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Nature and human interests in ecosystems: on farmers and species interaction, nutrient recycling and scarcities in agricultural landscapes

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Abstract

This paper discusses the potential for modeling nature and man in an exchange economy that comprises food, labor, land, and plant nutrients. The paper is habitat and landscape oriented and solves land conflicts, at least theoretically. (1) We discuss the need for exchange values in addition to human valuation of nature. (2) We review basic ideas of an exchange economy and its institutional setting; in particular, those of a principal-agent. (3) In a model we show how the assumption of this institution works in determining jointly human and nature exchange, values, and land use. Issues such as property rights, a nature objective, services to be exchanged, recycling, etc., will be introduced. (4) The principal-agent framework will deliver a mutually beneficial exchange. (5) The exchange tackles labor consuming nutrient recycling, and (6) a problem oriented statement will touch on property rights definition issues. (7) In modeling a cooperative land use strategy that recognizes mutual rights we reconstruct habitat and land use. By arguing in this framework we will gain a deeper insight into the interaction of landscape appearance, nutrient recycling, scarcity, evaluation and value generation. A further basic assumption is that there is a duality of instruments to get insight into nature's values. We use fitness, separately from the human objective, utility, to indicate scarcity in the human and natural sphere. To communicate values, alternative research outlines on nature scarcities are described and the implication for the management of agricultural prone eco-systems are investigated.

1 Introduction

It is the objective of this paper to broaden the debate about nature values, nature scarcity, or just nature exchanges with respect to an exchange of services between nature and humans, notably in a reasonable way, including nutrient recycling and food flows. Instead of pursuing the common perspective of evaluating nature by a benevolent expropriator – this being man – we will refer to an exchange between "equal" creatures [1]. Human expropriators have a tendency towards evaluating nature as a "free" good, if it is not already owned by other humans. Hence, there is a big need for institutional settings. These settings play an important role designing exchanges and in nature evaluation, which will be further explored soon, though from a different angle than human rights only. We will shift the perspective away from unilateral exploitation and ask what happens to the evaluation of nature if we pursue the idea of a justifiable exchange between humans and nature: one that is similar to an exchange between humans; that follows the concept of a principal and an agent, and that is based upon some property rights of nature. This property rights component should assure, that nature will not be exploited; at least in terms of nature as being an equal entity [1].

In order not to be misunderstood or to really preserve our surrounding ecosystems, rather than using rhetoric, human users have to be confronted with the real costs or prices of exploitative human activities that threaten nature These costs or prices should reflect scarcity in both the human and natural sphere [2]. The measuring of scarcity and consecutive pricing of nature by scarcity is a concept that requires objective functions, not only for men, but also for nature; clarification of material flows, such as food and nutrients; as wells as connections to joint resource occupation, for instance land. Then such concept shall offer a procedure to understand the creation to of jointly used landscapes. Especially, we need a research concept that is capable of establishing quantifiable objective functions for conflicting parties, nature and humans, and that should assure concisely derived marginal values (an exchange value). In this context the introduction of objective functions will help us to apply a joint scarcity concept to the human and the natural sphere as done elsewhere [3]. Our basic assumption is that there are complementary instruments, causalities and goals, and using these together will provide us insight into nature and man's behavior in a genuine exchange economy.

To be practical, we take fitness as nature's objective function. The reason for the depiction of the functioning of ecosystems as fitness is that it has already been frequently used [4] and is easy perceivable. Fitness is translated into a measurable concept which has to be explicitly specified in terms of treatable variables. Functioning and fitness are normative categories, but they are comparable to economic and human categories, such as utility and welfare. We will also introduce fitness most generically as a teleonomic category for nature following a functional approach of nature composition rather than a structural. Note, explicit objectives of nature are also requested in nature preservation to make alternatives comparable on an opportunity cost basis [5]; so the use is not unique in ecology.

2 Specifying nature exchange in a principal-agent framework

Our model is based upon the analogy of a human agent maximizing his/her utility in exchange for money with a principal who offers money in return for a service [6]. But we have no "money surrogate", immediately perceived as welfare increase for nature. With respect to a nature-human interface, we assume that "nature maximizes something"; that is "fitness" i.e. increase fitness due to a nature's land for labor swap. We consider "fitness" as a preference function, perhaps not more.

