Farming with Ecological Main Structures as Natural Pest Control: Modelling Land Use Regulations as Common Property

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Abstract: We address farming system analysis at the level of collective action by the question what is the contribution of an ecological main structures (EMS) and crop rotation to pest control? It will be analysed how a political economy approach of land use, including nature elements, can improve the rural situation. Our hypothesis is that, as a measure of crop protection, an EMS can help to reduce costs in pest control. We show mathematically that joint efforts in a community of farmers can result in building up an adequate size of nature elements in landscapes (an EMS) for maintaining bio-diversity.

Keywords: *ecological main structure, political economy modelling*

Introduction

The overall loss of species in farming areas through (1) modernization, (2) intensification and (3) mechanization of agriculture as well as minimising of nature elements such as (4) hedgerows, (5) small forest and (6) wetlands, etc. has attracted the attention of landscape ecologists and farming system analysts. In the past nature elements were common in most landscapes and visible as a so called Ecological Main Structure (EMS). Though, the term ecological main structure or as some times also called Ecological Network (EN) and Green (Blue) Veining (GBV) is a concept form the nineties (Jongman, 1995); however, it has a long tradition as describing cultural landscapes as environmentally rich and bio-diverse, and in the last years it has gained interest of landscape planning for biodiversity conservation (Brouwer and Godeschalk, 2004 and Grashof-Bokdam, 2009) as an active process. These EMS have strongly supported bio-diversity, which is considered a pre-requisite for eco-system services such as biological pest control, as well as maintained equilibria between pest pressures and agricultural productivity. One of the central elements of an EMS may be field margin (Internet: 2010), ditches, small woody areas, hedgerows as well as a special design of field sizes. Currently EMS structures have become a planning element in landscape ecology and landscape ecologist are experimenting in communities how to optimize EMS. An EMS or, for example, green-blue veining (term used by the Ministerie van VROM(NL), 2007; for simplicity we use EMS) is nowadays perceived as “a network of existing and planned nature areas connected by ecological linkage zones with the objective of preserving biodiversity”. The advantages of EMS are that nature provision or biodiversity maintenance is conducted at a community (parish) level and not individual farm level. However, this requires collective action (Ostrom, 1990) and, as will be discussed, a simple voluntary provision of farmers may not happen. However, this paper has not a focus on the ecological aspects, rather we will look into the socio-economic or institutional questions concerning the provision of an EMS. For instance, we will discuss an institution such as a “nature manager” which is connected with a community and model power aspects to guarantee the provision of the EMS. Such a nature manager can be perceived as a traditional “dike reeve” which was a common feature in European landscapes where common property management was needed to facilitate provision of public services; for example, drainage infrastructure or protection against the sea by collective action are typical cases, but also nature as a mode to protect against pests. To analyse such an institution we suggest a political economy model (Zusman, 1976) which allows us to compare statutory regulations and situations of the tragedy of the common. In particular we will investigate how interests in EMS exists, though not revealed by farmers.

In recent decades the need to have EMS seemed to have diminished and the function of EMS has been partly substituted by chemical pest control which is cheaper. This has raised public concern. However, ecologists tell us that the observable great loss of nature elements in rural landscapes, and hence the loss of biodiversity, should not only be a concern of the public, but also of the farmers, themselves, as their interest also may be harmed. Ecologists as a lobby group want multifunctional agriculture (Cahill, 2001) and urge governments to take measures to preserve bio-diversity and, especially, nature elements in cultural landscapes. Farmers do not see the rationale to concede land for an EMS, mainly because of costs.

There is a conflict that seems to be unsolvable, or it can only be politically solved. We think it is also a matter of understanding the current rural economic setting and political economy of EMS at local level. I.e. it is necessary to address the issue of an EMS and nature in rural landscapes form a combination of a system approach and the need for collective action (Castillo, D. and A.K. Saysel (2005) at community level. The core question is: What happens if farmers work together and, for instance, explore the potential for natural pest control opportunities in their farming system by creating an EMS? For this we need simulations. In such context a local “governance” structure, as a public management which “offers” pest control by a diverse nature, may play a role (see Rausser, 1992, on predatory versus productive government). Accordingly, we argue that institutional problems have been overlooked and both, farmers and ecologists, may benefit from natural elements and multi-functionality.

It is the primary objective of the paper to develop a model which helps to understand how farmers can be made supportive for bio-diversity projects that are based on EMSs. We show the potential for common property management fostering bio-diversity and controlling pests biologically, and we explain how to depict optimal public regulations within a framework of public bargaining. In our case public bargaining is initially about field margin provision of farmers. The paper is structured as follows: Section 1 gives an outline of the idea. It provides arguments for developing a model that caters for public choices on measures against production risk using a landscape approach (EMS). Section 2 presents a framework for modelling an EMS in conjunction with farm behaviour. Section 3 offers the result for group management by choosing a politically corrupt but powerful manager. Herby nature is a common property reducing costs and we assign nature service a value. Section 4 briefly discusses opportunities to imbed the analysis in a frame of crop rotations and how to make it spatially explicit. Finally the analysis is summarized and we give an outlook how to apply the approach.

Outline of the approach

The presented model uses the political economy approach on bargaining for public goods of Rausser and Zusmann (1992) to derive an objective function of a farmer community in nature conservation. Nature conservation is imbedded in a farming system which is exposed to collective action for maintaining hedges, buffer strips, ditches, etc., an EMS. The objective function will contain an EMS as a jointly producible, communally owned and managed resource. Biodiversity and pest control are retained through preserving nature elements in EMS (eco-agriculture and corresponding farming systems as in McNeely and Scherr, 2002). Though losing profits by cultivating less land, farmers concede land to a community because they gain indirectly from a better environment which helps them to control pests biologically. The aim is having less pest pressure in farm land through a more diverse biota by allocating land to nature. Farm land is private, but a “nature manager” has rights to impose statutory regulations on some land. Regulations imposed by a manager for the public good ‘nature’ are followed by farmers. In essence, the basis for the common property management is an EMS to which farmers voluntarily contribute. Land is used for hedges, stone walls, ditches, wet lands, etc.

