



Central and Decentral Aspects of Land Use: Optimizing Public Finance and Payments for Nature in Space by Control Theory

Ernst-August Nuppenau¹ 

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Abstract

Payments for eco-system services and nature (words are used synonymously) cannot be treated independently from spatial outlays. We adopt a modified “von Thünen” framework and ask for optimal land allocation in space in case of land rent change and regional preference. Yet, our approach is not circular; rather, we see provision of nature along transport routes (stretches, i.e. within a segment or wedge of circle) and ask whether nature (conservation) should be closer to cities or in the periphery; i.e. in terms of priorities, which are planning variables, nature is reckoned as integrated in farming instead of being a segregated entity. For the conflict of amenities from nature (usually wished closer to cities because of lesser transport costs for citizens) vs. provision at the periphery (because of lower opportunity costs), we develop a model which optionally foresees both nature along cities and in peripheral areas. Hereby, we work on the explicit question of land distribution between the two options in space. Our planning approach optimizes nature shares along a gradient from urban to peripheral areas. Further, we include land price dynamics, in general already very pronounced today in intensively used landscapes around cities, and reference to the situation that land prices close to cities are usually quite a bit higher than in periphery. This requests larger payments, inflicted on overall efficacy of programs. As nature provision conflicts with food provision and private land use, models should also comprise food needs of cities. Yet, we reckon spatial opportunity costs and costs are minimized. Benefits in space for citizens are also spatially distributed. We suggest using control theory in order to attain a comprehensive analysis for and answer to regional priority setting. Archetypally, an integrated vs. a segregated nature provision concept is pursued; nature becomes relatively arranged in a mixed landscape, and farmers receive payments differently.

Keywords Spatial modelling · Nature provision · Dynamic optimization · Financial flows · Environmental and eco-system service management

✉ Ernst-August Nuppenau
ernst-august.nuppenau@agrar-uni-giessen.de

Extended author information available on the last page of the article

1 Introduction

Seemingly, there is a change in opinions on what type of land use is best for farming areas around cities, i.e. in potentially multifunctional rural areas: intensive conventional farming without nature or mixed modified farming with nature. The question whether regional planning should go for nature protection in space as well as accommodating society's wish of welfare from amenities by paying farmers, or whether priority should still be given to food provisions is pertinent. Peri-urban areas and hinterlands have gained interest of citizens, and new trends in land use policy have emerged with the intention of sponsoring special farming types, mostly being ecologically sound and including eco-system services (ESS). These types, at least some of them, shall encompass nature elements instead of conformist farming [1]. Then citizens shall finance nature provision if farmers deviate and opt for nature provision, which means less income from food provision for them and demand for compensation. Planning and subsidization play a major role and the question is: should payments be uniform or differently planned and targeted in space [2]? Note that for several decades, farm income has already been in focus with regard to subsidization, but targeting for nature was minor at farm level and it was merely hoped that land use under generic programs offers more amenities and nature. Payments, for instance, were overall fix per area. Simultaneously, land rents benefitted from payments. Hence, we must analyse which frame determines which concept in land use theory and which policy type is central concerning land rent changes [3].

Recently, especially the design of targeted farm practices for special locations and payments for nature conservation as well as public interest in more sustainable land use have received much attention. This is seen from biodiversity promotion programs and city planning. Questions are what concerns researchers and how do people working in nature conservation see it [4], yet at spatial scale. Moreover, the issue of urban development and rural linkages is of major concern for spatial analysis [5] and subject to policy debate [1]. There is a strive for promoting nature and amenities in rural landscapes in general, and nature conservation in particular at selected sites, but it is said that payments must be further redirected to special elements of nature conservation in special regions with high potential instead of land use in general. For instance, different locations may matter more than others [6], bringing up the question of where promotion can be most beneficial and cost effective [7]. Whatever the types of land use, nature conservation, and intervention for amenities (for example, organic farming) shall be more integration in farming and cross compliance, incentives, etc. are needed. Then, there is usually compensation and payment for change in farm practices. It involves deliberations on contemporary agriculture as well as land use and pricing in long-run, and we see geographically diverse aspects in discussion [8], but again, we have to ask, where? At the level of planning and regional subsidization (as a concept of differentiated and optimal provision), locations differ by scope and there is a need for coordination and regulation of ideas for payment related to scope.

Many advocates (in policy debate and design) place a focus on intensity and see land rents as a core problem for farmers' survival in this context, and also as

hindrance in ESS provision. Nevertheless, intensity is different in space. As well regional land rents have gained interest in the context of the survival of farming of a preferred farming (farming with nature and for ESS). Demarcating conservation sites and achieving sustainability [9] should be done at periphery. There is a need for smart regional design, and targets have to be set regarding planning for farmers and nature. Then, the user aspect comes into play because we need to know the equilibrium between regional supply and demand, i.e. if we envision commodification: who pays and gains at what site? Further aspects are as follows: (1) if policy follows a regional paradigm, which means that there are urban centres and citizens living there seek amenities, this requires spatial outlines and preferences [10]. Do we need farming harmonized in space? (2) This should be expressed in policies of subsidization. (3) From a welfare point of view including utility from amenities and preference of nature in cultural landscapes, it creates benefits vs. losses in space. (4) At the broader level, we may have a problem of addressing sustainability targets differently (for example, areas of congestion differ from remote areas), and (5) at design level, fiscal aspects of costs (minimizing getting targets in space) and benefits (public, also in space) matter jointly.

