O_3 = ev_1 {y_1}^2 \tag{4}$$

$$O_4 = \frac{\sum_{b=1}^{3} \mu_b}{3} \qquad b = 1,2,3 \tag{5}$$

Subject to:

$T(\boldsymbol{y}, \boldsymbol{x}, y_o, LR)$
$\boldsymbol{p}, \boldsymbol{w}, p_o, w_o, w_L > 0$

Where:
O_1 profit; p_j price of regular output j; y_j quantity of regular output j; w_m price of input m; x_m quantity of input m; p_o AES payment hedgerows, availability of payments in the collective AES depends on a sufficient biodiversity level ; w_o cost of maintaining hedgerows; y_o quantity of hedgerows maintained; w_L costs of hired labour; O_2 quantity labour used on the farm; LR labour required in the production process; LI initial labour endowment; O_3 risk taken by the farmer; e risk aversion coefficient; v_1 variance milk price; y_1 amount of milk produced; O_4 overall biodiversity score; μ_1 small scale biodiversity score; μ_2 medium scale biodiversity score; μ_3 large scale biodiversity score; $T(\boldsymbol{y}, \boldsymbol{x}, y_o, L)$ technology set; $\boldsymbol{y}, \boldsymbol{x}$ vector of outputs and variable inputs respectively; $\boldsymbol{p}, \boldsymbol{w}$ vector of output and input prices respectively.

We calculate a biodiversity score using a logistic function. This function is specified in such a way that it implies that when the maintained amount of hedgerows is low the score is close to zero and when a certain threshold is passed the score is close to one. The advantage of a logistic function is that despite the abrupt switch we still have a continuous function which makes solving the model feasible. A logistic function was also used by (Natuhara and Imai, 1999) to predict species richness by environmental variables such as habitat area. Equation 6 shows how we calculated the biodiversity scores:

$$\mu_b = \frac{1}{1+e^{-\alpha * \frac{y_{ob}}{y_{ob}^*} - \beta}} \qquad b = 1,2,3 \qquad (6)$$

Where:
μ_b is the biodiversity score of biodiversity type b; y_{ob} is the amount of maintained hedgerows that contributes to biodiversity type b; ${y_{ob}}^*$ is the maximum amount of hedgerows that contributes to biodiversity type b and can be maintained, α is the speed parameter and β the biodiversity parameter.

By manipulating α we determine the speed at which the biodiversity score switches from close to 0 to close to one, the higher α the faster. We select here arbitrarily 30 implying a fast transition. By manipulating β we can determine where the switch takes place. For example, with a biodiversity parameter β equal to 0.7 the biodiversity score will drop rapidly to a value close to zero for a ratio $\frac{y_{ob}}{{y_{ob}}^*}$ smaller than 0.8. With a higher ratio $\frac{y_{ob}}{{y_{ob}}^*}$ the biodiversity score lies between 0.8 and 1. So, a higher biodiversity parameter implies that the switch occurs at higher ratios and with a lower parameter the switch takes place at lower ratios. Figure 1 shows how the biodiversity score differs depending on α and the $\frac{y_{ob}}{{y_{ob}}^*}$ ratio. Figure 2 shows how the biodiversity score differs depending on β and the $\frac{y_{ob}}{{y_{ob}}^*}$ ratio.
The biodiversity scores were determined for the species with small scale, medium scale and large scale key areas. An average of these scores was taken to calculate the overall biodiversity score.

3. Case study area

The study area Noordelijke Friese Wouden is situated in the province of Friesland, in the northern part of the Netherlands. The NFW is a 25,000 ha rural area specialized in dairy farming with some villages in between, where farming parcels are separated by hedgerows of alder belts and wooded banks (Oosterveld, 2013; van der Ploeg et al., 2010). Alder belts are rows of trees next to ditches, mostly alder trees, while wooded banks exist of a sand ridge that is overgrown by trees, bushes and herbs (Oosterveld, 2013). Hedgerows offer home and refuge to many species that are threatened by intensive agricultural practices (Besnard and Secondi, 2014).The soil in the NFW consists mainly of marine clay deposits on top of Aeolian sand deposits (Boer, 2003). The hedgerows stem from the time before barbed wire was introduced, and served to prevent livestock from roaming. Given its historical value the NFW is a national park (Oosterveld, 2013). Because of the cultural and biodiversity value of this landscape the farmers in this area are offered AES payments of 0.3 euro per m^2 to maintain their hedgerows. Within this area the farmer collective of the NFW plays an important role in nature and landscape conservation. The NFW submits a proposal for nature conservation to the Dutch government and is responsible for the implementation of these plans. This collective has around 800 farmer members in several municipalities spread over an area of 53,551 hectares. The area covered by the collective contains 971 km alder belts and 103 hectares of wooded banks (Noordelijke Friese Wouden, 2017). An average parcel in our sample will have four neighbours and 285 m^2 hedgerows. An average farm in our sample contains 0.91 ha of hedgerows and has 144 neighbouring parcels. The total amount of hedgerows in our sample is 8.19 ha.

4. Data

Available data

The model requires general farm data which is largely unavailable. Therefore we used data for the average Dutch farm that were available from different sources (RVO, 2010; Wageningen UR, 2015; Blanken et al., 2016; Meetjesland, 2016; Remmelink et al., 2016) for the following variables: costs of feed bought; costs of removing a possible phosphate surplus; costs of maintaining cattle; amount of feed produced on grassland; amount of feed produced on maize land; limits for phosphate application on grassland and maize land; milk price; labour costs; percentage cows to be replaced; price of new cows; price of slaughter cows; variance of the milk price; feed requirements per cow, cattle younger than one year and cattle between one and two years; phosphate content of grass, maize, feed bought, bound in milk, bound in carrying cows and bound in young cattle; labour hours needed for cultivating maize or grass; costs of cultivating silage maize and grass.

Data collection

Farm-specific information was collected from in-depth interviews with nine farmers in the NFW, which we contacted through the NFW farmer collective. All of them had hedgerows on their land, but not all participated in the AES scheme and maintained their hedgerows according to the AES guidelines. We asked each farmer about his/her farming objectives and their relative importance. In addition, facts concerning the type of farm, whether or not the farm was certified as organic, the number of cows and young cattle, the amount of milk produced on the farm, the amount of land, the different crops, the labour hours worked on farm, the amount of hedgerows, the location hedgerows and the maintenance of hedgerows were collected. Moreover, for all farms we had a map showing the exact size and location of all their parcels. Out of the nine farmers one farmer no longer had dairy cows, but he still owned and maintained his land. For this farmer we took the average milk production per cow and the average number of dairy cows in the region, since we assumed every farmer needed to be able to earn a subsistence income. We realise our small sample may not be representative of the whole region. However, it allows us to show how a small sample such as this can be used to create an artificial region which is suitable for running model simulations. In this way we are able to capture the mechanisms that are important in the collective AES system. In theory more farmers could be included in our model, but this would make solving the model more complex.

