Management of Ecosystem Services with a Focus on Biodiversity: Financing and Paying Services at Spatial Level in Landscapes

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Abstract

The focus of this paper is on the design of instrument variables (in the mode of payment for ecosystem services: PES) to achieve optimal service provision (ESS) at farming community level. These services shall improve production by reducing costs as public good and divert farmers' interest from using chemical inputs. In other words, preferring less costly nature compared to inputs purchased from the market is a vision. Apparently this depends on farm types and it must be shown how services can be evaluated to set priorities. We work with shadow prices. ESSs are built around biodiversity BD, its value and we may see disservices. To solve problems we suggest a programming approach. Then farmers providing ESSs are compensated and money has to be raised from farmers benefitting. The approach delineates interest functions and helps to simulate quasi-market coordination under governance elucidated as actively promoting habitats for ESS.

Instruments are outlined with regards public management for habitat provision, assuring ESS, which results in spatial organisations. They include land set aside for field margins (wildflowers), explicit outline of nature elements (hedges, etc.) and waivers on input use (reduced pesticides). We present the theoretical background for such farm level analysis in a cultural landscape where managers can address farm and field levels individually. In order to procure needed finance for payment on the one hand and to use this money efficiently on the other hand, farmers should be addressed as users and providers.

Keywords: common property management, spatial management of ESS

1 Introduction

"Payments for Ecosystem Services" (PES: Engel et al, 2008) are usually considered a tool for incentive in nature provision and detection of priorities in nature management. But also they should tell management what are priorities. We analyze priorities that can be detected from a shadow price analysis. Then the design of user fees charged to beneficiaries is based on priorities. These fees are used to offer compensation for habitat provision. It is assumed that a value oriented public management should appear in nature provision which is built on public *and* private actions. Perhaps, since providers should be paid and users offer money for services, a quasi-market solution is envisaged, yet its management is done by a public authority. Then, priority setting and valuation of species are imbedded in financial restrictions. This shall initiate successful public management of biodiversity (BD) in habitats. To match spatial supply and demand for biodiversity, here as a landscape management, shadow prices are received. Note equilibria (as request for governing by shadow price) have to be met if valuation type and management are agreed.

In fact, it has to be appreciated that charging fees for desired BD (positively valued) has to be linked to offering payments to farmers (providing BD). This results in different behaviour and interests with respect to ESS, yet suggested to be outlined at spatial level. Each farm type will work out different financial scenarios of participation, especially with respect to fees on the one side and payments on the other side. The question arises: how can we preferably link these fees and payments to land or BD. We are of the opinion that land is better than directly linking. Financial criteria can show contributions based on WTP or WTA. Finance depends on land use and instruments to be designed according to volumes of cash generated and spent. Plus, land has a keen role!

For this we need to delineate a spatial outline for supporting governance in finding the "best" instrument design. But, basically, we do not know the position of individual farmers, which is why we have to stylize benefits from provision in space as public management as coarse. Stylization works with presumed technologies. For instance, if sizes of farms (large) depend on current technology, farmers may calculate ESS benefits as minor and willingness to pay WTP is low. In contrast, small organic farms have a potentially high WTP for ESS that cannot be created at their own fields. The mix of farms has a big influence on capacities to generate finance at a local level; so we have to simulate. Also in cases of many potential beneficiaries a fee on chemical inputs and perspective to get ESS may create high cash flow. In a static world of given farm structures, high percentages of beneficiary farms will secure high WTP and hence finance to pay for provision. We have to model matching a farm or spatial structure. Vice versa choices of instruments impact structure. We will show how to justify financial contributions on the basis of ESS gains rooted in spatial production and how to find shadow prices as values.

It is the objective of the paper to show how questions on spatial land use, ESS outline and governance can be addressed by modelling farmers' interactions. We want to address spatial synergies and the need to design eco-nets for ESS provision by payments, addressing some farm characteristic. At the same time our PES outline shows how behavioral analysis can be used to obtain participation and incentives at the community level.