Moreover in reality taking the status quo not only as undersupply of nature (as evolved through drivers of modernization and documented dynamics of land use change over the last decades: [11, 12], nature disappearance is strong. A new pattern of intensity in agriculture has emerged which threatens nature, ESS and amenities are low. In this pattern, most economically integrated regions (like the EU) display central cities and the hinterland becomes less developed in terms of intensity [13]. Complexes of urbanization are nowadays directly surrounded by high intensive farming, whereas distant rural areas reveal low intensity and partly intact nature. Farms at the periphery are usually less intensive and some open space for nature still exists there. This follows the basic concept of agricultural geography of von Thünen [14], illustrated by Grigg [15], yet it is a modern version. Hitherto farmers have different costs (willingness) to accept (WTA) ecologically oriented schemes. Especially since location specific land rents (as gradients) have emerged, which are characterized through strong land price differentials, land prices play a major role in the allocation of land for nature. That also concerns the added regional value potential for amenities provision, and there is evidence for different provision scopes of amenities and policy [16] based on gradients.

In the opinion of the author and as an aim, it makes a lot of sense to spend time to contemplate a regionally differentiated policy. Specifically, the design of a regionally differentiated support system for farms and multi-functionality embedded spatial policy is needed which includes fiscal aspects as well as sources and generation of money. Especially sources of finance have to be found. From the point of view of public interest, yet in provision of amenities and nature, the distance between living (mostly urban) and rejoicing amenities (mostly rural) matters. To address the issue, we suggest taking a modified von-Thünen model in which amenities are derived from mixes of land use. Especially we suggest modified multifunctionality, and one should differentiate between integration and segregation of nature in farming [17].

It is the objective of this contribution to present a model [18] for a spatially differentiated payment system, which delivers amenities, ESS, nature, etc. It seeks finance

directly from urban users surcharging the conveyance reaching different locations in space. Amenities are associated with special land uses (for instance nature conservation as element of farming to be paid). Such land use competes with farm land under conventional endeavour for intensity (cropping, for instance of vegetables vs. pasture as in dairy farming, etc.) where the rent as stock variable is taxed. We optimize shares of land use types (conservation vs. conventional) and determine subsidies along distances from urban centre to rural hinterland. Firstly, our goal is to conduct a cost–benefit analysis and to minimize losses of value added at farm sector level; i.e. if a certain amount of land is converted to nature conservation, society bears the costs. Secondly, we encompass benefits of nature conservation as willingness to pay (WTP) by urban dwellers. Then, the balance has to be kept at regional and system (respectively system boundary) level. The model is still abstract because we do not consider specific cropping types in land use; rather we work categorically between conventional and nature conservation, recognizing farming as land use type. Though both can be separated (incl. national parks, forests, etc.) or integrated (hedges, buffer strips, etc. as integrated, [17]), we are interested in the combination. The emphasis is on shares of land devoted to the priority of use: food production or nature conservation.

(1) The paper is specified in terms of discussing issues on land allocation. (2) We look at a continuous outline of land use (as distanced from centre to periphery). (3) Nature conservation is priced along willingness to pay and accept. (4) The objective for nature and amenities as value generation vs. value added from farming is provided. (5) A control theory model in mode of dynamic optimization (optimal control of provision and pricing within space) is outlined. (6) In the model, we show how to find the optimal spatial configuration of subsidies and finance.