Data reconstruction

The farmers we interviewed were all located within the NFW. The nine farmers' land is not connected, however since we want to simulate biodiversity and farmer participation in a region, we create an artificial region containing these nine farms. For each individual farm we have a map showing its parcels of land, and how these parcels are located relative to each other. We used this information to create an artificial region, in which a total number of 288 parcels were assigned to nine individual farmer-agents. Since there is no reason to assume a specific spatial configuration, we calculated for each parcel k the probability that it neighboured parcel j of farm i in the sample. For the parcels k that belong to the same farm as parcel j this probability is either 1 or 0 as we know their exact location relative to parcel j. For the parcels k that belong to the other farms we calculated the probability by determining the number of potential neighbours. For example, imagine parcel 1 of farm 1 has 3 unknown neighbours and parcel 4 of farm 2 has two unknown neighbours. Parcel 4 could then be located any of the 3 unknown sides of parcel 1 with either of its two unknown sides. Furthermore assume that in total all the parcels not belonging to farm 1 have 100 unknown neighbours. Then parcel 4 of farm 2 has a probability of $\frac{1}{100}\times 3\times 2=\frac{6}{100}$ to neighbour parcel 1 of farm 1. We used the probabilities to calculate an expected amount of hedgerows maintained by multiplying the probability with the amount of hedgerows on each potentially neighbouring parcel and the parcel itself. One should note here that the effect of maintaining hedgerows on a single parcel on biodiversity is less extreme when one considers expected amounts. By multiplying the probability that each parcel is a neighbour times the amount of maintained hedgerows we take some kind of average over all the parcels that could potentially be a neighbour, thereby smoothening the effect a single parcel has.

5. Experimental design

In each of the scenarios we ran the model for 10 time steps in order to reach a stable outcome. It is important to notice here that time steps do not refer to specific time units, but refer to the time needed for the famers to respond to each other's actions in the previous time step. When making a decision, the farmer-agent takes the actions of the other farmer-agents in the previous time step as given. In the first time step the actions of the other farmer-agents are as indicated during the interviews.

5.1 Scenarios

Baseline: individual AES System
In this scenario AES payments are available if the farmer-agent properly maintains the hedgerows. The biodiversity feedback (arrow 1, 2, 3 in figure x) is in effect, but the payment feedback (arrow 4,5 in figure x) is not included. This scenario allows us to determine what the biodiversity and participation in the AES are in the individual AES system.

Collective AES system
In this scenario the first time step is equal to the baseline scenario. In each time step farmer-agents choose whether or not to maintain their hedgerows. The AES payment is only available

if the overall biodiversity score in the previous time step exceeds 0.8 (the range for this biodiversity score is 0-1). Both the biodiversity feedback and payment feedback are included. This scenario allows us to determine what happens to biodiversity and participation in AES when the collective AES system is introduced.

5.2 Model experiments

Lower biodiversity weights

In this model experiment we consider the effect of the switch from the individual to collective AES system in a situation where farmer-agents attach less value to biodiversity. We consider biodiversity weights that are in the range 0-50% of the original weight and for each of these weights we run the baseline scenario and the collective AES system scenario. When we lower the biodiversity weight, we increase the other weights proportionally to assure the weights will add up to one.

Differentiated payments

In this model experiment we allow for the possibility to differentiate payments between farmer-agents. We answer two questions in this experiment. First we ask what would be the minimum payment for each farmer for which he will choose to be in the AES. Second we ask what would be the minimum payment for each farmer for which he would choose to maintain all his hedgerows. In this way we calculate what would be the minimum costs of achieving maximum biodiversity.

Sensitivity analysis

To see how stable the model outcomes are we performed a sensitivity analysis for the amount of labour needed for maintaining hedgerows, the amount paid for maintenance and the milk price, this analysis can be found in appendix X.

6. Results

7.1 Results scenarios

Baseline Scenario

Figure x shows the biodiversity scores in each time step of the model for the baseline scenario.

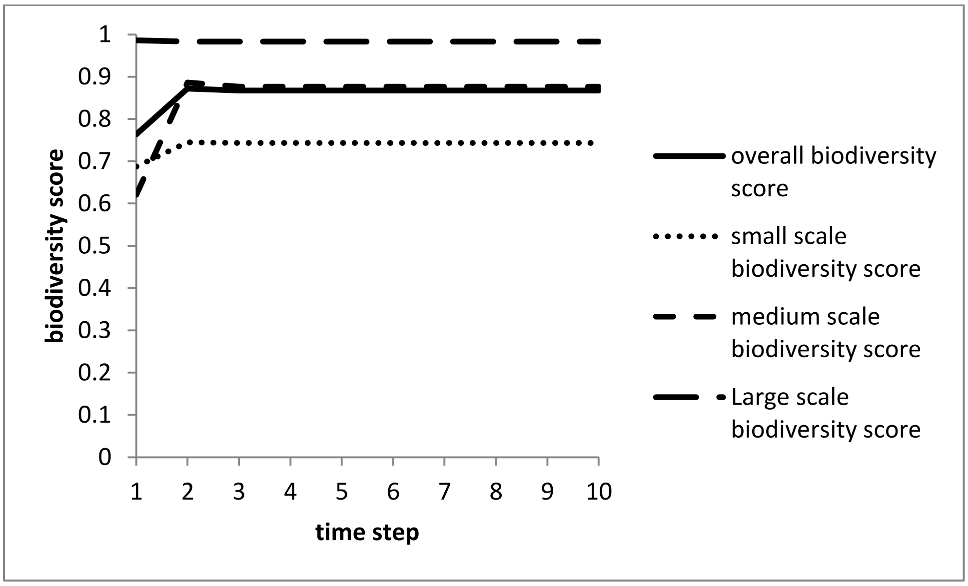


Figure x: Overall, small scale, medium scale and large scale biodiversity scores in the baseline scenario

Six farmer-agents participate in the AES maintaining 68531 m^2 of hedgerows. The overall biodiversity score stabilizes at 0.867 in the fifth time step. The highest biodiversity score is for large scale biodiversity, the lowest biodiversity score is for small scale biodiversity.

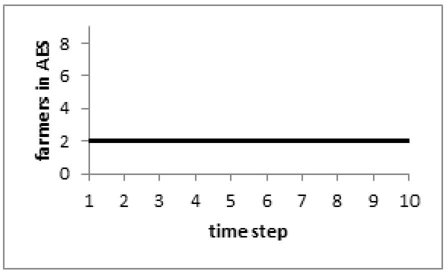
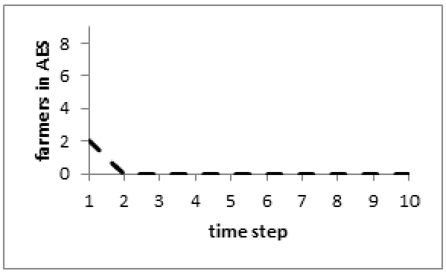
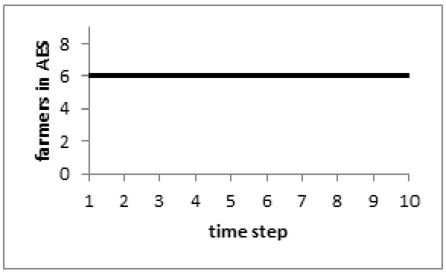
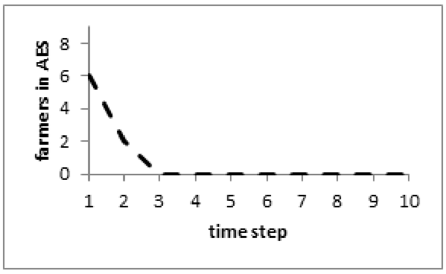
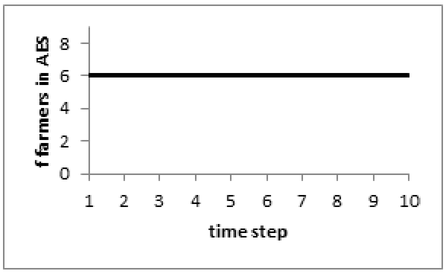
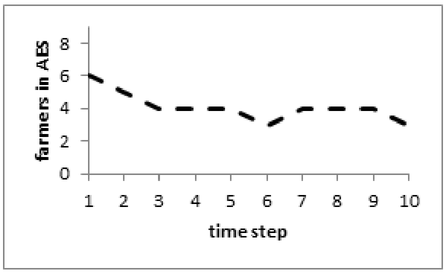
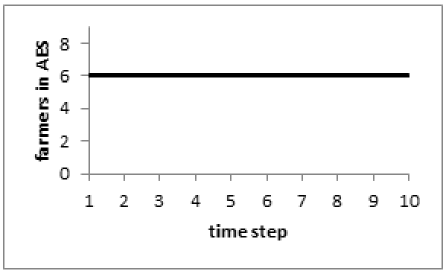
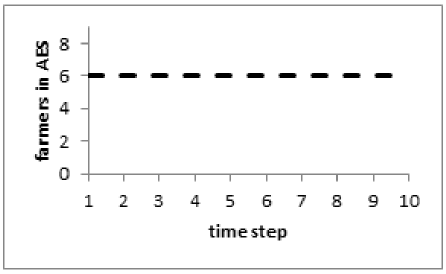
Collective AES system