2 Nature Provision and Land Management

Our argument on nature provision focuses at spatial land use design comprising individuals in a community of users which contribute to and benefit from ESS based on an Ecological Main Structure (EMS: Nuppenau and Helmer, 2006). Ideally one can perceive an EMS in land use as a network of (1) land strips, (2) corridors or (3) field margins that can be structured by farmers as buffers and their (4) connectivity. Adjoining field shapes (Lankoski et al. 2008) and (5) selected stepping stones that stretch into farms, form habitat nets. Finally we can postulate (6) controlled residual farming in fields and on margins as need for ESS. An assumption is that BD management is interested differently in margins, stepping stones, hedges, wetlands, stone walls, etc., depending on a "typical" landscape of the region. Farmers classify nature elements as a typical landscape.

For a technical and mathematical depiction of an EMS aiming at BD realizations, let us assume that a matrix Ω exists that "converts" a vector of habitats "h" in a vector of species "s", i.e. equation (1) is equivalent to a production function. The matrix can be considered as probability oriented depiction that can be recovered through a *Markov model*. The model tells us, as a two-sided measure, how to accomplish specie vector s_i living in habitats h_j. Vice versa, since species need support by multiple habitats h_j, a linear combination Ω_{11} guarantees a composition of habitats that supports "s". For the sake of finally dealing with several communities we classify s_1 species vector in community 1.

$$s_1 \geq \Omega_{11} h_1 \tag{1}$$

where $\mathbf{s_1}=[s_{11},s_{21},...,s_{i1},...,s_{n1}]$: species
$\mathbf{h_1}=[h_{11},h_{12},...,h_{i1},...,h_{n1}]$: habitats

"s" is a vector of species , i.e. trees, herbs, incepts, bees, etc., which, in this case, are of interest for farmers as they are members of community 1 in which $\mathbf{s_1}$ prevails, and $\mathbf{s_1}$changes cost functions (see below). A range of *positive* BD such as flowers, birds, insects etc. can be included in ESS. Species serve different amenities and are to be identified by farmers. Habitats $\mathbf{h_1}$ support or coincide with a wished composition of BD. For instance, in terms of field margins (green belts) gardening the landscape, etc., "h" can be spatially identified and described by sizes: $\mathbf{h_1}=[h_{11},h_{21},...,h_{i1},..., h_{n1}]$. It is an assignment of ecologists as public managers to discuss, classify and constitute habitats. Their job description relies on biological information and involves human activities, as will be soon shown. A crucial "nature design" problem emerges with the choice of sizes of habitats as these are related to setting aside field margins. Farm and public land is needed for habitats referring to spatial structures. We distinguish two components, *natural* and *man-made* components in habitat design for BD prevalence that bring about a linear combination (accurately between sizes of different habitats, set-a-side area, and labor L in (2)):

$$h_1 = [\Omega_{21} + \Xi_{11}] a_1 b_1 \tag{2}$$

plus $$\Gamma_{11\,1} = \Theta L_1 \tag{3}$$

where: a_1 = vector of field sizes
b_1 = percentage for habitats
L_1 = for habitat and species

whereas labor is subsumed under management options on land that support EES with habitat levels. Therefore, laboring for nature on a plot *i* for habitat *j* has to be developed to support h as technical measure Γ_{11}. Technically, we can speak of a matrix Ξ that is linking nature and labor by technical coefficients in matrix Θ_1. Θ_1 expresses the knowledge of a "gardener"/manager on converting labor into habitats and ESS support. The outline

(1), (2) and (3), i.e. an outline on a relationship between human inputs, decision making, labor, and semi-natural species provision, can be understood as a transformation of inputs into outputs which give desired BD. Again, to support improved nature (BD), habitats as public management are needed. By bringing features together, we receive (4) as species vector that is dependent on land b_1 (simply margins) and labor L_1. (4) *works* to promote natural processes of creation of BD in a landscape, enabling spatial priority setting.

$$s_1 = [\Omega_{11}[\Omega_{21} + \Theta L_1]a_1 b_1 \quad (4)$$

A key task for management (of public good "BD: s_1" as suggested in this paper) is to find out how b_1 and L_1 should be designed and how they are to be invested (and by whom), given that individual and public interests in community 1 exists on BD. Hereby opportunity costs prevail for land and labor recognition. Vector b_1 and matrix L_1 are farm-wise and public at the same time and they create marginal values (need pricing).