The production and cost functions as well as the decisions of farmers are normally not oriented towards bio-diversity giving lower private profits. The rational is to use the EMS as a basis to conduct a community-wise and private evaluation of nature. Since bio-diversity in form of multiple species occurrence shall reduce risk of crop failures, the public manager cares about nature and farmers. Caring requires a communal objective function containing nature. In modeling, technically, nature is represented by a bio-diversity index, which counts in management and enters objective functions. Then communally produced bio-diversity becomes an element in the production function of farmers, as it reduces the risk of crop failure. As will be shown by duality theory, bio-diversity can appear in a cost function of minimizing risk. We assume substitution between both, purchased chemical inputs and nature. Bio-diversity (represented as EMS) is then a risk reducing natural device through public management.

A reduction of financial costs in plant protection shall be achieved through a political economy approach of managing the commons. Note that costs of plant protection must enter the objective functions of farmers and the community. The model shows how an aggregation of private objectives can be perceived. On behalf of a community, a manager of the natural environment maximizes his net benefits from additional nature elements and minimizes costs from economic risks of crop failures. As opposed to an unorganized community, which degrades the environment, the managed community shall be better off. But the benefit is not the benefit of a benevolent dictator; it is skewed through a political process of rent seeking.

For farmers costs and benefits count differently. They have indirect benefits as reduced financial costs of risk, expressed as reduced purchases of equivalent chemical substances to combat pests. These pests occur if natural predators are not available due to lack of habitats. Direct costs are created by waivers of full utilization of land, such as buffer strips or field margins used for the EMS. Furthermore, farmers must use “resources” for rent seeking (Rausser and Zusman, 1992); hence, interactions must be researched. Since nature "production" relationships are essentially confronted with potential improvements, farmers are normally skeptical whether a risk reduction can really be achieved. In contrast, pesticides mostly offer immediate cures of pests and guarantee high yields. Apparently, there is a trade off between a will to save pesticides and the uncertainty of getting the delivery. The model reconsiders the problem of uncertainty by putting certain probabilities on natural processes and modeling decision making as a stochastic problem of crop failure and risk. It uses standard approaches of cost functions, techniques to cater for risk, and strategies of farmers to assure against risk.

Modelling of farm behaviour, risk and Ecological Main Structures (EMS)

A framework for farmers’ participation in bio-diversity/EMS and interest functions

Our basic analytical framework for the description of farmers’ participation is an Ecological Main Structure EMS (Oskam and Slangen, 1998). For diversity provision and pest control it focuses on spatial allocation of land use by farms (Wossink, et al, 1998) in the EMS (example see reference of http:www). This spatial frame will enable us to (re)formulate a political economy concept of the provision of public goods (Rausser and Zusman, 1992). We use an initially time oriented model as a spatial model. For this a stylized framework is necessary to get dimensions of space and farms in one dimension of decision making, given limited space. The concept outlined in Figure 1 also provides a tool for empirical application, since field margins and the size of the EMS are displayed. Figure 1 depicts the idea of a plot oriented agriculture including field margins. In a rectangular field system the latitudinal axis with equal distances (a_1, a_2 ,..., a_i, ... to a_n) shows the horizontal stretch of a farming community. (Equal distances of fields conceive a polder or settler framework of land distribution.) Sizes differ on the longitudinal-axis allowing farms to have different sizes (x_1,x_2,....x_j,...x_m).

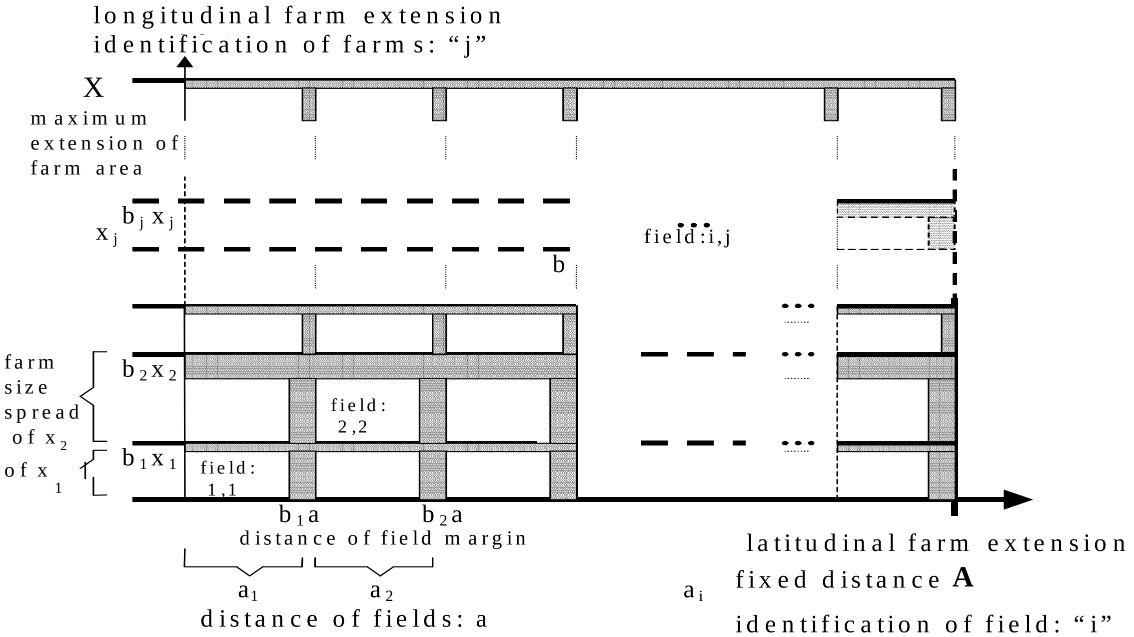

Figure1. Spatial Allocation and Ecological Main Structure

A mathematical outline

This framing of farms enables us to depict land allocation and the implementation of the EMS in the mode of field margins. To start let us define the field size as