The results at the end of the model run for the collective system were the same as the results in the baseline. A difference between farmer-agents' decisions in the baseline scenario and the collective system can be expected when there is a change in maintenance payment, which will occur if the biodiversity score drops below the threshold. This is apparently not the case here.

7.2 Results model experiments

Lower biodiversity weights

During the interviews we asked farmers to indicate the weight they attached to each of the farmer objectives. However, there is a risk that the biodiversity weights suffer from a bias. When a question is asked in a hypothetical way farmers do not need to take market and personal constraints into account or can be sensitive to the elicitation format used (Azevedo et al., 2003; Woldu et al., 2016). There is also the possibility that the weights reported by the farmers where socially acceptable answers or that the farmers in our sample cared exceptionally about biodiversity, leading to an overestimation of the importance of biodiversity. Therefore we ran the baseline and collective system scenarios again, but for biodiversity weights in the range 0-50% of the original weight. Since the weights in our model should add up to one, we heightened the other weighs proportionally when lowering the biodiversity score. Figure x shows the number of farmer-agents in the AES in the baseline scenario and the collective AES system scenario for the different biodiversity weights. Since the number of farmers in the AES did not change over the range 30-50% of the original weight, in the figure we only show the results for the range 0-30% of the original weight.

Biodiversity weights	Baseline scenario: individual system	Collective AES system
Biodiversity weight zero		
Biodiversity weight 10% of original biodiversity weight		
Biodiversity weight 20% of original biodiversity weight		
Biodiversity weight 30% of original biodiversity weight		

If the biodiversity weight is zero, only two farmer-agents are maintaining their hedgerows at the onset of the model run. Because the resulting biodiversity score is below the threshold, in the collective AES system the payment will not be available, and the biodiversity score will drop to zero. If the biodiversity weight is equal to 10 percent of the original weight, six farmer-agents participate in the AES at the onset of the model run. However, also then the biodiversity score is below the threshold, so that payments are not available and biodiversity drops to zero. Still two farmer-agents choose to maintain their hedgerows in the second step, because they are not primarily driven by the AES payment but by the perception of biodiversity around them. However, when they notice the low overall biodiversity score due to the low maintenance by the other farmer-agents in the second round they no longer maintain their own hedgerows in the third round. If the biodiversity weight is equal to 20 percent of the original weight, six farmer-agents participate in the AES at the onset of the model run. Since the biodiversity score is below the threshold, no payment is available. Therefore the number of farmers participating in the AES drops, and alternates between three and four farmers that keep responding to each other by maintaining small amounts of hedgerows. When the biodiversity weight is equal to 30-100% of the original biodiversity weight we do not see such a drop in farmer participation or biodiversity scores.

Differentiated payments

A larger number of farmer-agents can be convinced to participate in the AES if we differentiate payments. In this model experiment we first asked the question what the minimum payment needed to be for each farmer to be in the AES. The lowest compensation for each farmer-agent to be in the AES is zero for six farmer-agents, 0.9 euro per m^2 for two farmer-agents and one euro per m^2 for one farmer-agent. The total compensation paid for maintaining these hedgerows would then be 11954 euro. A small scale biodiversity score of 0.955, a medium scale biodiversity score of 0.999, a large scale biodiversity score of 0.909 and an overall biodiversity score of 0.954 will be reached. This is an improvement compared to the situation without differentiated payments, as in the baseline scenario in total 20559 euro is paid for maintaining the hedgerows, resulting in a biodiversity score of 0.867. The second question we asked in this scenario was what the minimum payment needed to be for each farmer to reach the maximum biodiversity score. To ensure the maximum biodiversity score at the lowest cost we should pay one farmer-agent no maintenance price, one farmer-agent 0.3 euro per m^2, one farmer-agent 0.4 euro per m^2, one farmer-agent 0.5 euro per m^2, one farmer-agent 0.7 euro per m^2, three farmer-agents 0.9 euro per m^2 and one farmer-agent 1 euro per m^2. The total amount paid for maintaining hedgerows is then 39009 euro.

Conclusions and Discussion

The number of farmer-agents that participate in the AES does not differ between the baseline scenario (individual AES) and collective AES system when we include the high biodiversity weights that resulted from our interviews. The overall biodiversity score is above the threshold, and therefore payments for maintaining hedgerows will be available in both scenarios. This suggests that the introduction of the collective AES system might not always have a profound effect on farmer participation and biodiversity. However, our results also showed that when farmer-agents have lower biodiversity weights a shift towards lower farmer-agent participation and lower biodiversity scores occurs. This shift starts due to the payment feedback, where payment is no longer available, influencing the farmer decisions and thus the level of biodiversity in the region. Due to the lower level of biodiversity in the region and the biodiversity feedback eventually all farmers stop their maintenance efforts. This shows how feedbacks in the land use system can interact resulting in a shift towards other maintenance choices. The results from the lower biodiversity weight scenario suggest that if biodiversity weights are indeed overstated or the farmers outside our sample do have lower biodiversity weights there could be a potential for a shift towards low farmer participation and biodiversity scores.

The results from our model suggest that as long as biodiversity remains above a certain threshold the collective AES system will not result in lower farmer participation. In this light the finding from Melman et al. (2016) that a moderately positive ecological effect for meadow birds is expected due to the collective AES system implies that no major shift in farmer participation is to be expected. Melman et al. (2016) did not take the economic efficiency and farmers' support for the collective system into account.

Differentiating payments in our model simulation makes it possible to reach higher biodiversity scores at lower costs. One could even imagine a situation where the higher biodiversity score due to differentiated payments could prevent a shift towards low farmer-agent participation. These results indicate that there might be gains from introducing differentiated payments into the AES system. Although this reallocation makes sense from an economic or efficiency point of view it will probably be not so easy to implement as farmers might consider it to be unfair.