2 Problem Statements

2.1 Nature and Amenities in Space

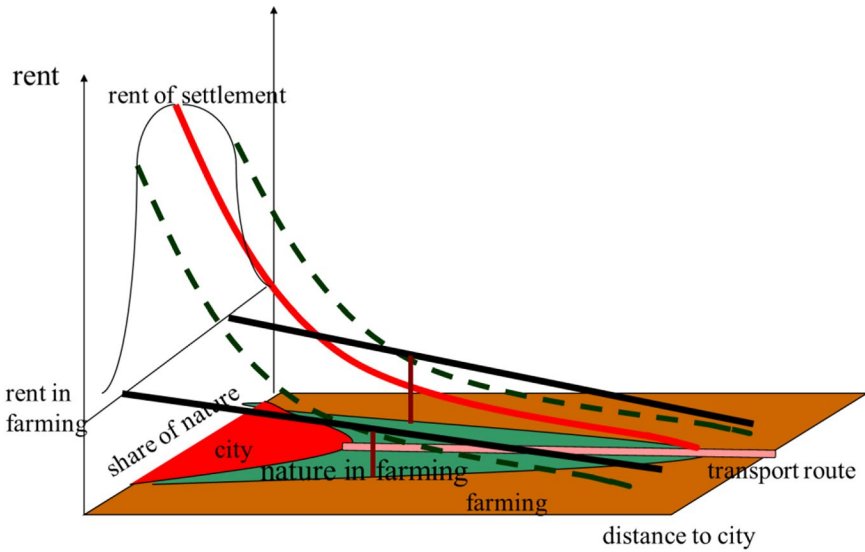
On the other hand, those who want to enjoy amenities (at a bulk level such as modern city dwellers) want cheap access to nature close to cities and due to income increase as well as preference change demand has increased [19]. Yet citizens face transport costs to go to the periphery. In reality, we have strong changes of landscapes around cities [20], negative for nature prevalence and preference close to city. For the moment (2020, with transportation costs (flights, rail, car declining relative to the income of urban inhabitants, the implication for needs of amenities and nature at local level may look limited. Nevertheless, for weekend and short-term amenities, air quality, etc., nature and ESS services (surrounding cities in peri-urban have been given some planning priority. Yet, it has to be incentivized, which means subsidization. But how does it look with subsidies for changing farm practice? Should nature be provided uniformly or where “nature” is cheapest? In which parts of local economies will we find the “best” by cost–benefit ratios for nature? The economists may say where opportunity costs and land rents are lowest and nature offers the best returns in terms of amenities ([21], but where is it? We need a system

approach. We have to put nature at differently at ground. Again, in the current situation of cheap flights, it may be correct to think: why? Even looking at emissions in transport and future concerns for real transportation costs, it might be better to find out where it is best positioning nature; closer to cities and in how far proximity to them? If the amenities are too far away from the city, then few inhabitants can use them. (For example, the Netherlands even have much nature conservation close to urban agglomerations where farmers are approached through expensive contracts: [22]).

There is another conflicting issue of payments and about costs and benefits because money spent in close distance to agglomerations is missing in far distance and driving up land prices. Location issues maybe further connected to questions of generating payments, and the question “how does the quality of landscapes matters for the WTP” is even more evident. Nature prevalence as observed and judged by the public (users) generates different views and willingness to contribute [23] matters; so, as visibility, it is of impact. In fact, regional remoteness can matter if there are less trade-offs with extensive farming and nature; in contrast, trade-offs can become bigger closer to city (at inner circle). Trade-offs seemingly widen with outer circles, i.e. towards periphery of interest for urbanites. Hence, we have a different WTP around cities and stretching to the periphery. In contrast, willingness to accept depends on land prices and strives for reduced intensity, which concerns willing farmers. This means that the government, which is presumably in charge, has to balance costs and benefits locally and at system and public level. It has to incorporate providers as well as users in joint planning. This means it has to incorporate behaviour of farmers who potentially put differently benefit at system: from being close to cities as compared to farmers operating outside in the periphery.

Finally, there is a need for spatial redistribution as a consequence of policy. For sure, as examples in the EU show, disputes emerge about regional creation and distributions of wealth by policy. While farmers in the Netherlands complain, if their lands were taxed, farmers in Romania would applaud if they received money, making it difficult to find a balance. Nonetheless, if nature conservation is requested by urbanites for various reasons, we must ask who pays and what role the government is for. For city dwellers seeking amenities, fresh air, more nature, etc. around cities, transferring money is beneficial, but the nature quality in general, i.e. close to cities, might be lower than at the periphery because of limited space and intensity. In contrast, things are different at the periphery. Nature can roam more freely, so to speak. While thinking about parks, nature provision (in huge areas and low-intensity regions) is the preferred choice for nature enthusiasts [9], but cost-benefits might vary, so we need the wider context.

We will analyse a compromise in space and specify the problem as a regional problem of financial transfers under the auspice and condition of spatially integrated cost–benefit optimization. The proposed model works within an extended von-Thünen framework. In Fig. 1, the conceptual framework is presented. It works with rents and amenities as well as with willingness to accept WTA and willingness to pay (WTP). They are considered in space. That is, if there is a strong preference for nature close to the city and more nature potential at the periphery, it has to be balanced (optimized) against budgets and opportunity cost. The changing and planning variable is “share



Source: own design

Fig. 1 Central and decentral aspects of nature provision

of land under nature” (amenity) as compared to no-nature-provision involvement in farming. We use control theory for attaining the shares (soon explained). If the size of nature matters, it becomes a continuous planning problem for a whole region defined in a spatial economy of nature provision. The economic can be divided into equal segments. This economy is simplified in segments cutting the circle around the city in sectors (slices) and as a sector we get an area as angle multiplying width with distance. Hence, we make it an empirical problem defined along a transport route (below) which can be solved by control theory.