2.1 Nature as agent

As intended for a preferences revelation of nature, the introduction of an entity, a "designer" agent of nature, at least mathematically, is the first step. It can be done by assigning a most practical objective-function (1) to agents. In the function (1), "N" reflects "nature's fitness". Fitness should be related to diversity of nature, "D", and be related to bio-mass "M", and it is considered a mean not an end. By this we take a functional approach of fitness. The stated nature's objective-function explicitly contains "M" and "D", and being linear given a weight ω, it is:

$$N = \omega \cdot M - [1 - \omega] \cdot D \tag{1}$$

Next we have to delineate the objective (1) as dependent on a specified species vector "s". In doing so we might use a quasi "evaluation", for instance, a physical weight "ρ"; then M := ρ·s. For further explanation: A weight "ρ" assigned to "s" is not direct a utility derived value (a price), though it measures the partial contribution of one creature as species in "s" to bio-mass. Note ρ can alternatively express current species' appearance in a "physical" way (for instance, the body weight of an elephant in contrast to a mouse). The function should also incorporate the respective species vector in such a way relevant elements of a maximizing process resume. Assuming nature as quasi optimizing (i.e. an ex-post of evolution and building the first derivative) unit, the objective-function becomes directly linked to a "nature production function" in (2). Observing the results of apparent species (ex-post constructivist's view of revelation) we can think again of the weighted objective-function between mass "M" and diversity "D" as revealed.

In a second step, to build the model around this baseline concept, we look at relationships between a composed set of habitats (land allocated to habitats which are characterized by a vector "b") and species appearance "s" (vector): For ecologists, habitats may be organized most easily and appropriately in a grid system [7] which enables a depiction of the problem of species presence in a cellular automata model. For economists, with a suitable subdivision of land in habitats, "b", a "production function of nature" is introduced that reflects nature's potential to accomplish a species set as a vector, "s", and importantly it is landscape oriented.

$$s = \Omega_1 b \tag{2}$$

Equation (2) uses "Ω_1" as a transition matrix from habitats ("design") to species (composition), whereas "Ω_1" contains probabilities. It refers to our "knowledge" of nature, inferable as probabilities to most likely "achieve" a certain vector of species if a certain habitat "design" is chosen. Species occupancy (nature design of territory) occurs in such a way that multiple habitats exist; with these habitats supporting the particular species composition. A further note: given that, the weights "ω" and "1-ω" are inferable. Figures can be calculated from observation. Next, diversity "D" shall be measured as a type of a Shannon-Wiener index, which is normally the sum of the product of relative appearance multiplied by the logarithm of appearance. This is approximated by: $s'\ln(s) \approx s'(1+s)$. Then, these deliberations are represented in a re-specified objective-function of nature such as:

$$N = \omega \cdot \rho' s - [1-\omega] \cdot s' (1+s) \tag{2a}$$

Since we are interested in the translation of habitats into species as a revelation of an "allocation structure" of nature (i.e. in terms of reproducing species appearance after evolution as a synonym: optimization), one can break down the objective to habitat levels and the subsequent function (2) is a first building block, so:

$$N = \omega \cdot \rho' \Omega_1 b + [1-\omega] \cdot b' \Omega_1' (1 + \Omega_1 b) \tag{2b}$$

Moreover, land for habitats is constrained, B_n. This aspect is important since the way we have "constructed" nature shall explore the analogy of scarcity in human land occupation. Competition for space matters, "Lebensraum", finally shaping landscapes. Landscape appearance is an assignment of species and habitats.

$$B_n = 1' b \tag{3}$$

Technically optimisation of (1b) given (3) provides a representation of habitats or landscape in a natural situation of no influence of humans on this landscape:

$$\begin{aligned} \omega \cdot \Omega_1 \rho \; + [1-\omega] \cdot \Omega_1 1 + \lambda [1-\omega] \cdot \Omega_1 \Omega_1 b + \Pi \lambda &= 0 \\ 1' b &= B_n \end{aligned} \tag{4}$$

Solved for habitats "b*" in a system (4a), as a reference, "natural" land use is:

$$\begin{bmatrix} b^* \\ \lambda \end{bmatrix} = \begin{bmatrix} \Omega_1 \Omega_1 & 1 \\ 1' & 0 \end{bmatrix}^{-1} \cdot \begin{bmatrix} [1-\omega] \cdot \Omega_1 1 + \omega \Omega_1 \rho \\ B_n \end{bmatrix} \tag{4a}$$