Our sensitivity analyses show that AES participation and biodiversity scores depend on the labour requirements for maintenance, the level of AES payment and the milk price. The sensitivity analysis on the amount of labour needed for maintaining hedgerows shows that farmer-agent AES participation is quite independent from the amount of labour needed for maintenance of hedgerows in the range 0.1-0.7 hours per 10 m^2. If we increase the amount of labour needed to 0.8 hours per 10 m^2 a tipping point is reached in both AES participation and biodiversity scores. If no labour is needed to maintain hedgerows all farmers participate in the AES. This suggests that the farmers' collective could organise an exchange of labour where farmers who attach a high utility to biodiversity might increase their utility by offering to help maintain the hedgerows on farms belonging to farmers who attach no utility to biodiversity. The sensitivity analysis on maintenance payment indicates that some farmer-agents will maintain their hedgerows even when no payment is available. Other objectives and farmer interactions also influence conservation choices, a finding which is in line with research by Runhaar et al. (2016). Van Dijk et al. (2016) noticed that farmers might even be willing to perform conservation measures when they do not get paid or won't perform, even when they get paid. The maintenance decision of farmer-agents depends on the milk price as well. If milk prices are lower biodiversity scores are slightly higher and vice versa. This suggests that farmers are willing maintain more hedgerows if the alternative becomes less profitable.

We realise our research has limitations, we mention four. First, in our model we do not allow the total amount of hedgerows to increase beyond the current amount of maintained plus unmaintained hedgerows in the NFW. This assumption is based on the fact that none of the farmers indicated a willingness to plant more trees, due to the restrictions on removing trees. Second, we use stated farmer objectives in this model, which might differ from the actual weights farmers might apply in their day to day decisions. Third, biodiversity in this paper is measured in quite a crude way. We capture only the effect of maintaining three specific species in small, medium and large key areas and their dispersion capacities. Therefore our biodiversity scores should be interpreted only as an indication of the effect on biodiversity. Finally, in this paper we considered the success of the collective AES system from the perspective of farmer participation and biodiversity scores. We did not score the collective system on its performance in other areas, such as the possible cost savings or reduction in monitoring efforts for the Dutch government.

The reported results are determined in a model simulation based on a small sample, and caution should be applied when generalizing these results. However, despite the caveats we think this paper contributes to the discussion on the implementation and effects of AES payments for maintaining wildlife and landscapes.

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Appendix A: GAMS model

The model describes the behaviour of the dairy farmers in the "Noordelijke Friese Wouden". It is assumed that the farm maximizes utility (A1). Utility equals the sum of the weights the farmer attaches to each of the farmer objectives times the normalized value of each objective. The farmer objectives are profit maximization (A2), labour minimization (A3), risk minimization (A4) and biodiversity maximization (A5). In the model utility is maximized subject to constraints (A2-A35).

Objective:

$$maximize\ \ U_i = \sum_{n=1}^{2} g_{in} \frac{O_{in}}{O_{in}{}^{*}} - \ g_{i3} \frac{O_{i3}}{O_{i3}{}^{*}} - \ g_{i4} \frac{O_{i4}}{O_{i4}{}^{*}} \qquad \text{(A1)}$$

$n = 1,..,4; i = 1,..,9$

Subject to:

$$O_{i1} = p_1 y_{i1} + p_2 x_{i22} + p_o x_{i7} - \sum_{m=1}^{8} w_m\, x_{im} - w_9 O_{i2} - \ w_{10} x_{i24} \qquad \text{(A2)}$$

$m = 1, \dots, 10$

$$O_{i2} = LR_i \qquad \text{(A3)}$$

$$O_{i3} = v_1 y_{i1}{}^2 \qquad \text{(A4)}$$

$$O_{i4} = \frac{\sum_{b=1}^{3} \mu_{ib}}{3} \qquad \text{(A5)}$$

$$y_{i1} = \ x_{i1} * e_{i4} \qquad \text{(A6)}$$

$$x_{i4} = \sum_{m=1}^{3} x_{im} e_m - x_{i11} e_{11} - x_{i12} e_{12} - x_{i13} e_{31} - x_{i14} e_{32} \qquad \text{(A7)}$$

$$x_{i5} = \ \max(\ 0, x_{i15} - x_{i16}) \qquad \text{(A8)}$$

$$x_{i15} = x_{i11} e_{11} e_{13} + x_{i12} e_{12} e_{13} + \ x_{i13} e_{31} e_{14} + x_{i14} e_{32} e_{14} + x_{i4} e_{15} - x_{i1} e_{i4} e_{16} \ - x_{i1} e_{17} - x_{i2} e_{18} - x_{i3} e_{19} \qquad \text{(A9)}$$

$$x_{i16} = x_{i8} e_{20} + x_{i6} e_{21} \qquad \text{(A10)}$$

$$LR_i = x_{i1} e_5 + \sum_{m=6}^{8} x_{im} e_m \qquad \text{(A11)}$$

$$x_{i18} = \sum_{h=1}^{H} e_{hi22} - e_{i23} \qquad \text{(A12)}$$

$h = 1,.., H$

$$x_{i18} = x_{i8} + x_{i6} \qquad \text{(A13)}$$

$$e_{i23} = x_{i7} + x_{i9} \qquad \text{(A14)}$$

$$x_{i8} = x_{i11} + x_{i12} \qquad \text{(A15)}$$

$$x_{i6} = x_{i13} + x_{i14} \quad \text{(A16)}$$

$$x_{i12} + x_{i14} = x_{i7} * e_{10} \quad \text{(A17)}$$

$$x_{i7} \leq e_{i23} \quad \text{(A18)}$$

$$x_{hi10} = x_{hi25} + \sum_{a=1}^{A} e_a * x_{ha19} \quad \text{(A19)}$$

$$a = 1, \ldots, A$$

$$x_{i21} = \sum_{h=1}^{H} x_{hi25} + \sum_{c=1}^{C} e_c * x_{hc20} \quad \text{(A20)}$$

$$c = 1, \ldots, C$$

$$\mu_{i1} = \sum_{h=1}^{H}\left(\frac{1}{\left(1+e^{\left(-\alpha*\left(\left(\frac{x_{hi10}}{e_{hi33}}\right)-\beta\right)\right)}\right)}\right) \Big/ e_{i35} \quad \text{(A21)}$$

$$\mu_{i2} = \frac{1}{\left(1+e^{\left(-\alpha*\left(\left(\frac{x_{i21}}{e_{i34}}\right)-\beta\right)\right)}\right)} \quad \text{(A22)}$$

$$\mu_{i3} = \frac{1}{\left(1+e^{\left(-\alpha*\left(\left(\frac{\sum_{i=1}^{9} x_{i7}}{e_{i24}}\right)-\beta\right)\right)}\right)} \quad \text{(A23)}$$

$$x_{i7} = \sum_{h=1}^{H} x_{hi25} \quad \text{(A24)}$$

$$x_{hi25} \leq e_{hi28} \quad \text{(A25)}$$

$$x_{i1}, x_{i2}, x_{i3}, x_{i4}, x_{i5}, x_{i6}, x_{i7}, x_{i8}, x_{i9}, x_{i11}, x_{i12}, x_{i13}, x_{i14}, x_{i18}, x_{i22}, x_{i23}, x_{i24} \geq 0 \quad \text{(A26)}$$

$$x_{i8} \geq x_{i18} * 0.8 \quad \text{(A27)}$$

$$x_{i2} = e_{i25} x_{i1} \quad \text{(A28)}$$

$$x_{i3} = e_{i26} x_{i1} \quad \text{(A29)}$$

$$x_{i1} \leq e_{i27} \quad \text{(A30)}$$

$$x_{i22} \geq e_9 * e_{i27} \quad \text{(A31)}$$

$$x_{i23} = e_{i30} * e_{i27} + x_{i17} \quad \text{(A32)}$$

$$x_{i1} = e_{i27} - x_{i22} + x_{i23} \quad \text{(A33)}$$

$$O_{i1} \geq e_{29} \quad \text{(A34)}$$

Add for the collective AES system setting:

$$If \ (\frac{\sum_{i=1}^{9} \mu_{i1}}{9} + \frac{\sum_{i=1}^{9} \mu_{i2}}{9} + \frac{\sum_{i=1}^{9} \mu_{i3}}{9})/3 > e_{36} \ then \ p_{ot=2} = p_o \quad \text{(A35)}$$

$$If \ (\frac{\sum_{i=1}^{9} \mu_{i1}}{9} + \frac{\sum_{i=1}^{9} \mu_{i2}}{9} + \frac{\sum_{i=1}^{9} \mu_{i3}}{9})/3 \leq e_{36} \ then \ p_{ot=2} = 0$$