2.2 Control Theory

As we intend putting the problem into a control theory frame, we need an understanding of this frame. Control theory [14], used as specifying a contingency of decisions in a systematic framework (usually time, here spaces), takes a dimension (again usually time) for evolution of policy instruments [24]. We switch to space as sequence and dimension. At the centre of the analysis, we see a change of stock variables and flows (policy tools) along distance. The stock (for example nature) accumulates over the dimension “distance” through choice of flows (payment). Stocks are changing systematically and intendedly (we will use several stock variables such as rent). Flow variables (we take finance as example) are optimized simultaneously with stock. Hence, we reinterpret von-Thünen in a continuous model of area as segments (distance) which are constituted by a space system which serves a portioned piece of land (segment of circle: see below). In contrast to the initial von-Thünen

conceptual framework (of having consecutive circles which direct specific land use) [25], we go along a continuous distance. Then, in our case, the share in land use (conventional vs. nature providing) is subject to distance check. Distance matters differently in terms of land use category, and it gives a spatial outline. We seek integrated land use as land sharing at distances (nature inclusion is part as percentage).

2.3 Area Allocation

As a conceptual framework which better fits the needs and provision of nature for ESS than a concentration of service, land use in space shall vary as percentage of incorporating nature in farming. For instance, the idea of having parks in place of cheapest opportunity costs is dropped. Instead, we plea for continuous integration of nature in farming and will optimize it in space through use of payments as an urbanly financed instrument. As the focus is a von-Thünen model of distance, distance as travel costs helps us meeting financial requirements for land sharing. Why and how? We will look for travel costs as basis for levies (see below) added as financing instrument. The expectation and enjoyment (consumption) of amenities (preferred nature) shall be differently prevalent in a cultural landscape for which we develop a WTP by distance, noticeable as revealed travel cost. We seek a combination of nature and farm land, whereas the latter are addressed for adaptation of eco-friendly farming. (The specific design is beyond the paper.) Farmers as providers (of nature: [26], by conscious farming) assure landscape richness for amenities. This can be also expressed as having nature elements in farming (on details about flora/fauna as result of, example, field margins, see [27]).

Actually, the issue of “how to basically address land use in space” arises if intensity of farming changes around a city [28]. For example, if land use for nature simply meant forest, then, yes, there would be a von-Thünen frame of inner and outer circles and the forest would be within the outer circles. But this is not what we aim for. We follow a different avenue and argue that in systems with integrated farming for food and nature (for instance using nature elements for ecosystem-services as management tool), there should be a gradual change. This may include stronger segregated versions vs. integrated concept of nature inclusion, for example, of parks solely in the periphery as a special case. From a regional preference and perspective of users, we think it is still valid to integrate nature and farming, mutually, because nature is the major source of amenity and farming of food. Areas closer to cities gain priority, but compete. Not only travel costs, but also perceived distances to amenity matter. There is scope to get preferences if nature becomes visible (WTP) including quality and distance as distinct categories from citizens [29].

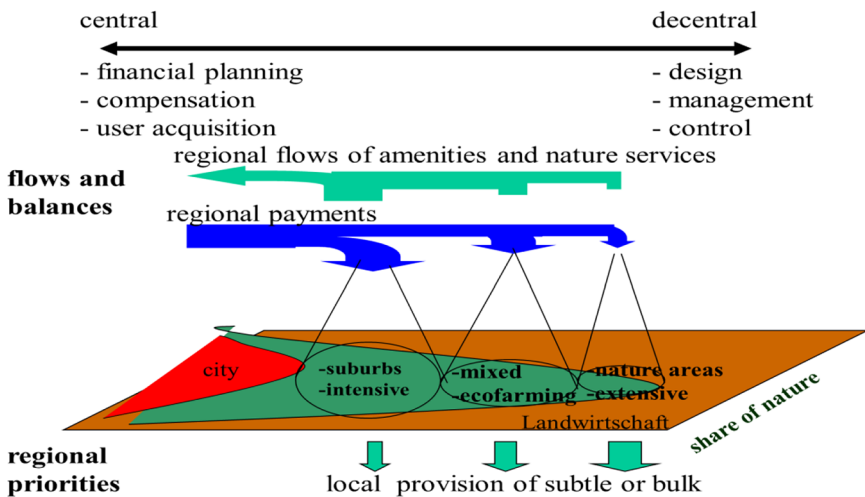
2.4 Stock and Flows

Now, what has to be taken into account for amenities and nature preference, i.e. at spatial level, in terms of stocks and flows? As well as how are flows to be conceptualized? There might be different investments in nature elements, which result in a different quality of nature. Yet, the government needs to sponsor that by financial support

(flows). The issue is that urban demand for nature is not universal with respect to space and specifics of farming [1]. It conflicts with what farmers do in order to meet rental payments and/or opportunity costs? Planning of flows is needed. Seeing nature provision as contrary to farm intensity, there is usually a conflict about economic and ecological reasoning at regional scale. High value nature conflicts with high intensive and value adding farming. To mitigate and offer compensation (money) helping farmers, nature has to be reckoned as something they factually provide, i.e. accepted provision. It has to be specially linked to landscapes, for example as shares stocks).

Flows of money for service shall address conflicts. Since it is the task of a conflict mitigating policy (at regional level and as flow) to outline a regional and spatial design and plan of nature potential and assign payment flows for service at a system level, our system of several flows aims at balancing and finding coexistence through participation and voluntary provision. Yet it is based on planning (hybrid of market and planning expressed in stock variables, nature share).