3 Objective Functions due to Land Allocation for Specie Occurrence

We postulate, that explicit recognition of, for instance, allocation of field margins towards the establishment of EMS by farmers, as well as small fields for diversity, have to be seen in conjunction with the loss of agricultural land for farming vs. land for nature (as outlined by Nuppenau, 2014). Then we need an applied approach on farm economics and objectives in landscape economy. It may bear similarity to optimized spatial outline of farms as in programming (Röhm and Dabbert, 1999), though we may have to stylize it.

In our model, land use is separated between conventional farming on remaining fields and conditional use on field margins (buffers in case of no harvests: Lankoski et al. 2003, or given restrictions in farm practices: Wossink et al. 1998). At EMS level, positive effects (i.e. cost reduction due to higher biological activity as ESS provision) are expected and this is portrayed as eco-farming, which stays in contrast to intensive farming with chemicals (Perfecto and Vandermeer 2007) are used. Depending on the size of the EMS, a positive net effect is postulated as joint product which is "s" as the community. The public-good aspect of nature depends on EMS design. For instance presuming that only one farm does eco-faming in a landscape, positive effects of field margins are private. In contrast, usually positive effects of BD and ESS can only be attributed to several residents' efforts in a landscape (see recently: Hashimoto et al. 2014), i.e. if they are public. Note the assignment of areas for EMS and duty to deliver "h" is part of spatial management seeking minimal costs, her "b". Yet, it is presumed that landowners need to see effects of ESS being communal benefits, otherwise they are biological topics, only.

We work with an adjusted total profit. This profit is recalculated using crop yields on the remaining conventional field and on the margins. Thus, profits are essentially determined by land allocation between the inner parts of the field and the field margin.

Theoretically, the objective function (5) is those of a representative farmer in field margin provision which corresponds to a constrained optimization approach (Chambers, 1988). Such constrained optimization and corresponding dual approaches are frequently used in production economics. Notice, at the same time "s" is public and "s" is a vector of ESS.

$$I_i^u = \sum_j [p_j^u a_j (1-b_j) + c_j^r a_j b_{ij} - C((1-b_{ij}), b_j, [\Omega_{11}[\Omega_{21} + \Theta L_1] a_j b^*_{ij}, l_j, \mathrm{L}^*_{ij}, r_j)] \quad (5)$$

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

I^u_j	= as profit
c^r_j	= compensation per area of restricted ecology favoring agriculture, (profit⇑)
b_j	= size change of the field i on farm j, area cropped, (profit⇓)
L_j	= Labor j on farm j, for nature (profit⇓)
C(.)	= cost function on quantity of q_{ij} at field l_{ij} with the yield $h=q_{ij}/l_{ij}$, (cost⇑=>profit⇓)
b_{ij}	= field margins, *individual* cost reducing effect by biological activity (cost⇓=>profit⇑)
s	= side effect of a *community* based ecological structure, i.e. ecological effect from main structure: measured as effect of specie occurrence; positive and negative
l_j	= labor, if labor is requested for nature in particular habitat improvement(cost⇑=>profit⇓)
r_j	= input costs, farm specific (cost⇑=>profit⇓)

By (5) we can model farm behavior as dependent on individual contributions to an ecological main structure b_i and the contribution of potential cooperative partners b_{ij}, resulting in "s", i.e. the public good of blessed species.

A community of farmers may decide on sizes b^*_{ij} for a main structure EMS and offering "b" is a source of habitats. This happens, perhaps only because a pressure on all of the farmers requires them to deliver allocations of field margins. The question arises: how we can we model behaviour in the landscape. For the sake of simplification and illustration of effects, which will coincide with a benevolent dictator hypothesis, we take a sector approach with different farmers as sum. It implies that profits of all farm activities are:

$$\Pi_c^u = \sum_i \sum_j [p_j^u a_j (1-b_j) + p_j^r a_j b_{ij} - C((1-b_{ij}), b_j, s, l_j, \mathrm{L}_j, r_j)] \quad (6)$$