Where:

U_i = *utility of farmer i*

O_{i1} = *profit farmer i in euros*
O_{i2} = *labour hours used on farm i*
O_{i3} = *risk taken by farmer i*
O_{i4} = *overall biodiversity score*

O_{i1}^* = *maximum profit in euros farmer i could obtain*
O_{i2}^* = *minimum labour hours that could be used on farm i*
O_{i3}^* = *minimum risk that could be taken by farmer i*
O_{i4}^* = *max overall biodiversity score farmer i could obtain*

g_{i1} = *weight attached to profit maximization by farmer i*
g_{i2} = *weight attached to labour minimization by farmer i*
g_{i3} = *weight attached to risk minimization by farmer i*
g_{i4} = *weight attached to biodiversity maximization by farmer i*

LR_i = *labour hours required on farm i*
LI_i = *initial labour hours available on farm i*

α = *speed parameter*
β = *biodiversity parameter*

v_1 = *variance milk price*

μ_{i1} = *biodiversity score small scale biodiversity type for farmer i*
μ_{i2} = *biodiversity score medium scale biodiversity type for farmer i*
μ_{i3} = *biodiversity score large scale biodiversity type*

y_{i1} = *milk produced on farm i (in 100 kgs)*

p_1 = *price milk in euro per 100 kg*
p_2 = *price old cows in euro per cow*
p_o = *price maintained hedgerows in euro per* m^2
$p_{ot=2}$ = *price maintained hedgerows in euro per* m^2 *in second time step*

w_1 = *maintenance costs in euro per cow*
w_2 = *maintenance costs in euro per young cattle < 1 year*
w_3 = *maintenance costs in euro per young cattle > 1 year*
w_4 = *costs per KVEM feed in euro*
w_5 = *costs of removing a kg of excess phosphate in euro*
w_6 = *costs of maintaining a* m^2 *of maize in euro*
w_7 = *costs of maintaining a* m^2 *hedgerows in euro*
w_8 = *costs of maintaining a* m^2 *of grass in euro*
w_9 = *costs of hiring an hour of labour in euro*
w_{10} = *costs of buying one more cow in euro per cow*

x_{i1} = *number of cows on farm i*
x_{i2} = *number of young cattle < 1 year on farm i*
x_{i3} = *number of young cattle > 1 year on farm i*
x_{i4} = *KVEM feed purchased by farm i*
x_{i5} = *kg phosphate surplus on farm i*
x_{i6} = m^2 *maize land on farm i*
x_{i7} = m^2 *maintained hedgerows on farm i*
x_{i8}= m^2 *grassland on farm i*
x_{i9} = m^2 *hedgerows not maintained on farm i*
x_{hi10} = *expected* m^2 *maintained hedgerows on parcel h of farm i and its neighbouring parcels*
x_{i11} = m^2 *grassland without damage from hedgerows on farm i*
x_{i12} = m^2 *grassland with damage from hedgerows on farm i*
x_{i13} = m^2 *maize land without damage from hedgerows on farm i*
x_{i14} = m^2 *maize land with damage from hedgerows on farm i*
x_{i15} = *kg phosphate produced on farm i*
x_{i16} = *kg phosphate that can be placed on land farm i*
x_{i17} = *number of new cows bought by farm i*
x_{i18} = *total* m^2 *land used in production on farm i*
x_{ha19} = *m2 hedgerows maintained on neighbour a of parcel h on farm i*
x_{hc20} = m^2 *hedgerows maintained on neighbour c of farm i*
x_{i21} = m^2 *hedgerows maintained on farm i and its neighbouring parcels*
x_{i22} = *number of (old) cows sold by farm i*
x_{i23} = *number of new cows on farm i*
x_{i24} = *number of new bought by farm i*
x_{hi25} = m^2 *hedgerows maintained on parcel h of farm i*

e_1 = *KVEM needed per cow*
e_2 = *KVEM needed per young cattle < 1 year*
e_3 = *KVEM needed per young cattle > 1 year*
e_{i4} = *100 kg milk produced per cow on farm i*
e_5 = *labour hours needed per cow*
e_6 = *labour hours needed per* m^2 *maize land*
e_7 = *labour hours needed per* m^2 *maintained hedgerows*
e_8 = *labour hours needed per* m^2 *grassland*
e_9 = *percentage cows that will be too old for milk production on farm i*
e_{10} = *share of land affected by maintained hedgerows*
e_{11} = *KVEM produced on a* m^2 *of grassland without damages*
e_{12} = *KVEM produced on a* m^2 *of grassland with damages*
e_{13} = *kg phosphate in a KVEM from grassland*
e_{14} = *kg phosphate in a KVEM from maize land*
e_{15} = *kg phosphate in a KVEM purchased*
e_{16} = *kg phosphate in 100 kg milk*
e_{17} = *kg phosphate in a carrying cow*
e_{18} = *kg phosphate in a young cattle < 1 year*
e_{19} = *kg phosphate in a young cattle > 1 year*
e_{20} = *kg phosphate allowed on a* m^2 *of grassland*
e_{21} = *kg phosphate allowed on a* m^2 *of maize land*
e_{hi22} = m^2 *area parcel h on farm i*
e_{i23} = *initial* m^2 *land used for hedgerows on farm i*
e_{i24} = *maximum* m^2 *of hedgerows that could be maintained in the region*
e_{i25}= *number of young cattle < 1 year per cow on farm i*
e_{i26}= *number of young cattle > 1 year per cow on farm i*
e_{i27} = *initial number of cows on farm i*
e_{28hi} = *maximum amount of hedgerows that could be maintained on parcel h of farm i*
e_{29}= *subsistence income farmers*
e_{i30} = *percentage cows that can be replaced by young cattle farm i*
e_{31} = *KVEM produced on a* m^2 *of maize land without damages*
e_{32} = *KVEM produced on a* m^2 *of maize land with damages*
e_{hi33} = *maximum expected* m^2 *hedgerows that could be maintained on parcel h of farm I and its neighbouring parcels*
e_{i34} = *maximum expected* m^2 *hedgerows that could be maintained on farm I and its neighbouring parcels*
e_{i35} = *number of groups of parcels and neighbours on which hedgerows occur*
e_{36} = *threshold overall biodiversity score*
e_a = *probability parcel a is a neighbour of parcel h of farm i*
e_c = *probability parcel c is a neighbour of farm i*

Within this model the farmer aims to maximize his utility, as depicted by equation (A1). Utility depends on four farming objectives; profit maximization, labour minimization, risk minimization and biodiversity maximization. Whether or not a farmer attaches value to each of these objectives depends on the weights for the farmer objectives. If a farmer does not care about an objective, this objective will obtain a weight of zero.

Profit is the result of the revenue from milk production, the revenue from selling cows that are no longer productive and AES payments, minus the costs of normal production including the costs of maintaining hedgerows, the costs of labour and the costs of buying new cows (A2). Labour used on the farm is equal to the amount of labour hours needed for all of the farms activities (A3). Risk depends on the variance of the milk price (A4). The overall biodiversity score depends on the biodiversity score for the small scale biodiversity type, the medium scale biodiversity type, and the large scale biodiversity type (A5).