$$l^*_{ij} = a_{ij}\ x_j \tag{1}$$

From such definition we modify the size l^*_{ij} of a field. The area contributed to the ecological main structure f^*_{ij} is identified at field “i” of a farm “j”. It can be depicted as percentage of the size of the field. Using a Taylor series expansion for a rectangular field “$a_i{*}x_j$” multiplied by a percentage b_j, we receive an approximated f_{ij} as size of field margin, applied, depending on b_j

$$f_{ij}= a_{i,0}\ b_j{*}x_j + x_{j,0}\ a_i{*}b_j - a_i\ b_j * x_j\ b_j \cong 2\ x_j\ a_i * b_j \tag{2}$$

where: $0 \le b_j \le 0.2$ and $a_i\ b^*_j * x'_j\ b^*_j \cong 0$

Accordingly, the remaining area that is not subject to field margins is defined as:

$$l_{ij} = (1-b_j)\ l^*_{ij} = (1-b_j)2\ x_j\ A/n \tag{3}$$

In this formula, the part of the latitudinal-axis, i.e. the distance of the field “a_i”, is already measured by the length of farms “A” divided by the number “n” of farms (equal length of farm "a" and half distance of x). The advantage is an equivalent expression of a constraint imposed by an EMS “B”, i.e. by the “length” of a farm, as a time constraint (Rausser and Zusman, 1992: their time frame becomes a spatial frame and “B” expresses the EMS in field margins). For instance, if 300 hectares for an EMS have to be obtained from 1000 farms of average size of 10 ha, each farm has to provide a size of 0.3 ha which is given in (4):

$$B \le \sum_i \sum_j a_i\, x_j b_j \text{ ; and since } A = \sum_i a_i \text{ by assumption: } B \le \sum_j A\, x_j b_j \Leftrightarrow A \le \frac{B}{\sum_j x_j b_j} \tag{4}$$

The spatial presentation (Figure 1) helps to specify the individual use of farm land, including the provision of field margins b_j, in terms of the overall constraint imposed on farmers.

$$l_{ij} = (1-b_j)\, l^*_{ij} = (1-b_j)\, x_j\, A/n = (1-b_j)\, x_j \frac{B}{n\left[\sum_j x_j b_j\right]} \qquad (5)$$

Having specified total individual farm land as part of a risk reducing EMS and knowing ecological impacts of the EMS on crop risk, we can proceed to model individual farm behaviour.

Farmers' behaviour in margin provision for an EMS

This section presents a mathematical expression of three aspects of farm behaviour: (1) a depiction of risk and decision-making; (2) a possible voluntary provision of field margins by farmers for an EMS; and (3) an outline of positive ecological effects which reduces costs due to higher biological activity. Hereby, the EMS is managed as public goods (Rausser, 1992). We propose two steps to reduce complexity and minimise on notation in stochastic affairs.

Risk and Costs

In a first step we assume that a farmer faces two distinct situations to which he attributes probabilities: y_g stands for good and y_b for bad yields. In a second step we introduce ρ which stands for the probability of good yields and $(1-\rho)$ for disaster, respectively. Farmers with a probability of ρ will obtain a gross margin p^c_j and have cost C^c. Gross margins and costs (low because of reduced pest pressure) are favourable in case of prevalence of high bio-diversity associated with the EMS. Average costs are lower than without EMS because pesticide use is low. However, with a counter probability $(1-\rho)$ farmers detect pest on their field (for instance insects or fungi) and either will have lower yields or use additional chemical inputs, i.e. increase their costs. Note a disaster (crop failure with a certain probability) can occur even if an EMS exists or pesticides are used, respectively. Disasters apply also to preventive pesticide use (the alternative to the EMS), perhaps on a lower probability but at higher costs. Strategically expressed, farmers who will join a community have, as a reference, a situation where profits from non-joining a community are given as additional pesticide costs and good yields. Profit considerations of farmers and corresponding decision making are focused on incremental profits from joining a community which has a farming system with EMS. These complex issues are modelled assuming a probabilistic decision where two probabilities are interlaced: assessment and failure. Pesticides uses, prevailing are: to go for a strategy of natural control or to apply a strategy of chemical control. We start with an expected difference

$$\Delta E[\tilde{\Pi}_{j,A}] = E[\tilde{\Pi}^c_{j,A}] - E[\tilde{\Pi}^p_j] \qquad (6)$$

of profits as prime criteria for improvement and use a probabilistic approach of yields, where

$$E[\tilde{\Pi}^{c}_{j,A}] = \rho_l\,(1+\Theta)\,\Pi^{s,c}_{j,A} + (1-\rho_l)(1-\Theta)\,\Pi^{n,c}_{j,A} \qquad (6')$$

as well as consider the second term as a calculated reference at given probabilities

$$E[\tilde{\Pi}^p_j] = (1-\rho_p)\Pi^{n,p}_j + \rho_p \Pi^{s,p}_j \qquad (6'')$$

where:

$E[\Pi_{j,A}]$ = expected profit gain on farm i (the reference of the fix profit has been dropped) composed of

$\Pi^{s,c}_{j,A}$ = profits with EMS and community, higher probability of good yields due to good nature

$\Pi^{n,c}_{j,A}$ = profits are diminished due to pest infection though an EMS exists and no use of pesticides

$\Pi^{n.p}_{j,A}$ = profits though a chemical pest control has been conducted and expenditures for pesticides

$\Pi^{s,p}_{j,A}$ = profits with no EMS put pesticide application and higher yields due to chemical pest control

ρ_l = probability of farmers with no pesticide use modified under the prevalence of the EMS

Θ = change in probability of farmers to face pest, being altered by the size of the EMS as index

ρ_p = probability indicating risk of farmers after application of pesticides or prevalence of the EMS

For simplicity, further we sort for and focus on elements that contain the impact of the change in probability. Distinct profits and strategies have to be specified, whereas we focus on profits "with" and profits "without" a community oriented EMS. Such discrete profit categories need to be established. Moreover, we assume a linear shift in the supply function of farms and a quadratic cost function (Chambers, 1988); at least we do it later to get decisions.