Equation (6) is a function which added profits of farmers. We consider this community welfare. As community welfare (6) has to be explicitly re-specified. For the cost function we use a quadratic function (7). A quadratic function (7) provides linear derivatives (Paris and Howitt, 2001). Also, (7) checks cross effects and it can be empirically evaluated.

$$C((1-b_j), b_j, s, r) = \gamma_{01j} b_j + \gamma'_{02j} s + 0.5 b'_j \gamma_{1j} b_j + \gamma_{2j} b_j r_j + 0.5 s' \Gamma_{1j} s + 0.5 s' \Gamma_{1j} L_{1j} 1 + \gamma'_{2j} s \; r_j \quad (7)$$

Note the farming systems of individual farmers are given by constraints and can be modelled. To explain coefficients and constraints effects, by s, b and L, again we refer to Paris and Howitt (2001). They have revealed how maximum entropy can be used to get interaction between effects of constraints and shown how imposed behavioral restrictions deliver response functions. Equation (7) can be evaluated in programming farms that show different practices (given that mixed or specialized farming in landscapes (7) will look differently) and ESS count differently for farms. Summing the number of n participants in total and expressing the summation in a matrix version, we get merging coefficients as representation of a community. And we dropped "*a*" for area; it is included in "*p*".

$$I_i^u = p_i^u(1-b_1) + p_1^r b_1 - \gamma_{011} b_1 - \gamma_{021} s_1 + 0.5 \cdot b_1^{'} \Gamma_{111} b_1 - 0.5 \cdot s_1^{'} \Gamma_{211} s_1 + 1_1^{'} L_1 \Gamma_{32} s_1 + b_1^{'} \Gamma_{311} s_1 - b_1^{'} \Gamma_{411} r_1 - b_1^{'} \Gamma_{511} r_1 \quad (8)$$

In version (8) variables for landscape design are (1) vector "b" (field margins) for any field that is given in a spatial structure and (2) "s" (species as appreciated BD) (Nuppenau, 2014). For comparison Bamiere et al. 2013 provided geometry or GIS versions of habitats, which translate a landscape in agronomic units. (3) "p" values are gross margins as vector and (4) "L" is a set matrix linked to land. Variables "b" and "L" reflect farm contributions to "s". They appear likewise as management and design problem for provision of "s" as well as profits depend on the capability to obtain b and L optimal.

4 Modelling "Supply" and "Demand" for a Generic Social Optimum of ESS Getting

4.1 Supply

To be explicit for PES simulations which request supply and demand and shall use above quadratic expression (8) we must now include payments *to* those farmers who provide habitats and receive compensation (WTA). Vice versa we also must look at payments *from* farmers (WTP: user fees) who benefit. Yet exploring farm behavior under PES is the aim, primarily touching land issues for habitat provision. But it is not only land. In flexible modelling of setting-aside land for habitats, farmers can even do more. This includes laboring, reducing pesticides and having smaller fields). Here, we can use expanded criteria for payment, similar to methods given by Nuppenau (2014). But, now farmers are benefitting from ESS and restrain land use partly voluntarily, given ESS "s" provision, while habitats are indirectly supplied by all farmers and spatial management. It means provision relies on a functional relationship between land set-aside and PES getting interests. Taking into consideration that farmers believe they lose, i.e. are not fully compensated for land by payment, correct compensation is important. Hopefully ESS prevalence encourages them to deliver land for nature at low compensation "c" for "b"; i.e. if they reduce costs on the basis of expected incidence "s" to which they contribute.