There are two commodities that are produced on the farm: milk and biodiversity. The revenue from milk depends on the milk production, which is the result of the number of cows times the milk production per cow (A6). Of course, cows need to be fed. Feed can be produced on farm, and feed needed in excess of the on-farm production can be purchased from the market (A7). Feed production depends on the type of crop grown (grass or maize) and possible damages to production due to shade from the hedgerows. If more phosphate is produced on farm than can be placed on farm land, there is a phosphate surplus that has to be removed from the farm (A8). Phosphate produced on farm results from phosphate included in the feed minus the phosphate captured in the milk, cows and young cattle (A9). Phosphate that can be placed on land is determined by multiplying the allowed amount of phosphate per m^2 of grass or maize with the m^2 of grass and maize on the farm (A10). The labour required on the farm is sum of the labour needed for feeding and milking the cows, the labour needed to work the farm land and the labour needed to maintain the hedgerows (A11). The total amount of land that can be used in production is the land available on the parcels of the farm minus the land needed for hedgerows (A12). The amount of land used in production can be used for growing grass or growing maize (A13). Land used by hedgerows can either be maintained or not maintained (A14). Grassland can be divided into grassland with and without damages from hedgerows (A15). Maize land can be divided into maize land with and without damages (A16). The total amount of land with damages can be calculated as equal to a share of the land used by maintained hedgerows (A17). The total amount of maintained hedgerows cannot exceed the initial amount of hedgerows (A18).

In our model we translate the amount of maintained hedgerows for the small scale, medium scale and large scale types of biodiversity in a biodiversity score. The basis for calculating this score is to compare the amount of maintained hedgerows in the model with the maximum amount of hedgerows that could be maintained. For the small scale biodiversity type we consider for each parcel the amount of hedgerows that is maintained on the parcel and its direct neighbours. For the medium scale biodiversity type we compare the amount of hedgerows that are maintained on the own parcels of the farm plus the amount of hedgerows that are maintained on the neighbouring parcels of the farm. For the large scale biodiversity we compare the amount of hedgerows that are maintained in the total region. We use the information on the parcels of the individual farms to create an artificial region. We calculate for each parcel the probability that it neighbours parcel h of farm i in the sample. For the parcels h of farm i this probability is either 1 or 0 as we now their exact location. For the parcels of the other farms we calculate the probability by determining the number of potential neighbours. We then use the probabilities to calculate an average expected amount of hedgerows maintained on each parcel and its direct neighbours by multiplying the probability that parcel A neighbours parcel h with the amount of hedgerows on each potentially neighbouring parcel and add the hedgerows maintained on the parcel itself (A19). We multiply the probability that parcel C neighbours farm i with the amount of hedgerows on each potentially neighbouring parcel of farm i and add the hedgerows maintained on farm i itself to calculate the expected amount of hedgerows on the farm and its neighbouring parcels (A20). Using these expected amounts of hedgerows we can calculate the biodiversity scores for small scale, medium scale and large scale biodiversity. We calculate the biodiversity scores by a logistic function, and the score depends on the ratio of maintained hedgerows and the maximum amount of hedgerows that could be maintained for that type of biodiversity (A21, A22, and A23).

Of course, the sum of the hedgerows maintained on each of the parcels of the farmer is equal to the total amount of hedgerows maintained by the farmer (A24). The amount of maintained hedgerows on each parcel cannot exceed the amount of hedgerows on that parcel (A25).

The number of cows, number of young cattle younger than 1 year, number of young cattle older than 1 year, the amount of feed purchased, the phosphate surplus, the m^2 of maize, the m^2 of hedgerows maintained and not maintained, the m^2 of grass, the m^2 of grass without damages, the m^2 of grass with damages, the m^2 of maize without damages, the m^2 of maize with damages, the total amount of land used in production, the number of old cows sold, the number of new cows on farm and the number of new cows bought cannot be negative (A26).

Cows produce manure, which contains minerals. To prevent environmental damages due to a surplus of these minerals used on land, the EU formulated regulations that place a limit on the amount of minerals from manure that can be placed on land. The Dutch farmers and government have successfully argued that it is safe to put a bit more of these minerals on the Dutch soil type. This has resulted in an EU agreement called derogation, which allows for applying more minerals on land if a farm has at least 80 percent grassland. In order to be viable for derogation the farms in our model have to maintain at least 80 percent grassland (A27). The number of young cattle younger than 1 year and young cattle older than 1 year are estimated by taking a share of the number of cows, where the share taken was determined in the farmer interviews and differs for each farmer (A28 and A29). The number of cows cannot exceed the initial number of cows (A30). The number of cows sold is larger than or equal to the number of cows that is too old for production (A31). The number of new cows on farm equals the number of new cows coming from young cattle and the number of new cows bought (A32). The number of cows on the farm is the result of the initial number of cows, minus the cows sold plus the new cows (A33). In order for the farm to survive the farmer has to reach a certain subsistence income (A34).

To model the collective AES system the price paid for maintaining hedgerows depends on biodiversity achieved in the previous time step (A35).

Appendix B: Biodiversity scores for the different biodiversity types depending on labour needed for maintenance

Figure B1 and Figure B2 show the biodiversity scores for the different biodiversity types in both the baseline scenario and the collective system.

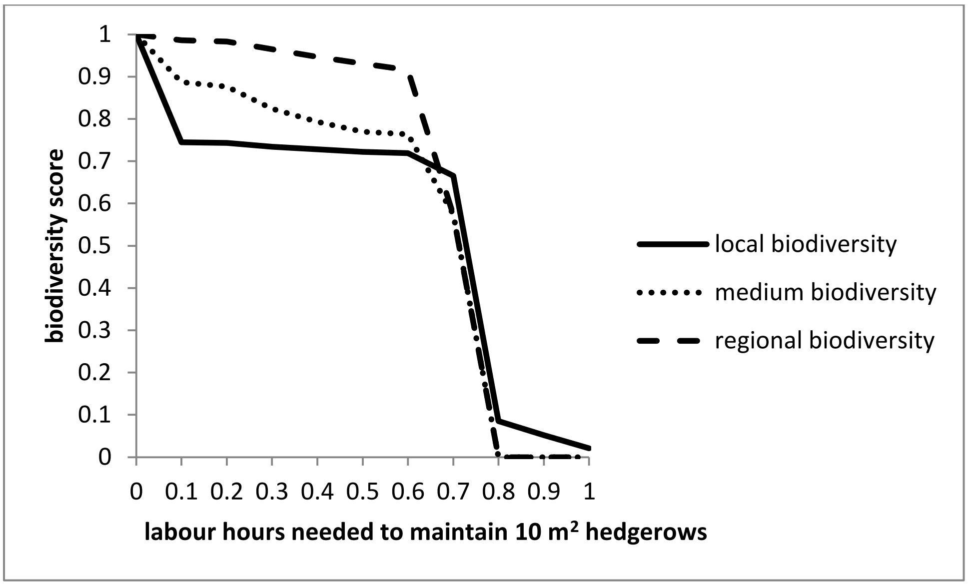

Figure B1: Small scale, medium scale scale and large scale biodiversity score at the end of the model run in the baseline scenario