Then, we look for win-win situations and this brings flow balancing into the picture of economics. In a scenario where citizens want amenities and farmers want high intensity close to cities, land allocation is a tricky thing. For instance, real WTP is only there if nature is there. The tendency for politics is to say “let us have nature provision at minimal cost” but at periphery [9], which is not what consumers want and pay for. At the periphery, conflicts seem to be less and equivalently payments are lower at the expense of having it at the “wrong” places. We need a system approach for all distances as stock/flow analysis. Also, from an economist’s point of view, there are transport costs and carbon dioxine emissions (ecological), respectively,if one lets citizens move to the periphery. For this, again, we need planning to assure offerings (Fig. 2).



Source: own design

Fig. 2 Flows and stocks

Indeed, we have to be sensitive about interactions of partial payment design and indicative planning in regions. Suggesting a sharing of land for nature as approach and leaving things to local governance would not work, we shall have a mix or hybrid between central planning and local affairs. And, especially payments must be targeted to shares and intensity. In this paper, we touch upon planning, targeting, and flows and think local governance does fine tuning.

Next, a type of forecasting (towards outer spaces) emerges if one takes into account different private cost–benefit calculations of farmers and citizens; yet, at any location, “supply” and “demand” is contingent, and government becomes a bearer of interest, may set spurs and accrues finance to enable local tunings. Even in mode of methodological individualism, we have to add social costs of transport, including costs for carbon emissions. Concerning social benefits flows from nature, it is a question of how to nominate them and how to get regional planning done and assure subsidiary (for example in Germany: [30]).

3 Methodological Approaches and Conceptual Framework

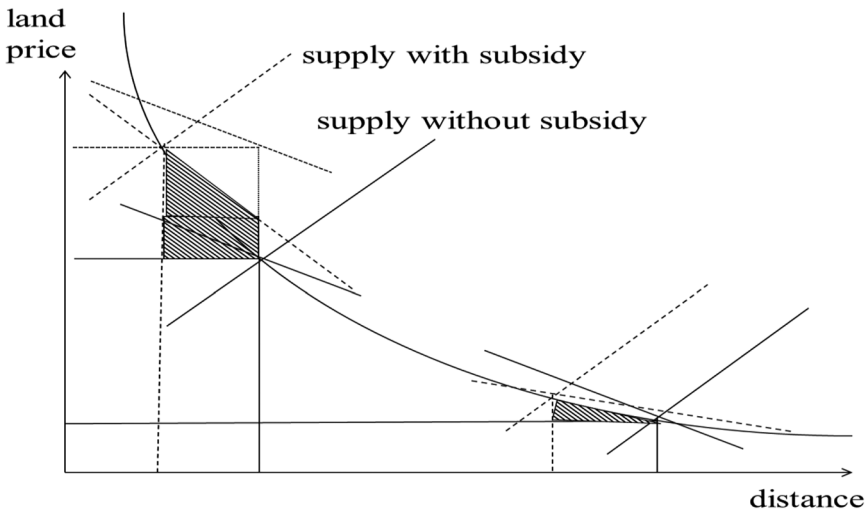
3.1 Concept of Nature Provision in Space

We assume that there is a WTP for nature by city dwellers; actually, WTP varies in space; we also presume regional differences with regard to use and willingness of offer between urban, peri-urban, and rural, which can be activated by a political process of notice. In particular, virtual WTP is one thing, actual payment another. Contributions can be activated by travel costs as add-ups revealing factual WTP. As markets do not exist yet, corresponding benefits, costs, budget issues, and expenditures are currently not material. They have to be elucidated and, in particular, put in relation to size/volume of nature offer. Activation is needed. From a planning point of view, the scale of nature surrounding a city and remaining farm land must be optimized simultaneously [31]. Optimization is not merely about finding singular participating farms, points of sale, etc. and assuring delivery, but allocation as share. It renders subsidization. Payments (ideally as supply equals demand for a specified commodity) are spread and to be systemized along a gradient from centre to periphery. The coordination of service flows, finance generation, and payment takes place in space and needs to be pondered, eventually by the city councils or regional government. Regional flows of subsidization for nature as well as more supplies are to be coordinated and put into a systematic categorical outline, which in our case is distance.

Secondly, it has to be made clear why nature provision (offering of amenities and ESS) is a public welfare issue and how it relates to space if farmers as land users are providers with opportunity costs. That is, planning must be achieved with transport behind as a public cost and rents as private. Within the frame of regional land use, changes in land use for conservation/nature, in general, are affected by costs and benefits at an integrative regional scale. In a world of cities at core of demand and rural areas as providers in space, which are formed by regional advantage, for instance, land prices matter and there is a tendency

(again) to think that conservation should be practised where prices are lowest. Rents and real costs differ and real provision cost calculations (at nominal costs along payments for land acquisition) matter. Payments are based on PES concepts; they should be compatible with nature (provision), but extra rents occur on the side of providers (willing farmers, see Fig. 3). In developed economies of differentiated land use intensity (location) and land prices, the city-rural-nexus of rent seeking is a result of sensitive land price development and intensity dissimilarities between locations.