The major thing to be noticed concerns the cost modelling of EMS. In this respect, we assume that farmers see community oriented risk reduction by an EMS as a yield changing function. Yields are associated with a changed probability $\rho(1+\Theta)$ due to an index Θ (explained later). As well, if a preferable situation of having good yields (low exposure to pests) is not occurring, farmers will buy pesticides. With a probability $(1-\rho)(1-\Theta)$ a threshold is exceeded where farmers have to apply pesticides which reduce their gross margins. Finally, if a disaster occurs (a bad situation after decision) costs are forgone and revenues are low.

$$\Lambda\overline{\Pi}_{j,A} = \sum_i [p_j y_{g,i} \rho_i (1+\Theta) l_{ij} - C^c_{ij}(l_{ij}\rho_i (1+\Theta), r_j)] + \sum_i [p^*_j y_{d,i} (1-\rho_i)(1-\Theta) l_{ij} - C^c_{ij}(l^*_{ij}(1-\rho_i)(1-\Theta), r_j)] - E[\tilde{\Pi}^p_i]$$

where additionally : (6a)

$p_i y_{j,i}$ = adjusted gross margins per hectare, including yields, (profit$\Uparrow$) including y yields

l_{ij} = remaining area of the field i on farm j, area cropped, (profit$\Uparrow$)

$C^c(.)$ = cost function on quantity of q_{ij} at field l_{ij} with yield $y=q_{ij}/l_{ij}$, (cost$\Uparrow$=>profit$\Downarrow$) if the EMS exists

r_j = costs of inputs, farm specific, especially pesticides, etc. (cost$\Uparrow$=>profit$\Downarrow$)

r'_j = costs of additional input after detection of pests, farm specific, especially pesticides (profit$\Downarrow$)

This specification of risk includes a varying cost function. Functions must be given ex-ante. Financial costs are apparently lower when no pesticides are applied. Alternatives are expected costs: From our given specification of risk, as a discrete representation of yield fluctuations, alternatives of choice and opportunity costs emerge associated with regimes and probabilities. Note, we can subtract equal terms, but must assume risk neutral behaviour.

$$\Delta\overline{\Pi}_{j,A} = \sum_i [p_j \rho l_{ij} \quad C^c_{ij}(l_{ij}\rho\Theta, r_j) \quad C^c_{ij}(l^*_{ij}(1 \quad \rho_i)(1 \quad \Theta), r_j) \quad (1 \quad \Theta)\rho r'_j l + (1 \quad \rho)(1 \quad \Theta) p'_j l \quad c'_j] \tag{6b}$$

Presentation (6b) and profit notation can be further simplified taking additional costs and revenues as opportunity costs into account and integrating them in perceived new cost function

$$\Lambda\overline{\Pi}_{j,A} = \sum_i [p_j \rho l_{ij} \quad C_{ij}(l_{ij}\rho\Theta, r_j)] : C_{ij}(l_{ij}\rho\Theta, r_j)] = C^c_{ij}(l_{ij}\rho\Theta, r_j)] + C^c_{ij}(l^*_{ij}(1 \quad \rho_i)(1 \quad \Theta), r_j) \quad (1 \quad \Theta)\rho r'_j l + (1 \quad \rho)(1 \quad \Theta) p'_j l \qquad 6c)$$

Field margins and balancing private cost and benefits

In a second step we add the positive indirect effect of a crop insurance (average better profits by less expenditure for pesticides), which has been discussed above as difference in expected profits, and add the direct negative impact of land allocation on profits (less profits due to field margins) which will be discussed soon. In equation (6d), we introduce as policy measure a land share (%) to be devoted to an EMS, "b_j" (above), and balance farms' effects.

$$\Pi_{j,A} = \Pi^l_{j,A}(\ldots, b_j) + \Delta E[\tilde{\Pi}^r_{j,A}] \tag{6d}$$

Consecutively we must distinguish between a margin, b_j, and the overall size of the EMS, B. For a farm we state a positive b_j impact, though small, of land devoted to field margin $\theta_j b_j$ on costs; the collective impact Θ is bigger, explained later. For notice, farmer behaviour in field margin provision is written as constrained optimisation (Chambers, 1988) and broadly forms:

$\Pi_{j,A} = \sum_i [p_j l_{ij}(1-b_j) - C^c_{ij}(l_{ij}(1-b_j), \rho\theta_j b_j, \rho\Theta, r_j)]$ (6d')

where: increase: "⇑" and decrease "⇓" :

b_j = field margin as percent of field size (profit⇓)

$C^c_{ij}(\ldots)$ = corrected cost function (see above) including choices according to risk variation by the EMS

Now we split horizontal and vertical components of the size of a plot as explained previously. In that case of a regulator's influence on field margins, as a %: b_j, profits are adjusted to

$\Pi_{j,A} = \sum_i [p_j x^*_j a_i (1-b_j) - C(x^*_j a_i (1-b_j), \theta_j b_j, \Theta, r_j)]$ with constant latitude a: $x^*_j = a\ x_j$ (6e)

Now, assuming linear homogeneity in land with respect to the cost function and equal distances of fields on the horizontal axis, $\Sigma a = A$, a sum of profits from fields "i" can be rewritten as:

$\Pi_{j,A} = A[p_j x^*_j (1-b_j) - C(x^*_j(1-b_j), \theta_j b_j, \Theta, r_j)]$ (6f)

Equation (6f) is a most simple representation of profits as land allocation, as gross margins per hectare, as input costs of pesticides, and as strategic variables of risk. It also enables a treatment of public management. We soon analyse this public management. Note that no management serves as reference. Though, due to limitations we do not depict it here.