Our result (4a) needs further explanation: (1) Nature is "constructed" by given species, and it is site specific. The construction enables a revelation of nature's fitness or "will", if personalized. Equation (4a) differs in species numbers occupying a certain territory. (2) A mixture of habitats and multiple-occupation is possible. (3) We are primarily interested in the revelation of nature's "habitat design" with respect to species composition in quantitative terms to get a natural landscape composed of habitats that are indicators of natural fitness. (2) For establishing an exchange, we presume nature optimally figures out how to use habitats under a given land constraint, though a potentially offered compensation may matter and alter it. Since we will model the "invasion" of humans in these habi-

tats, scarcity of land and the capability to occupy territories is an important issue. (5) Habitats and land occupation are research categories because, in our model, nature is habitat oriented and causality runs from a predetermined habitat design to an obtainable species composition. (6) We have recognized 2 elements in the maximized objective-function, bio-mass and -diversity. There may be other components such as resilience, etc., but we have omitted dynamics for simplification.

2.2 Outlining the exchange of nature as agent

Next, we have to answer questions such as: What could be the potential exchange? Would nature "give up" land and reduce its habitat occupation in exchange for services provided by humans (Services as payments)? How can food and nutrients flows be included? etc. At least human labor services should have an impact on nature's production function (2), and hence fitness. Labor should augment the potential for the occurrence of species (though not every species will benefit). We need a function that caters for mutual exchange: I.e. (1) Land "b" for farmers from nature and (2) labor "L_n" for nature from farmers (component in the first brackets in equation (5)). Further note: (3) "Nitrogen" is extracted and must be compensated for ecological reasons, i.e. the exchange should recognize recycling, not food extraction, only. Now, what role plays labor? As a basis it can serves as a "payment" for nature on habitat level. Labor is organized into a matrix which means that specific labor is specially intended to single species Nitrogen is a general medium to augment species' appearance. (It reduces scarcity by making land "more nutritious"). It takes the position of a "currency". Then: (5)

$$\begin{aligned} s &= \Omega_1[E + L \cdot \Omega_0][b^* - b] + \Omega_2[n_0 + \Omega_3 w] \\ &= \Omega_1[b^* - b] + \Omega_1 \cdot L_n \cdot \Omega_0][b^* - b] + \Omega_2[n_0 + \Omega_3 w] \end{aligned} \tag{5}$$

substitutes equation (2). Note as innovation to [8] we introduce in (5) the recycling of nutrients from food consumption as waste "w" to close the nutrient cycles, at least partially. Waste from humans can be food or species related (see coefficients). We assume a qualification or recalculation of used food into nutrients firstly, and then a supplementation of nutrient deliveries to species secondly.

For explanation on labour, exchange and payment. In equation (5), for example, imagine that the planting of additional willow trees for nesting birds creates better habitats for those birds using this habitat. This requires labour for planting. Function (5) can be used in the reformulation of nature's objective-function (6).

$$\begin{aligned} N = {} & \omega \cdot \rho' \Omega_1[b^* - b] + \Omega_1 \cdot L_n \cdot \Omega_0][b^* - b] + \omega \cdot \rho' \Omega_2[n_0 + \Omega_3 w] \\ & - [1 - \omega] \cdot [b^* - b]' \Omega_1'[1 + \Omega_1'[b^* - b]] \end{aligned} \tag{6}$$

Formulation (6) can be understood twofold. In economic terms it is an "interest" function by nature for exchange. Hence, it can also be interpreted in game theory terms; we will later refer to the underlying aspects of such a game). In technical terms it is the easiest way to represent an "interest" function of nature in a principal-agent framework [6]. Newly maximizing the function (6) we get a response function that opens the eyes of a human principal to nature's willingness

to accept "contracts", apparently, on a mutually beneficial basis (utility and fitness improvement). For instance, a farmer notices that he has to "pay" for land with labor if he wants to maintain the ecosystem providing him services (later). The success criteria is the "fitness" of nature. Furthermore, a willingness to pay for land with labor by humans is an indicator of nature's marginal values, i.e. an explicit respect towards the property right of nature. "Values" are derivatives from objective-functions, i.e. marginal values to pursue fitness, nothing else!