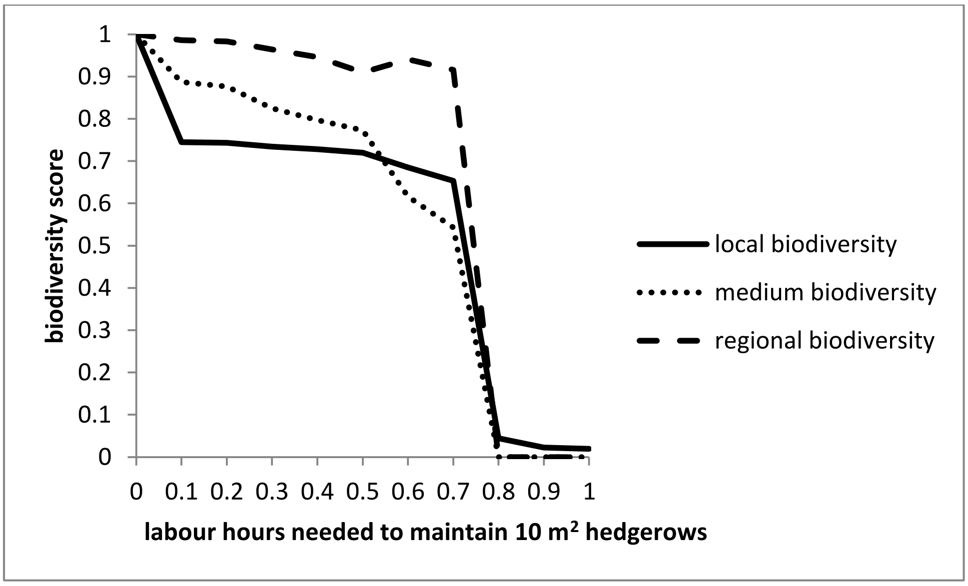

Figure B2: Small scale, medium scale scale and large scale biodiversity score at the end of the model run in the collective AES system

Appendix X: Sensitivity analysis

Sensitivity analysis labour

During the interviews, farmers found it difficult to indicate the amount of labour needed to maintain hedgerows. The estimates given covered a wide range. An estimation of 0.2 hours per 10 m^2 per year seemed reasonable to us given the farmers estimates, but we performed a sensitivity analysis to provide insight in the effect of using different amounts of labour needed in the model. One would expect that when the labour needed for maintenance of hedgerows is increased sufficiently, the farmer-agent will stop maintaining his/her hedgerows. At some point it will either be too expensive to hire additional labour, or the negative effect of using hired labour on the farmer-agent's utility will become too large. Figure 3 shows the number of farmer-agents in the AES for different amounts of labour needed to maintain hedgerows and figure 4 shows the overall biodiversity score for different amounts of labour needed to maintain hedgerows.

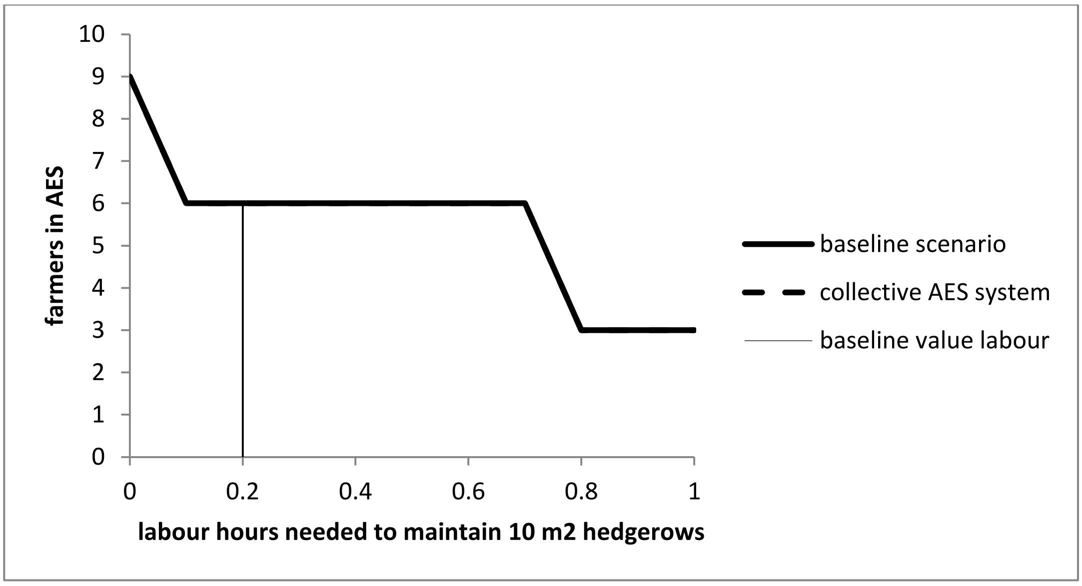

Figure 3: Farmer-agents in AES at the end of the model run for different amounts of labour needed for maintenance of hedgerows

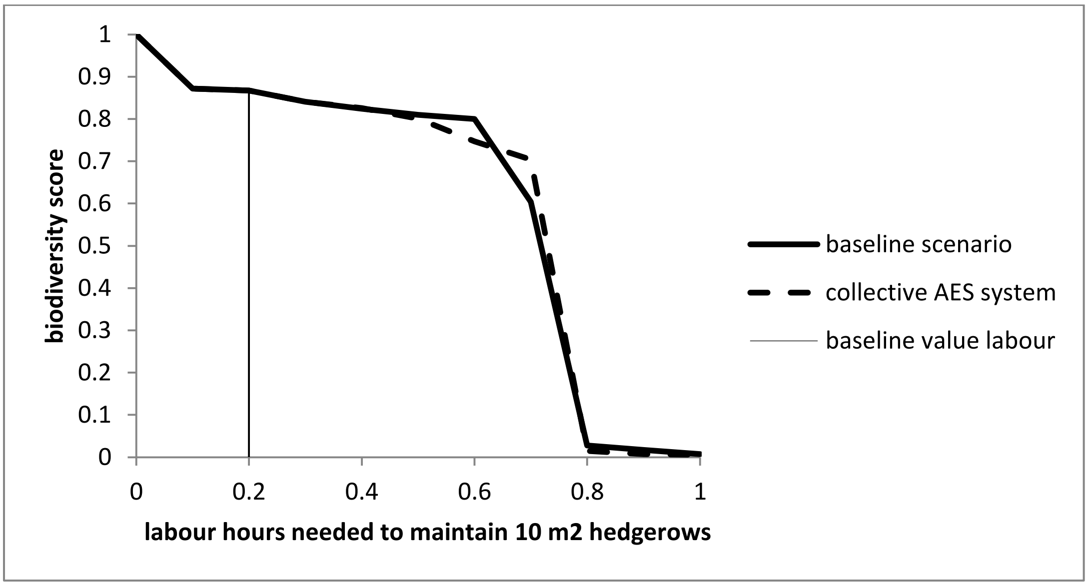

Figure 4: Overall biodiversity score at the end of the model run for different amounts of labour needed for maintenance of hedgerows

When we ran the model for different amounts of labour required we found no stable solution for the biodiversity score in the labour range 0.3-0.7 hours per 10 m^2, because farmer-agents kept changing their actions in response to each other's actions. However, the number of farmer-agents participating in this labour range stayed constant over the different time steps, and the difference in biodiversity score between the final time steps was very small. If no labour would be needed to maintain hedgerows all farmer-agents would participate in the AES and the maximum biodiversity score would be reached. The amount of labour needed does not influence the number of farmer-agents that maintains hedgerows in the range 0.1-0.7 hours per 10 m^2. If the amount of labour required reaches 0.8 hours per 10 m^2 a tipping point is reached and the number of farmer-agents that maintains hedgerows suddenly goes down to three. Even though the number of farmer-agents is constant in the range 0.1-0.7 hours per 10 m^2 the overall biodiversity score decreases gradually in this range until it also reaches the tipping point at 0.8 hours per 10 m^2 and the overall biodiversity score drops sharply. At this point the negative effect of using extra labour on the utility of the farmer-agent outweighs the positive effect of having a higher biodiversity on the utility of the farmer-agent. In terms of farmer-agent participation in the AES there is no difference between the baseline scenario and the collective AES system, but in terms of overall biodiversity score the collective system performs slightly worse when no AES payment is available. If no payment is available, there will not only be a negative effect on utility through using more hired labour when maintaining hedgerows, but also on profit since the costs made for maintaining hedgerows will not be compensated.