Implementing of positive relationship of field margins and EMS

The opportunity for a positive relationship between public management of risk reduction by an EMS and field margins is depicted in relationship (7a). A change in risk of crop failure shall be linear regressible on sizes of the EMS. Note that the sizes of effects are individualised in order to care for special impact and interest of farmers. We state a constant and linear part:

$\Theta = \Theta_{0j} - \Theta_{1j}\mathrm{B}$ (7a)

As a further explanation: Function (7a) can be considered a reduced form of a sequential functional relationship between a risk of crop failure and bio-diversity on the one hand and bio-diversity and construction of EMS on the other hand. A diversity index D serves as measure related to the EMS.

$\Theta = \Theta^{**}_{0j} - \Theta^{**}_{1j}\mathrm{D}$ and $\mathrm{D} = \Theta^{*}_{0j} - \Theta^{*}_{1j}\mathrm{B} \Leftrightarrow \Theta = \Theta^{**}_{0j} - \Theta^{**}_{1j}[\Theta^{*}_{0j} - \Theta^{*}_{1j}\mathrm{B}] = \Theta^{**}_{0j} - \Theta^{**}_{1j}\Theta^{*}_{0j} + \Theta^{**}_{1j}\Theta^{*}_{1j}\mathrm{B}]$ (7b)

Admittedly, this is only a crude representation and a more elaborated scheme is perceivable. This may include a detection based on the cropping pattern (see later). But, it suffices to explain the core arguments. A complex representation of bio-diversity would require a more detailed argument on the management side.

Next, introducing ecological constraint "B", derived from the corresponding A of farm length (see equation 4 and 5), gives profits on individual level expressed as dependent on allocation "b_j" of field margins *and* communal achievement (requirement) risk depend on "B" for farm j:

$$\Pi_{j,A} = \frac{\mathrm{B}[\mathrm{p_j x^*_j}(1-\mathrm{b_j}) - \mathrm{C}(\mathrm{x^*_j}(1-\mathrm{b_j}), \theta_j \mathrm{b_j}, \Theta_{0j} - \Theta_{1j}\mathrm{B}, \mathrm{r})]}{\sum_j \mathrm{x^*_j b_j}} \qquad (6')$$

Technically the issue seems to be clear: A community of farmers may decide on B, because the pressure of pests forces them to allocate field margins. But how is it about costs and stategies? And the further question remains: Will individual optimisation behaviour go for the b_j's recognising the positive effects on Θ? As a public good the ecological main structure "B", i.e. the empirically measurable equivalent of nature provision by the *community of all farmers*, is of potential interest; yes, but: A question is how to describe the management. Note the management is a common property problem. For that we need an objective function and the optimization of a manager on behalf of a community. In the following this we will use a political economy concept (Rausser and Zusman 1992). To sketch the argument, we look at optimisation towards b_j in (6') after expanding to the community level. Then we can optimize by setting first derivatives equal 0. Note, there is a difference between individual and collective decision making since they influence each other (positively: Rausser and Zusman 1991).

Bargaining Equilibrium

In this section we briefly sketch the concept of bargaining and statutory regulations. A more elaborated version can be found in Nuppenau (2002). It is an application from political economy. The model is from Zusman (1976) and a multiple agent model. In that model a bargaining process can be ultimately modelled as a specific functional form of an objective, such as:

$$L=[\prod_j (I_j - I_j^0)](I_m - I_m^0) \tag{8a}$$

Equation (8a) is an interior solution of the bargaining process (Rausser and Zusman (1992). The social optimum is a special case. In the normal case of a manager the monitoring and enforcement is in the hand of a manager who has power. He is biased person like a native chief who can be bribed gaining power. As Zusman (1976) has shown, bargaining a solution is not the same as policy preference function. Instead, he states that the weights reflect analytic properties of two aspects, the "production function" and the "resources devotion" aspect of power in bargaining (bribing). Following the arguments and referring to proves of the author (Zusman, 1976), a treatable version of equation (8a) is given in (8b). Further, (8b) reveals an over-proportionality in costs (second part) as managers increase the EMS size.

$$W=\sum_j [1+w_j][\frac{B[p_j x_j^*(1-b_j)-C(x_j^*(1-b_j),\theta_j b_j,\Theta_{0j}-\Theta_{1j}B,r)]}{\sum_j x_j^* b_j}] - \tau_0 B + 0.5\tau_1 B^2 \tag{8b}$$

In equation (8b), weights *w*$_1$, ..., *w*$_k$, correspond to the ratio of achievements (optimal interest function in the bargaining process being a first derivative of the strength that is acquired from the threat strategy not to co-operate (Zusman 1976). Formally we can get and expression:

$$...; w_j = \frac{(I_j^{opt.} - I_j^0)]}{(I_m^{opt.} - I_m^0)]} = \frac{\partial s(c_j, \delta_j)}{\partial c_j} \tag{9}$$

Finally, calculating derivatives b_j' of the public welfare function "W" provides a solution:

$$\frac{\partial W}{\partial b_j} = B(1+w_j)[\frac{[p_j x_j^* + C_b^*(x_j^*(1-b_j),\theta_j b_j,\Theta_{0j}-\Theta_{1j}B,r)]}{\sum_j x_j^* b_j} + \frac{x_j^*[p_j x_j^*(1-b_j)-C(x_j^*(1-b_j),\theta_j b_j,\Theta_{0j}-\Theta_{1j}B,r)]}{-[\sum_j x_j^* b_j]^2}]=0 \tag{9a}$$

$$\frac{\partial W}{\partial B} = (1+w_j)\frac{[-C_B'(x_j^*(1-b_j),,\theta_j b_j,\Theta_{0j}-\Theta_{1j}B,r)]}{[\sum_j x_j^* b_j]} + [\tau_0 - \tau_1 B] = 0 \tag{9b}$$