In equation (7) the newly optimized habitats (which determine the composition of species) include a voluntary waiver on land (exchange) to the "benefit" (fitness) of nature (payment: L is an incentive and equation 7 is an incentive constraint). Since, both, labor and nutrients, compensate losses, a type of a constraint on incentives prevails. Optimization is a matter of endogenous vectors "b" and "λ".

$$\omega\Omega_1\rho + \omega\Omega_1\Omega_0 L_n\rho - [1-\omega][\Omega_1 b^* + \Omega_1\Omega_1[b^* - b]] + I\lambda = 0 \qquad (7)$$
$$1'b = B_n$$

The solution for vectors "b" and "λ", in the equation (8), is an "offer" function:

$$\begin{bmatrix} b \\ \lambda \end{bmatrix} = \begin{bmatrix} \Omega_1\Omega_1 & I \\ 1' & 0 \end{bmatrix}^{-1} \cdot \begin{bmatrix} [1-\omega]\cdot\Omega_1 b^* + [\omega\omega_1 + \Omega_1\Omega_0 L_n]\rho \\ B \end{bmatrix} \qquad (8)$$

As a result of nature response, we get a linear system (8a); (8b is not displayed):

$$b = \Psi_0^* B_n + \Psi_0^* b^* + \Psi_1^* L_n\rho \qquad (8a)$$

The response function (8a) reflects an constructed exchange of land for labor (5), that implicitly contains "s", and it can be recognized as an "incentive constraint".

2.3 Humans as principals

Humans, for instance as farmers, maximize economic returns from a specific vector of species "f" (human owned species, different from natural ones and considered as farm species or non-"free") as interest function. Again we assume a production function (9) that calculates relationships between land occupation in habitats b (notice as the waivers of nature) but now occupied by humans for "f". Furthermore, in function (9), labor devoted to care for farm species is included, and, importantly, the function depends on natural components "s". For instance, the services from natural predators are explicitly recognized. The recognition of natural biological activity, "s", in equation (9), constitutes the ecologically important live support aspect. The farmer's production function consists of three components: land, labor, and species. It reflects a double dependency on nature.

$$f = \Theta_1'[[E + \Theta_2' L_a']b + \Theta_3' s] = \Theta_1' b + \Theta_1'\Theta_2' L_a b + \Theta_1'\Theta_3' s \qquad (9)$$

Now inserting equation (5) for "s" gives (9a)

$$f = \Theta_1^*[E + \Theta_2^* L_a']b = \Theta_1^* b + \Theta_1^*\Theta_2^* L_a b + \Theta_1^*\Theta_3^*[L_a'\Omega_1^*[b^* - b] + \Omega_1^*\cdot L_n\cdot\Omega_0^*][b^* - b] + \Omega_2^*[\eta_0 + \Omega_3^* w] \qquad (9a)$$

To close nutrient cycles we assume a balance $w = \Omega_4 f - z$, whereas z are system losses which can be reduced by labor L_w: $z = \Omega_5 L_w$. Then f in (9b) is a reduced form. If coefficients in matrices and vectors are recalculated to simplify, we get:

$$f = \Theta_1[E + \Theta_2 L_a + \Theta_3 L_n]b + \Theta_4 L_n b^* + \zeta_0 n + \Theta_5 L_w \qquad (9b)$$

For further simplification we assume humans are farmers, are primarily concerned with food production, and a food market exists. As a result farmers sell food (wheat, cows, etc.) as species "f" at prices "p" on markets, and have to recognize the recycling of organic matter to nature at costs "r". Monetary values enter the debate as marginal utility; farmers' objective or interest (10) is profit, composed of human prices. Next, there is a constraint μ on labor (or alternatively a wage).

$$F = p'f - r'n_0 - \mu \cdot [L - l'[L_n + L_a + L_w] \cdot 1] - \rho' \Phi' (L_n + L_w)' (L_n + L_w) \Phi' \rho \qquad (10)$$

Labor costs are modeled as Lagrange function of adding up constraints on a vector basis; this is necessity, because we have labor devoted to nature, farming and recycling. Finally, a specific negative discomfort of humans working for nature and waste is introduced in (10). Insertion of function (9b) into the objective-function (10) provides criteria (11) for decision making of a farmer as principal:

$$F = p'[\Theta_1[E + \Theta_2 L_a + \Theta_3 L_n][\psi_0^* B_n + \Psi_0^* b^* + \Psi_1^* L_n \rho] + \Theta_4 L_n b^* + \zeta_0 n_0 + \zeta_1 L_w]$$

$$- \mu[L - l'[L_n + L_a + L_w] \cdot 1] - r'n_0 - \rho' \Phi' (L_n + L_w)' (L_n + L_w) \Phi' \rho \qquad (11)$$