Appendix B shows the biodiversity scores for the different biodiversity types in both the baseline scenario and the collective system. In both scenarios the biodiversity scores for all three the biodiversity types (small scale, medium scale and large scale) show a sharp decline when labour needed to maintain hedgerows is equal to 0.8 hours per 10 m^2.

Sensitivity analysis maintenance price

The AES payment for maintaining hedgerows is 0.3 euro per m^2. For this payment six farmer-agents are willing to maintain their hedgerows. To see how farmer-agents respond to a changing compensation we perform a sensitivity analysis. Figure 5 shows the number of farmer-agents in the AES for different maintenance payments and figure 6 shows the overall biodiversity score for different maintenance payments.

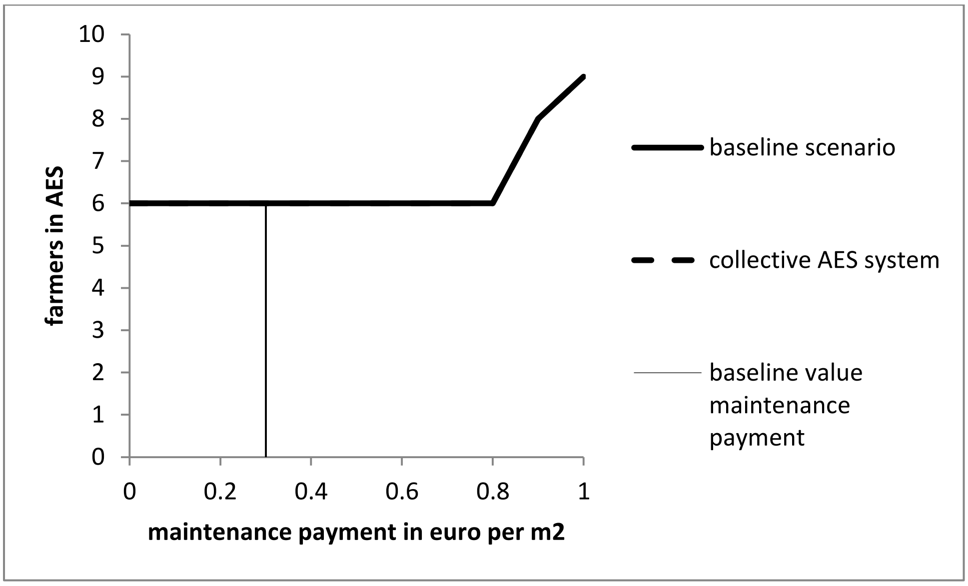

Figure 5: Farmer-agents in the AES at the end of the model run for different maintenance payments

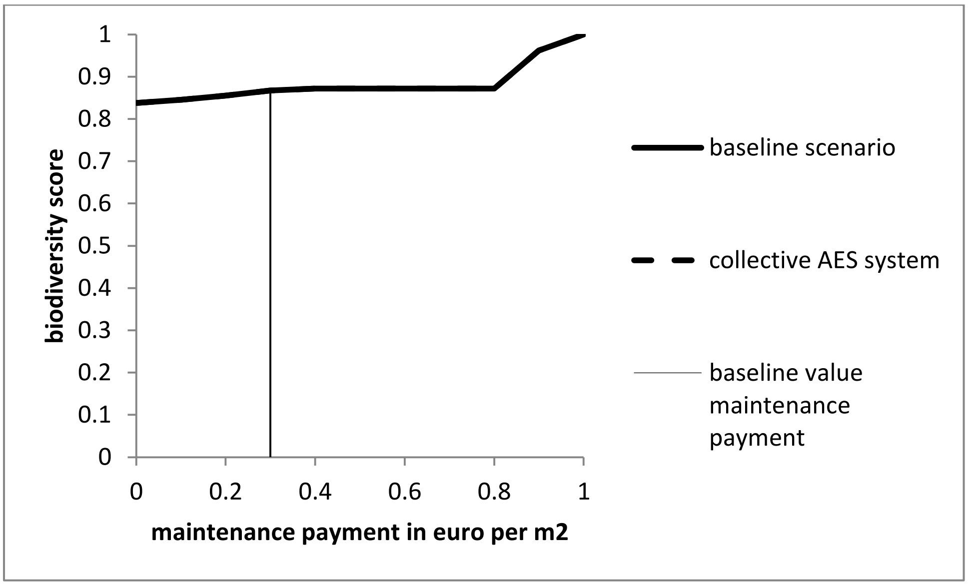

Figure 6: Overall biodiversity score at the end of the model run for different maintenance payments

Our sensitivity analysis shows that six farmer-agents are willing to maintain hedgerows even if they do not receive a payment at all. A maintenance payment below 0.3 euro per m^2 results only in a slightly lower amount of hedgerows that are maintained. If we increase the payment for maintaining hedgerows, the amount of farmer-agents maintaining hedgerows remains stable in the range 0-0.8 euro per m^2. If the price is 0.9 euro per m^2 the number of farmer-agents maintaining hedgerows increases to eight. If we increase the price to 1 euro per m^2 all farmer-agents will choose to maintain their hedgerows and the maximum biodiversity score will be achieved. This suggests that there is a possibility to differentiate payments, shifting payments for the farmer-agents that attach a high utility to biodiversity to the farmer-agents that do not attach (a high) utility to biodiversity for maintaining hedgerows.

Sensitivity analysis milk prices

The milk price in our model is the expected average milk price until 2026, which is equal to € 34.50 per 100 kg milk. However, milk prices vary over time. Therefore we analysed the effect of a 10 and 25 percent increase or decrease of the milk price on the biodiversity score. If we run the scenario with a 10 percent lower milk price there are six farmer-agents in the AES, and a small scale biodiversity score of 0.745, a medium scale biodiversity score of 0.887, a large scale biodiversity score of 0.986 and an overall biodiversity score of 0.872 is reached. These biodiversity scores are slightly higher than in the baseline scenario. Lowering the milk price with 25 percent does not increase the biodiversity score further. Apparently, if the milk price goes down, spending more time on maintaining hedgerows becomes a more attractive option, but this effect is limited. If the milk price increases by 10 percent there are six farmer-agents in the AES and a small scale biodiversity score of 0.740, a medium scale biodiversity score of 0.860, a large scale biodiversity score of 0.979 and an overall biodiversity score of 0.860 is reached. These biodiversity scores are slightly lower than in the baseline scenario. If the milk price increases with 25 percent there are six farmer-agents in the AES and a small scale biodiversity score of 0.737, a medium scale biodiversity score of 0.845, a large scale biodiversity score of 0.974 and an overall biodiversity score of 0.852 is reached. Apparently, if the milk price goes up, spending less time on maintaining hedgerows becomes a more attractive option. Since the overall biodiversity score is above the threshold there is no difference between the results in the individual and collective AES system.