$$I_i^u = p_i^u(1-b_i) + c_c b_i - f_c s - \gamma_{00} - w\ 1^{'} L_i^{'} 1 - \gamma_{01} b_i + \gamma_{02i} s_c + 0.5 \cdot b_i^{'} \Gamma_{11i} b_i - 0.5 \cdot s_c^{'} \Gamma_{21i} s_c + 1^{'} L_i \Gamma_{32i} s_c + b_1^{'} \Gamma_{31i} s_c - b_1^{'} \Gamma_{41} r_i - b_1^{'} \Gamma_{51i} r_i \quad (9)$$

where: c = compensation
f = charge for ES service

The suggested actual payment “c” in (9) can be given as a net calculation. Thus, in our case, payments are given as “c” multiplied by “b” minus “f” for “s”, or vice versa. Net positions then have to be balanced by the management. In simulations of optimal provision we must supplement the corresponding payment for reduced costs as given in (9). Money in management as payment “c” for activities “b” and fee “f” for nature benefits “s” is balanced. Note “c” is a granted compensation that has to be financed by fee “f”. Equally “c” and “f” have to work at a community level either as generic or specific. In a generalized market simulation they are same for all farmers and set. Further, an advantage of “b” as landscape design instead of BD “s” is its visibility. Again, as shown by Nuppenau and Helmer (2006), we can model provision as supply “b” by “c”; now newly driven as linked to “s” (Chambers, 1988). For individual farmers we get conditional supply:

$$b_{1i} = \Gamma^{*}_{11\,i} q_{1i} + \Gamma^{*}_{12} L_{1i} 1 - \Gamma^{*}_{13} c_{c1} + \Gamma^{*}_{14} s_{1i} + \Gamma^{*}_{14} x_{1i} \qquad (10)$$

This is the result of a first derivative of (9) to “c” including an interest in “s” that provides “b” at lower levels of requested “c”. Subsequently, from another optimization, which is the usual supply of commodities, “q” can be derived on basis of gross margins “p”. Finally, a reduced form version of WTC*ontribute* on the basis of compensation is:

$$b_{1i} = \Gamma^{**}_{12} L_{1i} 1 - \Gamma^{**}_{13} c_{c1} + \Gamma^{**}_{14} s_{1i} + \Gamma^{**}_{14} x_{1i} \qquad (10')$$

Finally, for aggregated ESS provision we need to horizontally add individual farm contributions. Yet, as land and field parcels are not substitutes, a complex “supply” results:

$$s_1 = [1 - [\Gamma_{11} \Gamma_{21} a_1 \Gamma^{**}_{14} s]^{-1} [\Gamma_{11} [\Gamma_{21} + \Theta L_1] a_1 [\Gamma^{**}_{13} c_{c1} + \Gamma^{**}_{14} x_1] \qquad (11)$$

It means the management has to find a balance between “f” based on “s” and “c”:

$$[1 - [\Gamma_{11} [\Gamma_{21} + \Theta L_1] a_1 \Gamma^{**}_{14}] s_1 = [\Gamma_{11} [\Gamma_{21} + \Theta L_1] a_1 [\Gamma^{**}_{12} L_1 1 - \Gamma^{**}_{13} c_{c1} + \Gamma^{**}_{14} x_1] \qquad (12)$$

The condition (12) can serve as a balance for "s" and "c". Note that the endogenous labor contribution "L" must also be optimized according to the same concept.

$$\partial I^{u}_{i} / \partial_1 L_i = \gamma_{02\,i} - \Gamma_{21\,i} s_c + \Gamma^{'}_{32\,i} 1 \;\; L_i + \Gamma_{31\,i} b^{'}_{i} = w_i \qquad (13)$$

So basically the supply includes "b" and "L" but it refers to "s" as conditionality.

4.2 Demand

Vice versa, “s” should be a demand driven WTP, if prices prevail, derived from (9). Technically, demand can be retrieved from shadow prices as a result of given prevalence of joint provided “s”, i.e. if we take first derivatives for constraints (14). Yet from public finance it is understood that marginal benefit functions vertically add for public goods (Mitchell and Carson, 1989; only private goods add horizontally. Note for reduced form (15) WTP is similar to contingent valuation of species). λ_{si} is given at farm level:

$$\gamma^{*}_{02\ i} - \Gamma^{*}_{21\ i} s_c + \Gamma^{'}_{32\ i} 1 \ \ L^{'}_{i\ i} = \lambda^{'}_{si} \tag{14}$$

And, adding the individual functions, in a final step, delivers the “landscape demand”:

$$\sum_i \gamma^{*}_{02\ i} - \sum_i \Gamma^{*}_{21\ i} s_c + \sum_i \Gamma^{'}_{32\ i} 1 \ \ L^{'}_{i\ i} = \sum_i \lambda_{si} = \lambda_s \tag{15}$$