To solve (9), assumptions on functions are needed. We can use a reduced form cost function (Chambers 1988), that depicts land management of farms and EMS as a quadratic variable; implicitly it contains a substitution of chemical pesticides and the EMS. Note, normally, linear supply and factor demand functions match with such quadratic costs. A reduced form is:

$$C(x_j^*(1-b_j),\theta b_j,\Theta B,r) = \gamma_{0j}\theta b_j + 0.5\gamma_{1j}\theta b_j^2 + \gamma_{2j}\theta b_j r_j + \gamma_{3j}\Theta B + \gamma_{4j}\Theta B^2 + \gamma_{5j}\Theta B\theta b_j \tag{9c}$$

For simplification γ_{ij} coefficients cater for scaling and substitution of public, biological EMS and private, chemical pest control. This translates EMS into risk reduction. Since (9) is composed of ecological and economic risk components it reflects farm behaviour. Inserting equation (9b) in (9a) and using a quadratic approximation of individual optimality conditions for farm j we receive for farmer j:

$$(1+w_j)[p_j x_j^* - \gamma_{0j} + \gamma_{1j} b_j - \gamma_{2j} r_j] - [\tau_0 - \tau_1 [\sum_j x_j^* b_j]] = 0 \tag{10a}$$

For convenience we have dropped the coefficients of the eco-impact function (7a and b). The optimisation of the public manager's objective function (9) is a correlate between private farm optimisation and public (manager's) optimisation reflecting the bargain. Hereby the alternative EMS size and biological pest control in the landscape is established. For instance, with a number of k farmers, a linear system of k equations exists (10b). For all b_j (i=0 to k) we get a system wise optimality of field margins that can be solved for $\boldsymbol{b}^{\boldsymbol{b}\prime}=[b^{\boldsymbol{b}}_1, ..., b^{\boldsymbol{b}}_j, ..., b^{\boldsymbol{b}}_k]$

$$\begin{bmatrix} (1+w_1)\gamma_{11} + \tau_1 A x_1^* & & (1+w_k)\tau_1 A x_k^* \\ & \cdots & \\ \tau_1 A x_1^* & & (1+w_k)\gamma_{1k} + \tau_1 A x_k^* \end{bmatrix} \begin{bmatrix} b^b_1 \\ \cdots \\ b^b_k \end{bmatrix} = \begin{bmatrix} (1+w_j)[p_1 x_1^* - \gamma_{01} - \gamma_{21} r_1] + A x_1^* \tau_0 \\ \cdots \\ (1+w_k)[p_k x_k^* - \gamma_{0k} - \gamma_{2k} r_k] + A x_k^* \tau_0 \end{bmatrix} \tag{10b}$$

(10b) is a matrix and vector representation. Finally to solve the system, the left hand side can be expressed with matrix Γ^* multiplied by b^b and the right hand side is vector given farms "j":

$$\Gamma^*_1 \boldsymbol{b}^b = (1+w)[p-\gamma_0-\gamma_2 r] + Ax_i\tau_0 \Leftrightarrow \boldsymbol{b}^b = \Gamma^{*\,-1}_1 (1+w_j)[p-\gamma_0-\gamma_2 r] + Ax_i\tau_0 \tag{11}$$

The resulting bargaining vector $\boldsymbol{b}^{\boldsymbol{b}}$ depicts a possible solution. This bargain solution reflects the political power structure w, and ecology. I.e. $\boldsymbol{b}^{\boldsymbol{b}}$ also depends on the ecological knowledge of a public manager. If power is equally distributed, a vector $\boldsymbol{b}^{\boldsymbol{s}}$ can be calculated showing a social welfare solution. In contrast, Figure 3 assumes that the social situation is not achieved, rather powerful large farms dominate. A social objective function is merely theoretical if pressure groups have non-equal power. The model can be used to analyse deviations from that. In Figure 2 willingness to devote area to a EMS for community pest control is depicted for two types of farms, large and small. Three cases are shown: (1) tragedy of the common (not discussed), (2) bargaining (public manager with own interest) and (3) social (equal power of farmers). The Figure states the hypothesis that eventually large farmers with a lot of influence will devote less land. The actual situation can be only clarified by an experiment. The paper shows the formal approach for including socio-economic aspects into landscape planning; an empirical investigation in a pilot study is due. We need to know how social planners are received by farmer communities. For instance, the model can be expanded to payments for contributions.

Currently, at several places (Netherlands, England, etc., see Internet 2010) experiments are conducted; however mainly from an ecological perspective of landscape ecologists. The land is primarily used for field strips used as ecological corridors and a lot of money is spent. This costly component may halt application and statutory regulations are an option as shown. From the above analysis it should become evident that heterogeneity of farms in terms of size, yields, and location should be included in EMS design. Opportunity costs in terms of labour used combating pests or pest costs are also important. There is scope to integrate the