In Fig. 3, the aspect of nature provision as dependent on local supply and demand as well as the influence of distance is exemplified. The concept of land market (underlying the construct) may be a reference. It distinguishes demand for conventional farming and farming with nature. We assume that in a reference situation (low intensity of farming), some nature is already prevalent. Then, a subsidy for eco-agriculture ([1], synonymous with nature farming) increases competitiveness and excess supply is achieved through subsidies. We separate social and individual marginal benefits of farming types. Note, in realization, profits in food production at farm level are still given. Figure 3 depicts benefits accrued from a change in allocation; foods are liable as farm-products, not amenities. The reason is to avoid double counting. In effect, as residual in presentation, we can accomplish “costs” for nature provision which are firstly stated as profit loss; but then, we need to recognize (tacitly and secondly, below) that reallocation gives artificial benefits and farm net effects will be positive.



Source: own design

Fig. 3 Payments, costs, land acquisition, and welfare gains at distances

As suggested, introducing payments and then distinguishing payments regionally (to achieve localized change based on societal costs referenced and preferences) is necessary. For this, we finally seek to achieve the results for a cost–benefit analysis of the total area around a city. As will be shown, it is possible to build a spatial cost–benefit function. In doing so, we must integrate any local transaction, i.e. at any distance and in comparison to costs at distances (from centre to periphery) and sum up. Then, allocation of land as percent of land involved is dependent not only on local payments, but also on “market” pricing of land (rents which are prevalent development of land pricing). How moderating payments from one region to the next region? Payment becomes a policy instrument, yet, firstly because the government makes money available and secondly because farmers respond (either through participation constraints or even incentive constraints). Then, the distinction between payments and benefits are to be understood.

3.2 Willingness to Pay

In neo-classical economics, the purchasing power of individuals (as WTP, willingness to pay for nature) counts and (regional) markets would serve to maximize welfare, whereas transportation costs are included. However, we have the problem that nature, ESS, and amenities are not commodified. A government, taking into account WTP and cost of provision, shall work out plans and equilibria and optimize the rate of local provision by procuring money from citizens, here through surcharge on transport, and channelling it to local providers (farmers). The transaction is apparently anonymous. But, as indicated, it will affect land use and rents differently. Notice, here, land allocation is determined by opportunity costs (rents: Fig. 3). The government allots money, and nature provision is spatial but at real prices for land. A method to find preferences in this regard is the travel cost method [32].

The preferences and potential propensity to pay of consumers (citizens’ WTP) should determine the size of nature provision (share in landscape) at any location. Yet the size of nature is a matter of land allocation (share) and quality (ESS). There is a request for a raise in corresponding money for nature quality. In our case, we include quality of nature “ y ” (varying in distance and dependent on N : flora, fauna, etc.) as argument and think about revealed travel costs. The relevance can be explained by a possibility of changing quality of nature in space. As has been said, remote areas have a higher quality since farming intensity is lower and nature becomes connected at a large scale; especially if it includes parks [9], nature can increase quality. Yet, if (i) we put distance “ d ” and payment for transport “ t ” at the centre for WTP, further if (ii) we specify WTP in Eq. (1) as marginal utility and (iii) add a notice about travel costs in spatial terms (as associated with a reckoning of distance in an exponential version). Usually, we find a formula for depicting willingness to pay, which is transport expenditures, such as

$$WTP(d) = \mu_0^* + \mu_1^* n(d) + \mu_2^* y(d) + \mu_3^* e^{\mu_3 \cdot d} \quad (1)$$

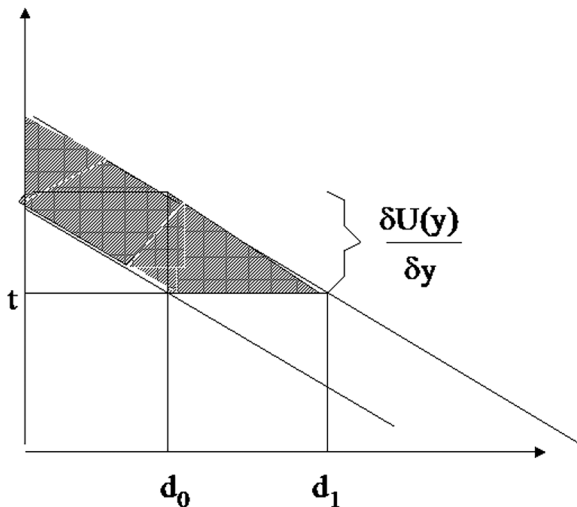
Note, nature is site specific, and later, we have to generalize for the whole catchment. Though WTP serves as a procurement tool (as a whole: revelation), it is contingent on distance choice. As depiction of travel costs (later plus tax) and revelation of preference, version (1) can be obtained from contingent valuation [32]. In that version, location of payment and quality differ. That is, if quality becomes explicitly recognized, the final price (WTP) for nature is transport cost plus tax and quality and it allows us to retrieve welfare (as function). Revelation corresponds to efficacy of the transport system and explains valuation recursively.