This is a joint and collectively received valuation for “s”, notably optimal at the community level and it brings marginal WTP. By equating marginal WTP/WTA (equations 12 and 15) we get a virtual equilibrium for social welfare, yet: $s'\lambda_s - c'b = 0$. This equilibrium can serve as a reference for public management. The logic is that *supply* and *demand* for “s” can be separated and any farmer faces supply needs “b” paid by “c”. Then demand for “s” should be at “f” for a farmer in a market; but this is a problem with the logic of public goods. However, demand does not work without recognition of a mechanism on allocation of fees which is community-wise agreed. Property rights are unclear. Perhaps, for getting right to charge a fee (on average in a simulation) the average PES level can be calculated as $f = 1/n\ \Sigma\lambda_s$; hereby shadow prices translates into a price (fee). But supply price “c” is not discerned and PES does not clarify distribution aspects?

4.3 Balancing finance, social optimum and critics

The question arises of how to set “c” and “f” in a balanced way. This implies assumptions. In market simulations there would be equal “c” and “f” for each farmer. This implies “b” is generic in modelling of habitat provision at “c”. Concerning budgets it says that money from farmers is collected according to marginal benefits and compensation is partially paid (primarily for negative effects). This will leave individual farmers with different net positions. With regards to participation, a manager gets knowledge on individual positions and compensates or charges. Yet, a question arises of whether the manager can make surplus or whether he has an own objective function (Nuppenau, 2014)? Extra notice, an ecological management might not be interested in making money at all. Rule setting and budgeting are, perhaps, should serve the performance of a stable participation. Then we may take a separate look at using ecological goals (a specific BD; see: Nuppenau, 2014), and finance is a mean, only. For modelling it implies that “landscape design and nature provision” are references serving as a tool to get specific BD.

5 Social Welfare Optimization

Rather than starting with supply and demand as suggested in PES, the question might be: *what is the contribution of public management*? Primarily “c” and “f” have to be individualized on the basis of the above reference! We have to pursue the idea of a public management because there will be: *no market*. But, management can be done applying economic principles of interest. A manager could have power to impose individual regulations on waivers in land use and determine compensation in negotiations. Regulations can be derived from a social optimization of (16). This is a first step (as reference system for negotiation). In this regard species occurrence "s" is an intermediary objective, i.e. a goal by which efficacy of management is judged. One can think that a manager enhances welfare of individual farmers derived from regulations that let her/him procure habitats and eventually labour. Since we work with vectors and management optimises "s", i.e. provision at community level, in a first step, "s" is a determining variable for costs in (16):

$$I_1^c = p_i^{'}(1-\mathbf{b_1}) + p_1^{r'}\mathbf{b_1} - \gamma_{011}^{'}\mathbf{b_1} - \gamma_{021}^{'}\mathbf{s_1} - \gamma_{031}^{'}\mathbf{l_1} + 0.5\cdot\mathbf{b_1^{'}}\Gamma_{11}\mathbf{b_1} + 0.5\cdot\mathbf{s_1^{'}}\Gamma_{21}\mathbf{s_1}$$
$$-\mathbf{b_1^{'}}\Gamma_{41}\mathbf{s_1} - \mathbf{b_1^{'}}\Gamma_{51}\mathbf{l_1} - \mathbf{l_1}\Gamma_{61}\mathbf{s_1} - r_1^{'}\Gamma_{71}\mathbf{b_1} - r_1^{'}\Gamma_{81}\mathbf{s_1} - r_1^{'}\Gamma_{91}\mathbf{l_1} \quad (16)$$

By inserting "s" from (4) we make the problem in equation (16) endogenous and express the social benefit of *community 1* as a function of b_1 and L_{11}. This ends in collective welfare (17). In equation (17) farmers' fields are individualized and labour is constrained. Allocative decision making of the common pool manager determines the social optimum.