Note n_0, the non-species related exchange criteria, is still undetermined. Moreover we assume that recycling requires labour. Determining the unspecific payment from equation (6) results in a participation constraint given fitness N^*(6a):

$$n_0 = [\omega' \Omega_2]^{-1}[\omega[\rho' \Omega_1 + \Omega_1 L_n \Omega_0][b^* - b] - [1 - \omega][b^* - b]' \Omega_1'(1 + \Omega_1'[b^* - b]) - N^*] - \Omega_3' \Omega_5' L_w$$

3 Optimising nature's appearance from farmers' perspective

In equation (6a) we have to insert the response function (8a), giving us (6b):

$$n_0 = [\omega \rho' \Omega_2]^{-1}[\omega[\rho' [\Omega_1 \psi_0^* B_n + \Psi_0^* b^* + \Psi_1^* L_n \rho] + \Omega_1 L_n \Omega_0][\psi_0^* B_n + \Psi_0^* b^* + \Psi_1^* L_n \rho]]$$

$$- [1 - \omega][\psi_0^* B_n + \Psi_0^* b^* + \Psi_1^* L_n \rho]' \Omega_1'(1 + \Omega_1'[\psi_0^* B_n + \Psi_0^* b^* + \Psi_1^* L_n \rho]) - N^*] - \Omega_3' \Omega_5' L_w$$

Taking further into consideration this criterion of participation (6b), the production function (9b), and incentive (8a), altogether in objective (11) gives an overall objective of farmers (11a). The function (11a) is based upon farmers' "knowledge" of production conditions and nature. It represents their own disutility, matrices Θ_i, and the "response" of nature to labor provision for exchange: the Ψ_is:

$$F=p'[\Theta_1[E+\Theta_2 L_a+\Theta_3 L_n][\psi_0^* B_n+\Psi_0^* b^*+\Psi_1^* L_n\rho]+\Theta_4 L_n b^*+n_0]-\mu[L-1'[L_n+L_a+L_w]1]$$
$$-\rho'\Phi'[L_n'+L_w'][L_n+L_w]\Phi\rho-[p'[\Theta_1[E+\Theta_2 L_a+\Theta_3 L_n]\zeta_0++r'][\rho'\Omega_2]^{-1}[\omega\rho'[\Omega_1\psi_0^* B_n$$
$$\Psi_0^* b^*+\Psi_1^* L_n\rho]+\Omega_1 L_n\Omega_0][\psi_0^* B_n+\Psi_0^* b^*+\Psi_1^* L_n\rho]-[1-\omega][\psi_0^* B_n+\Psi_0^* b^*+\Psi_1^* L_n\rho]'\Omega_1'(1$$
$$+\Omega_1[\psi_0^* B_n+\Psi_0^* b^*+\Psi_1^* L_n\rho])-N^*]-r'\Omega_3'\Omega_5' L_w \qquad (11a)$$

Note, the remaining explicit decision variables are (1) labor for nature improvement, (2) farming, and (3) waste recycling. Implicitly, a farmer decides on land, he occupies from nature and species. As service he recycles and "buys" nutrients. Amounts of compensation, devoted to nature, are decided internally. It guarantees functioning of nature taking fitness as incentive. After a simplification and sorting of variables L_n, L_w, and L_a, a quadratic objective (11b) is identified as:

$$F=p_1'\Psi_{10}^* L_a\psi_{01}^*+p_1'\Psi_{11}^* L_n\Psi_{12}^*\psi_{02}^*+p_1'\Psi_{21}^* L_a L_n'\Psi_{22}^*\psi_{02}^*+p_1'\Psi_{31}^* L_n L_n'\Psi_{32}^*\rho-r'\Psi_{41}^* L_a\Psi_{42}^* b^*$$
$$-\rho'\Psi_{51}^* L_n L_n'\Psi_{52}^*\rho-r'\Psi_{61}^* L_n\Psi_{52}^* b^*+r\rho'\Psi_{61}^* L_n L_n'\Psi_{62}^*-N^*-\mu[L-1'[L_n+L_a+L_w]\cdot 1]$$
$$-\rho'\Phi'[L_n'+L_w'][L_n+L_w]\Phi'\rho-r'\Omega_3'\Omega_5' L_w \qquad (11b)$$