However, as nature provision is not only identified as land use but rather prevalent nature N matters, a design problem emerges. Indeed, nature must be a mix of land in varying distances; the overall integrity of nature in the whole sub-catchment also matters. (We could use the word catchment as synonym for nature acquisition ground of citizens living in the centres; i.e. city dwellers usually living in the centres seemingly act as “fishermen” striving for a “catch” of nature). Actually, we propose that from a user’s perspective quality is a combination of nature (N : as observable quality, below) and achievement by farm practice (land devoted to provision (n : being merely size or percentage of land under nature provision)). To keep mathematics as simple as possible, our specification of the objective is multiplicative between N “Nature” and the area procured. Nature in this regard is a quality index N set between $0 < N < 1$ (Fig. 4).

3.3 Central and Decentral Aspects of Welfare (Improvements) Through Nature Provision

How can we translate valuation from travel cost and contingent valuation into welfare accumulated over space as well as make it suitable for our case of finance

Fig. 4 Depiction of transport costs in a circular economy of distance [33]



Source: According to Just et al. 2008

for planning? There is a mathematical background of firstly specifying an objective of a consumer, secondly optimizing it (i.e. as if benefit minus cost prevails), and thirdly recovering the function as revelation or optimal behaviour and interest pursuance. Mathematically, one can use behaviour to find welfare and payment as integration of area below a demand (mathematically as integration over marginal utility function [33]). According to that frame cost equivalents for the WTP are travel costs t per distance multiplied by a factor for quality and distance as an index.

$$t_1^* \cdot y \cdot d_1^* \tag{2}$$

The travel distance can be assigned to a segment of the circle (Fig. 5). That is, the coefficient for distance depends on segmentation. We assume that segmentation creates exponential cost change; it depends on a number of segments because a user has to travel to the hinterland.

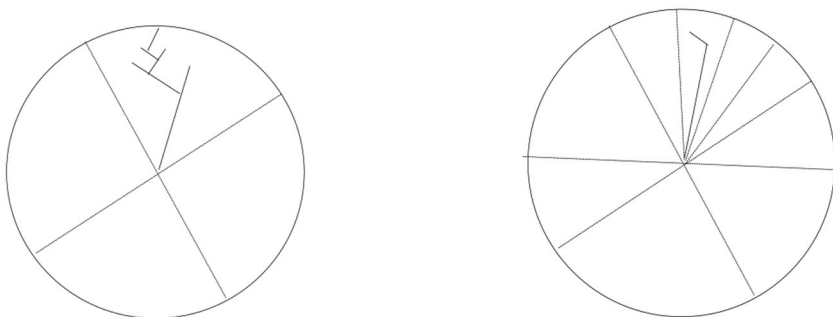
$$t_1^* \cdot y \cdot e^{\mu_3 \cdot d} \tag{3}$$

Figure 5 gives the argument for distance in a segment of a circle and we further elaborate on optimization (given number of segments or going beyond to internally specify segment numbers). Correspondingly and in a simple, though treatable way, we will specify the objective function in the fashion of a quadratic outlet (i.e. if demand is linear, the objective is quadratic by integration); formally, it means getting coefficients of utility if we use linear demand. Hence, starting with the specification of a utility function, it must depend on area and quality:

$$U(N, n, d) = \mu_{01}n_d + .5\mu_{11}n_d^2 + \mu_{02}N_d + .5\mu_{22}N_d^2 + \mu_{12}n_dN_d + \mu_{31}e^{\mu_3 \cdot d}n_d + \mu_{32}e^{\mu_3 \cdot d}N_d \tag{4}$$

where:

n = land und nature (integrated farming)



Source: own design

Fig. 5 Travel distances to periphery (in case of 4 segments)

N = nature as quality

D = distance

For the moment, WTP and utility from N are broad concepts (for segments in (4)). It needs further elaboration (below). For empirical investigation of preference, we can make it location specific; i.e. from optimization of the benefit function minus travel costs at distance (“ d ”; (5) and (6), as linear, assuming location-specific preferences with expectation of nature), we get

$$\mu_{01} + \mu_{11}n_d + \mu_{12}^*N_d + \mu_{31}^*e^{\mu_3 \cdot d} - t_1^* \cdot N_d^* = 0 \tag{5}$$

$$\mu_{02} + \mu_{22}N_d + \mu_{12}^*n_d + \mu_{41}^*e^{\mu_3 \cdot d} - t_1^* \cdot n_d^* = 0 \tag{6}$$

From a sequence of observation for Eqs. (5 and 6), yet the empirical analysis of travel cost concept) WTP can be established through spatial regression, i.e. if we work with the function stated above, and local information forms current nature and land allocation preferences.