$$I_1^c = p_1^{'}(1-\mathbf{b_1}) + p_1^{r'}\mathbf{b_1} - [\gamma_{011}^{'} + \gamma_{021}^{'}\mathbf{\Omega}_{11}[\mathbf{\Omega}_{21} + \Theta_1\mathbf{L_{11}} + r_1^{'}\Gamma_{81}] - r_1^{'}\Gamma_{71}]\mathbf{b_1} - \gamma_{031}^{'}[\mathbf{l_1^*} - \mathbf{L_{11}}1]$$
$$+ 0.5\cdot\mathbf{b_1^{'}}\Gamma_{11}\mathbf{b_1} + 0.5\cdot[\mathbf{l_1^*} - \mathbf{L_{11}}1]^{'}\,\Gamma_{31}[\mathbf{l_1^*} - \mathbf{L_{11}}1] - \mathbf{b_1^{'}}\Gamma_{51}[\mathbf{l_1^*} - \mathbf{L_{11}}1] - r_1^{'}\Gamma_{91}[\mathbf{l_1^*} - \mathbf{L_{11}}1] \quad (17)$$

Technically function (17) is optimized in (18). ESS provision "s" depends on public management of "b" and "L"; one can state individually optimal compensations and fees. I.e. (17) is used in benefit-cost-analysis by taking first derivatives of b and L. Optimization

$$\partial I_i^u / \partial_1\mathbf{b_1} = -p_1^{'} + p_1^{r'} - [\gamma_{011}^{'} + \gamma_{021}^{'}\mathbf{\Omega}_{11}[\mathbf{\Omega}_{21} + \Theta_1\mathbf{L_{11}} + r_1^{'}\Gamma_{81}] - r_1^{'}\Gamma_{71}] + \Gamma_{11}\mathbf{b_1} - \Gamma_{51}^{'}[\mathbf{l_1^*} - \mathbf{L_{11}}1] = 0$$
(18a)

$$\partial I_i^u / \partial_1\mathbf{L_{11}} = \gamma_{021}^{'}\mathbf{\Omega}_{11}\Theta_1\mathbf{b_1} + \gamma_{031}^{'} + \Gamma_{31}[\mathbf{l_1^*} - \mathbf{L_{11}}1]\mathbf{l_1^{*'}} - \Gamma_{51}\mathbf{b_1^{'}} - \Gamma_{91}r_1^{'} = 0$$
(18b)

delivers a vector and a matrix telling the optimal acquisition. Optimization is like in Theil (1971) for a given problem of finding "b" elements on fields and requests labour "L" From optimal b and L, given the above behavioural function, c and λ_s can be derived for individual farms. Yet, again, the procedure assumes that the manager can set contracts and makes no financial extra. By objective function (17) he should not make a surplus.

6 Rearranging for Land and Labour Restrictions

The above outline of an ideally optimized welfare (notably for farmers only, not the management) is depending on ESS; land and labour is in common pool management. Unfortunately, in an autonomous community the manager eventually has only "some" access rights to land and labour. For the moment acquaint authority and rights were not discussed. It could be assumed that provision is without any quarrel. However, eventually the manager needs power. In contrast, farmers will be very cautious in authorizing too much power to the management. A first fixing of power can be aimed to limit full access to land and labour by a community manager. This regulation sets limits for resource access. Particularly fixing labour means it becomes a regulated optimization. Presuming that individual farms will not adjust their labour allocation unlimitedly for the sake of providing labour in habitat improvement, management becomes constrained. Public management usually has to recognize this in order to obtain participation. The critical aspect is to show how to find a way of modelling a collective welfare function and optimization under the rules of limited access. An idea to enter the discussion could be to assure that public management is not overriding community-wise agreed private rights. It means simulation can work with limiting access to initially privately controlled land and labour and find-out what are the values for constrained access of management in terms of forgone acquisitions of benefits from ESS? Note benefits are unequally distributed.

Then the task is to establish a negotiated limit on access that might be unanimously agreed and can be stated as community rule. In a simple version it would means that the management runs the model with various labour and land access constraints and presents results to farmers for participation and agreement on fees and compensations. For the above specification it implies we can just add the land and labour constraints like in (19). Another version would be taking the welfare functions of any individual farmer (without ESS provision) and putting his optimization as a participation constraint in a game. Then the question is: which alternatives do farmers have to specify their objective without public management and in how far we can introduce flexibility?