Finally, the optimization of equation (11b) gives the optimal labor allocation. Mathematically, equations (12a) to (12c) are first order derivatives of (11a).

$$p_1'\Psi_{10}^*\psi_{01}^*+p_1'\Psi_{21}^*\Psi_{22}^*\psi_{02}^* L_n-r'\Psi_{41}^*\Psi_{42}^* b^*-\rho'\Phi' L_n-\mu 1=O \qquad (12a)$$

$$p_1'\Psi_{11}^*\Psi_{12}^*\psi_{02}^*+p_1'\Psi_{21}^*\Psi_{22}^*\psi_{02}^* L_a+2p_1'\Psi_{31}^*\Psi_{32}^*\rho L_n-\rho'\Psi_{51}^*\Psi_{52}^*\rho L_n'-r'\Psi_{61}^*\Psi_{52}^* b^*$$
$$+r\rho'\Psi_{61}^*\Psi_{62}^*\rho' L_n'-1\mu+\rho'\Phi L_n\Phi'\rho=O \qquad (12b)$$

$$-1\mu+\rho'\Phi L_w\Phi'\rho-\Omega_3'\Omega_4' r=0 \qquad (12c)$$

$$[L-1'[L_n+L_a]+L_w\cdot 1=0 \qquad (12d)$$

They serve to solve the exchange. Using equations (12a to c) a system of 2n+1 equations prevails. Solving it can be done easily using a matrix inversion of (12):

$$\begin{bmatrix} L_a \\ L_n \\ L_w \\ \mu \end{bmatrix} = \begin{bmatrix} 0 & \Psi^{12} & 0 & 1 \\ \Psi^{21} & \Psi^{22} & 0 & 1 \\ 0 & 0 & \Psi^{33}\,0 & 1 \\ 1' & 1' & 1' & \end{bmatrix}^{-1} \begin{bmatrix} \Psi^{13}\rho+\Psi^{14}p \\ \Psi^{23}\rho+\Psi^{24}p+\Psi^{22}b^*+\Psi^{22}x \\ -\Omega_3'\Omega_5' r \\ L \end{bmatrix} \qquad (13)$$

For instance, writing the result of L_n in separate functions, the labor provision is

$$L_n=\varphi_0^*+\Phi_1^*\rho+\Phi_2^* p+\Phi_3^* x \qquad (13a)$$

for nature. We see that labor devoted to nature is determined by exogenous ecological and economic variables such as human exchange values (prices) "p", ecological preferences (weighting of species) "ρ", and other constrained vari-

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ables "x". This result (13) can be used, by inserting into equation (8), to determine the habitat occupation, which means variables such as land cleared by humans "b" are endogenous to the system. Note, this endogenous determination means that landscapes as habitat composition are a result of co-ordination between human utility and natural fitness. Note further, labor to be devoted to nature is objectively determined by human preferences for products (marginal utility) and nature's preference (i.e. weight coefficients in the ecological preference function).

4 System orientation, welfare, distribution, and institutions

Since the model, in its current form, is neither dynamic nor particularly system oriented, with the exception of nutrient recycling which requires labor, further research is needed. Note, currently the farm sector and nature are merely connected by their exchange, which is no system closure. Especially since the fertilizing of nature for alleviation of scarcity in nutrients and land acquisition has potentials to alter the potential to acquire resource by nature and humans, a dynamic game would be a next step in making the model more applicable to empirical research. But static analysis must be taken as the starting point for further consideration.

Nevertheless, it is already fairly interesting to further explore the idea of having a "real equilibrium in exchange between nature and humans" as presented. Note: the principal-agent equilibrium is only a Nash equilibrium. This implies that nature is the passive "agent", while humans are active, i.e. superior and it can exercise "market power" over nature. With respect to superiority, humans play the decision maker's role, exploiting the live support function of nature and design landscapes. Though this constellation is still in favor of humans, the property rights have changed from a pure exploitative setting in land ownership (nature as slave) to first rights of nature (land). A less exploitative situation occurs. The welfare of humans may not decline from an actors perspective, but the total sum of "utility" from habitat occupation should be higher, and property rights should be given. This situation is depicted in the upper left part of a Diagram 1. Humans improve their utility "actively", using the exchange, whereas fitness of nature increases "passively", until human utility is maximized. Note: nature cannot "actively" increase fitness because humans "control" the exchange. However, rights can be altered if we think of more complex starting conditions for b*: for instance, landscape appearance become outlined as "rights and institutions".