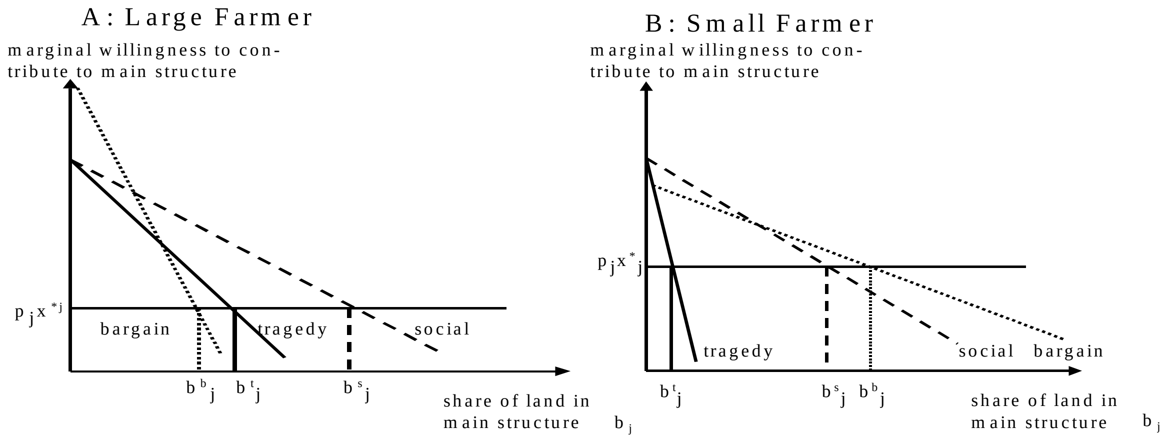

Figure 2. Bargaining solution and modified willingness to contribute after bargaining.

Two approaches (landscape ecology –EMS- and political economy -dike reeve-). In practical terms it means to do “secondary” planning in space for an EMS along the above outline of a depiction of interests in the provision and statutory regulation. The number of farms and their cropping specialization, i.e. modern vs. traditional mixed farming is also important. To accommodate the analysis a modified version with typical farms in a community will facilitate a feasible application, likely. Especially mixed farming with crop rotation implies a challenge. This aspect can be included if we expand the approach to a time related frame (next outline).

With regard to bargaining strategies, which are, at a first glance, revealed as participation or defection, the model will help to understand the interest position of farms. Large farms have a large interest but low stake. So in practice it will be interesting to know how compensations can be constructed which makes them for concerned. The issue of the social interest may result into a uniform size of the field margin, in general. But some farmers will be given concessions. For example if there pest pressure is low, they practice rotations, etc. There is much scope to streamline the model with more realistic interventions for statutory regulations. Such type of analysis is both, theoretical and practical. The above approach shows how simulations can support practical communication with stakeholders on regulations. Especially by modelling one can save time or avoid frustrations of participation, for instance, by pre-selecting such experimental suggestions which will have no chances.

EMS, crop rotation, and field organisation

In the previous section a mode was outlined by which an EMS can become the subject of a public interest as an input to pest control. The concept, used, was a spatial depiction of a landscape. Furthermore, via the creation of field margins, we can create a more bio-diverse landscape including nature elements on field margins. Another mode is to look at crop rotation. The above analysis did not go into specific production programs of farmers, however.

In this section we suggest an outline on possibilities to model crop rotation as part of the above analysis of a collective action in landscape design. As above analysed, a farm is cluster of fields having a certain length $\Sigma b_j = B$ and width $\Sigma a_j = A$. One can fit parcels (plots, fields) within a landscape. This also applies to rotation. For example (in Figure 3), we assume that six crops shall fit in a rotation. If six fields are 10 ha each, and if a = 500 m, then b_j = 200 m. So we can depict cropping patterns by b_j. A next step is to qualify land. A way of doing so is by introducing categories of yields and types of crops. In Figure 3 we use three different categories: good I, normal II, and bad III yield. Also in Figure 3 we illustrate how quality varies in time. Then crop allocation can change from period 1 to period 2. As preferred crops like wheat generally require good land, we sequentially allocated land 1 (good I) to wheat (note this can be done in linear programming; here it is only for demonstration). After the transition between periods programming has produced a new distribution of land quality which follows new field sizes. In a model, activities (allocation) for years can be chosen according to long run profits (discounted) prevailing over a planning horizon of thirty years, or even more.

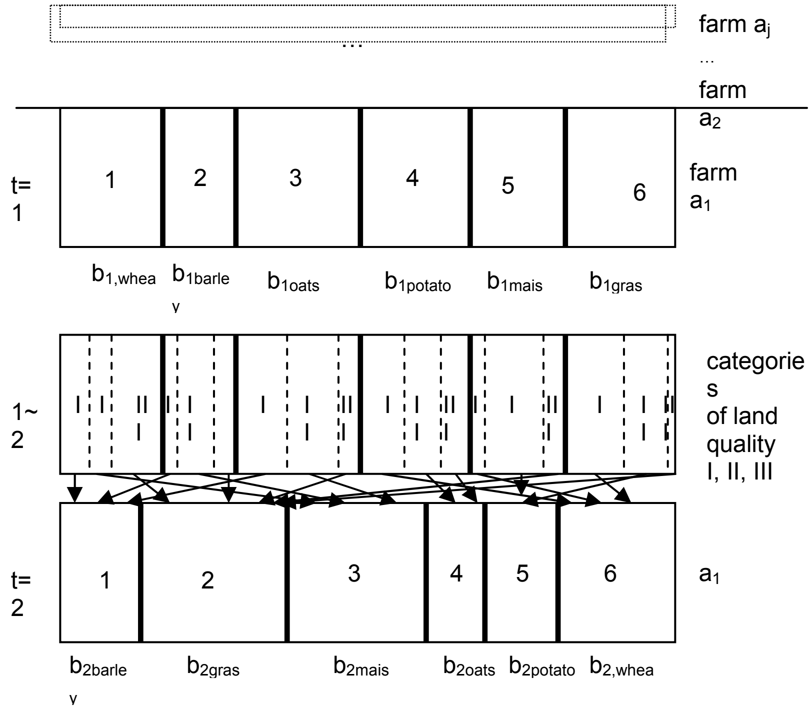

Figure 3. Field Size and Allocation at Farm Level.

So, if we supplement the spatial allocation with a sub-module on periodical allocation a diverse landscape can be the result. This diverse landscape must be related to a similar pest index as mentioned before. The advantage is that farm planning can be associated with quality categories and an EMS, being a minimal knowledge system on land quality vs. degradation. Then farmers are assigned different rotations in time which give different pest pressures.