Constraints and flexibility shall bind the manager and protect *public interest* from too much resource extraction. I.e. limiting management at critical level matters in public optimising (to attain a benevolent management). Though this might be unrealistic, the modelling offers steps to achieve a compromise. First of all, as an indication, we might optimise equation (19) to find a *first best solution* to nature provision in a community with reference to a rule of "minimal labour and land use injection" from the private. Then a social welfare optimisation can be used which is constraint as in following formula:

$$I_1^c = p_1^{'}(1-\mathbf{b_1}) - [\gamma_{011}^{'} + \gamma_{021}^{'}\mathbf{\Omega}_{11}[\mathbf{\Omega}_{21} + \Theta_1\mathbf{L_{11}} + r_1^{'}\Gamma_{81}] - r_1^{'}\Gamma_{71}]\mathbf{b_1} - \gamma_{031}^{'}[\mathbf{l_1^*} - \mathbf{L_{11}}1] + 0.5\cdot\mathbf{b_1^{'}}\Gamma_{11}\mathbf{b_1}$$
$$+ 0.5\cdot[\mathbf{l_1^*} - \mathbf{L_{11}}1]^{'}\,\Gamma_{31}[\mathbf{l_1^*} - \mathbf{L_{11}}1] - \mathbf{b_1^{'}}\Gamma_{51}\mathbf{L_{11}}[\mathbf{l_1^*} - \mathbf{L_{11}}1] - r_1^{'}\Gamma_{91}[\mathbf{l_1^*} - \mathbf{L_{11}}1]b^* + \lambda_1[l - 1^{'}\,[\mathbf{l_{1,0}^*} - \mathbf{L_{11}}1]]$$
$$+ \lambda_2[b_{1,0}^* - \mathbf{1}^{'}\,\mathbf{b_1}]b^* + \lambda_3[c_l^{'}\mathbf{b_{1\mathit{x}}} - f_l^{'}[\mathbf{\Omega}_{11}[\mathbf{\Omega}_{21} + \Theta L_1]\mathbf{b_{1\mathit{x}}}] \qquad (19)$$

Formula (19) offers a constrained behaviour of a manager who trades ESS within limits. Corresponding fees "f" and compensation "c" can be calculated as based on behavioural response (inverse functions). It means "c" and "f" are mathematically achieved by regressing them on already obtained "b" and "L", and vice versa achieved "s" gives information on individual WTP. Hereby instruments become endogenous. The budget implication can be re-calculated and any constraint level forces management to iterate the EMS scale. In (19) we artificially introduced a physical constraint on rights of access to land and labour for regulation which is now at landscape level; but it needs confirmation: A simple way would be to average: n $\underline{b} = \Sigma b_i$ and to get approval of that $\underline{b}$, i.e. on EMS size.

Next, since some services may also stretch beyond a community WTP and WTA and the managements can calculate cost and benefits a trading between communities can be foreseen. For regional pricing purposes in PES schemes, district evaluations can be introduced which come with provision and using of otherwise public goods. This is similar to the introduction of (BD) user associations (Babu, 2008). The result is a set of price on “s” provided or requested between communities. Additionally prices can be equated with land rents and wage rates. The aim for management would be to get a proxy for binding individual contributions to equilibria of cost-benefits. Hence, prices emerge for b and L. Equation (19), as social welfare, is flexible to pave the way to get beyond limits. A community can agree on larger or smaller provision by showing benefits from ESS.

7 Summary

This paper outlines a spatial approach for ESS provision that reckons the supply capacity for ESS through habitat and land use waivers by farmers. At the same time, farmers benefit from ESS being a public good. It is shown how simulation can offer valuations of ESS. Moreover, they put marginal benefits accrued by individual farms in the position to serve as source of finance. However, the difficulty is that ESS provision, in the case of a landscape oriented service such as biodiversity BD, is joint and this requests public management. Nevertheless PES schemes can be simulated to get a pricing.

8 Literature

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