Secondly, we used an exchange of land and labour which is mutually recognised as "reasonable" within a "socialisation" of nature (make them equal) as entity, i.e. we obtained an exchange that revealed scarcity of labour and land from the point of view of nature and humans, although their interests are opposing. Thirdly, for empirical research, controlled status quo on natural habitats may serve as benchmark for determining the local values. Values are explicitly contained in obtainable objective functions. But some aspects concerning rights remain unclear.

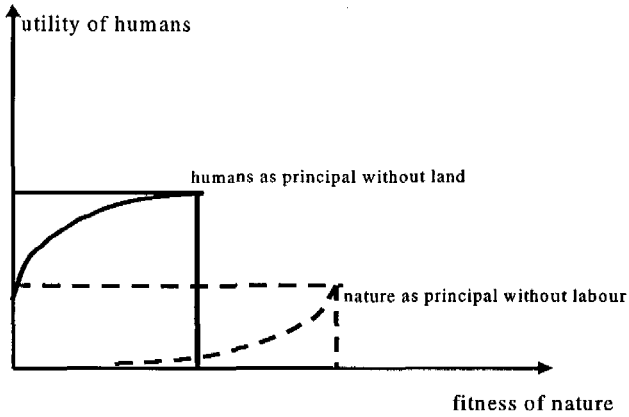


Diagram 1: Welfare distribution and institutions.

For qualifications on rights; the given institution is thus: a human is principal and nature is an agent. We may change the situation and regard humans as agents and nature as the principal (lower right side of Diagram 1). This means altering the sequence of decision making. Firstly, humans maximize utility based upon labor offered in exchange for land use, i.e. nature becomes the real landlord and humans have to provide labor for nature, receiving rights to plant and harvest on nature's land. (Analytically, the corresponding procedure is not different from the previous work.) The results are also provided in Diagram 1. Nature "actively" controls the exchange making it superior, as can be seen in Diagram 1. Now: What are the gains in analyzing nature exchange from this angle or from new institution as a thought experiment? Primarily, the thought experiment raises the issue of: what is a relevant initial institution for rationalizing the exchange? Note: It is not the intention of this paper to question human superiority. The reasoning behind it is merely: We will receive another optimal point of exchange which as another corner solution (Diagram 1). How does this all fit into a more general exposition of a real equilibrium? Let us look at the result in Diagram 1. We recognize that the newly derived utility and fitness from the second optimal point of exchange are different, the given initial right favored nature, and marginal values (prices) are different. A real equilibrium may lie between the corners. It should be noticed that a move on the second line form zero to larger fitness of nature is a mode of optimization (evolution). It means to "invent" mutually improving situations from the perspective of superior nature. Identifiable as win-win situations, both corners are quasi optima given institutions. Then, Diagram 1 represents the utility-fitness transformation curve, starting from initial property rights, but where to go?

5 Summary

The principal-agent framework served as a concept to derive an exchange between nature and humans on the basis of mutual respect and rights on respected

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property. We considered humans to be the principal and nature the agent. The exchange was specified as nature providing land to man and a live support system, and with humans providing labor to nature as payment. In addition, organic fertilizer compensates for a waiver on land use. Within this framework we can formulate an optimal exchange of nature in terms of services; i.e. pricing as if inferior nature and superior humans had negotiated. The model showed habitat occupation and offers deliberations for landscape appearance.

Superiority refers to the human ability to anticipate the behavior of nature, and respect its preference, fitness. This enabled us to specify nature exchange as relative (subjectively driven) and revealed (objectively measured). The ratio of exchange can be interpreted as an exchange value, relative price or respective value, since it is based on scarcity in both, the human and the natural sphere. Nature's exploitation, preservation, and revelation of exchange values, notably as "objective" observable willingness to exchange all occur simultaneously. The perceived "market" for exchange is a synthetic market and, by a "thought experiment" which uses the principal-agent framework, we derive the exchange inclination of nature. However, this hypothetical experiment is based upon empirically retrievable information, and a mathematical solution is provided.

In future we should qualify the exchange of nature as depending on exchange regulations or quasi bargaining solutions and definitions of property. The idea can be included in dynamic and system models to make it more applicable. A principal-agent focus on economic and ecological interfaces provides an integrative part for value detection since the results for exchanges determine interests.

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