Furthermore, the technology coefficients (yields) must not be the same all over the time. In programming this can be depicted by a transition matrix relating quality to rotation choices. In such type of modelling we can combine the differentiation of technology and quality categories. Quality categories become constraints (see above). They are plan-able and foreseeable for farmers. The availability of land in different quality categories changes with different rotations. Foreseeable changes in programming means that changes can be directed (task of the public manager) and modified by behaviour of the community (planned as decisions).

A further path which can be explored could be the introduction of a yield index for plots in a certain rotation. This index D_r corresponds to the above diversity index D as a measure of the benefits from an EMS. However we must now include all farmers with the margin and crop type at a specific field. Again margins and field are given as i=farm, j=field, and r=rotation.

$$\Theta = \Theta^{**}_{0j} - \Theta^{**}_{1j} D_r \ \& \ D_r = \Theta^{*}_{0j,r} - \Theta^{*}_{1j,r} [\ b_1 \ \ldots \ b_n]$$

$$D_r = \Theta^{*}_{0j,r} - \Theta^{*}_{1j,r} [\ c_{1r} b_{1,1,r} \ \ldots \ c_{nr} b_{1,n,r} \ \ldots \ c_{1r} b_{m,1,r} \ \ldots c_{1r} b_{m,n,r}] \qquad (12))$$

where additionally :

$c_{m,r}$ = category of soil quality according to rotation choice at farm m and in rotation

The eco-system quality index is now a function of the composition of land, which a farmer chooses as a selection for the EMS, and of a specific rotation, which give a quality of the eco-system. The essential thing is to see rotations and EMS as public good for management.

Summary

To summarize: We can depict the opportunity to model an ecological main structure (EMS) in a landscape and complement it with the farming system element of a public network of field margins. For such a system we outlined the economic and managerial capacities to achieve the EMS as a public good. The argument was built around the notion that an EMS and improved nature will decrease pest pressure in a community of farmers. We explicitly showed the possibilities of farmers to calculate the benefits form an EMS in a comparison with of costs for chemical control. Hereby a probability oriented concept was suggested which includes the four aspects, that pests occur or not and that the EMS or the chemical control are preferred. Finally we supplemented the analysis with some hints how the approach can be extended to the inclusion of crop rotations. Also crop rotations are considered a public good. A question is how to integrate the spatial aspects into management.
As a result the paper demonstrates how a public assignment of field margins to farms in an EMS can be modelled given that the manager is a biased manger. Moreover, the model allows us to calculate power coefficients which are the endogenous basis for a success of the regulations. There is further scope to apply the model and get it run for a diverse landscape. The type of explicit socio-economic modelling of regulations for nature provision, presented here, enables an interdisciplinary approach of landscape ecology and institution economics.

References

Brouwer, F. and F. Godeschalk (2004) Nature management, landscape and the CAP. Report 3.04.01, Agricultural Economics Research Institute (LEI), The Hague. http://www2.lei.wur.nl/publicaties/PDF/2004/3_xxx/3_04_01.pdf

Cahill, C. (2001) The multi-functionality of agriculture: What does it mean? EuroChoices, Spring 2001, pp. 36-40**.**

Castillo, D. and A.K. Saysel (2005)Simulation of common pool resource field experiments: a behavioral model of collective action. Ecological Economics 55, pp. 420– 436.

Chambers, R., 1988, Production Economics. New York.

Internet 2010: http://www.altera.wur.nl/uk/research/specialisation+landscape/ecolnewt

Grashof-Bokdam, C.L., Chardon, J.P., Vos, C.C., Foppen, R. P. B, WallisDeVries, M., van der Veen, M. And H.A.M. (2009) The synergistic effect of combining woodlands and green veining for biodiversity Landscape Ecology 24, p. 1105–1121.

Jongman, r., H.G. (1995) Nature conservation planning in Europe: developing ecological networks. Landscape and Urban Planning 32 , pp. 169-183.

McNeely, J.A. and S.J. Scherr (2002) Ecoagriculture: Strategies to Feed the World and Save Biodiversity. Washington.

Ministerie van VROM (NL) (2007) Green-blue veining: agro- biodiversity as innovation for sustainable agriculture, http://www.ontwerpenmetnatuur.wur.nl/NR/rdonlyres/53BA532A-618A-4D4B-984B-770704522C7B/44954/Greenblueveininginnovationforsustainableagricultur.pdf

Nuppenau, E.-A. (2002) Institutional and Political Economy Modeling of Nature Evaluation and Provision by Rural Communities. In: Hagedorn, K., Environmental Cooperation and Institut-ional Change, Theories and Policies for European Agriculture. Cheltenham, S. 214 - 236.

Oskam, A. and L. Slangen (1998) The Financial and Economic Consequences of a Wildlife Development and Conservation Plan. A Case Study for EMS in the Netherlands. In: Dabbert, S., et al., The economics of landscape and wildlife conservation. Wallingford, p. 113-134.

Ostrom, E. (1990) Governing the Commons: The Evolution of Institutions of. Collective Action. Cambridge.

Rausser, G. (1992) Predatory versus Productive Governments. The Case of US Agricultural Policy. Journal of Economic Perspectives, 6/3, pp. 133-157.

Rausser, G. C. and P. Zusman (1992) Public Policy and Constitutional Prescription. American Journal of Agricultural Economics. 74/2, p. 247-257.

Wossink, A., Jurgens, C. and J. van Wenun (1998) Optimal Allocation of wildlife conservation areas within agricultural land. In: Dabbert, S., et al. (ed.), The economics of landscape and wildlife conservation. Wallingford, p. 205-216.

Zusman, P. (1976) The incorporation and measurement of social power in economic models. International Economic Review, 17/2, p. 447-462.