3.4 Citizen Welfare Improvements by Nature Provision in a Travel Segment around a City

The above outline for welfare measurement will enable us to a systematically gathering of empirical information of WTP by location; however, we have to understand the background of amenity, distance, nature, etc. A prime question is, whether it is correct to identify nature as urban citizens looking for the “commodity” of nature being supplied at different locations, or whether it is generic in the whole system. That is, is there a “market” provision or do we need planning and public procurement of finance to enable payments to farmer location specific? Apparently, provision is specific in planning and in terms of landscape. Then, rather realization follows after planning and WTP comes later. Provision is public and holistic. For a smart depiction, this deliberation means we have to reckon WTP derived from the whole hinterland.

Another problem emerges. The suggested version must actually distinguish between a preference function per user and the number of users. In Eq. (7), we modelled preferences, for instance, as a per capita part multiplied by users c . Yet, it comes with a user’s wish for $N(d)$, and $n(d)$ is a share in land (% or absolute distance in a segment as given (Fig. 1):

$$U_c(N, n, d) = c_u \cdot \int_d \{ \mu_{01}n(d) + .5\mu_{11}n^2(d) + \mu_{02}N(d) + .5\mu_{22}N^2(d) + \mu_{12}^*n(d)N(d) + \mu_{31}^*e^{\mu_3 \cdot d}n(d) + \mu_{32}^*e^{\mu_3 \cdot d}N(d) \} d\delta \tag{7}$$

where additionally: c = number of citizens in urban agglomeration

In this version, as a first step, the total utility is determined by the per capita service released at all sites (integral) and the number of citizens. In fact, we describe the whole population as being exposed to nature, but amenities maybe to be designed differently for those who choose different locations. The normative context and issue is as follows: will citizens uniformly use nature or differently (as portion attributed to location) and will they find locations which suit their specific preferences (more below)? However, it might be argued that the population interested in nature and amenities will adjust along an offer curve and as a secondary optimization problem we shall recognize a distribution of user intensity (discussed later). Then, we get

$$\begin{aligned}
 U_c(N, n, d) = \int_d c(d) \cdot \{ & \mu_{01}n(d) + .5\mu_{11}n^2(d) + \mu_{02}N(d) \\
 & + .5\mu_{22}N^2(d) + \mu_{12}^*n(d)N(d) + \mu_{31}^*e^{\mu_3 \cdot d}n(d) \\
 & + \mu_{32}^*e^{\mu_3 \cdot d}N(d) \} d\delta
 \end{aligned} \tag{8}$$

Further note, mathematically, the use of an integration of a product (multiplication in (8)) creates severe formal issues. One solution is to circumvent the multiplication outline mathematically, as can be done with the product rule (below), just by a different function. In that case, we presume population (in a segment) of the city, which is interested in a specific nature travelling at certain distances, can be introduced empirically different. For instance, an exponential function for the distribution of initial travel pattern (yet of total visitor population) can be a starting point. (Such complex derivation we will do below.) Yet, with taxing use patterns, it will change (below); specifically when taxing is location-specific on $N(d)$, a new pattern emerges.

Alternatively and less complex, we can work with a reduced version of linkage between regional preference and potential users such as (9). In regard to that visitor size $c(d)$ (number of potential users at distance) and per capita preference matter, we suggest simplifying conceptually visitors flow and communicate, in a macro model (catchment), on behaviour (in regression). Users are potentially derived from spatial regression in a given catchment. It links the expectations for nature procurement with the number of potential visitors. Then, we use

$$c(d) = \mu_{c0} + \mu_{c1}n(d) + \mu_{c2}N(d) + \mu_{c2}(t(d) + s(d)) \tag{9}$$

However, as generalized we can (must) include a shift of WTP by the size of touched area and nature. That is, from a construction of prevalence of different intensities, we can reconstruct the area and citizens' distribution of interest. Presumably, we start with the assertion that there is no regional preference, but only transport counts. Then, having a population $c(d)$ which is visiting, we can reference to the logic of the share of farming with nature (elaborated below). For the moment, from use density inclusion, we will get an operational function, which is derivable.

$$\begin{aligned}
 U_c(N, n, d) = & \int_d [\mu_{c0} + \mu_{c1}n(d) + \mu_{c2}N(d) + \mu_{c2}(t(d) + s(d))] \cdot \{\mu_{01}n(d) \\
 & + .5\mu_{11}n^2(d) + \mu_{02}N(d) + .5\mu_{22}N^2(d) + \mu_{12}^*n(d)N(d) \\
 & + \mu_{31}^*e^{\mu_3 \cdot d}n(d) + \mu_{32}^*e^{\mu_3 \cdot d}N(d)\} d\delta
 \end{aligned}
 \tag{10}$$

Finally, besides problems from a mathematical point of view, which leads the model resulting in a cubic function or polynomial expressions, instead for analytics, we better approximate (10) as quadratic. Then, some remarks on linking mathematics to reality are necessary: it is plausible that over the last decades, urban interest in rural areas has even resulted in counterurbanization [34] and populations in considerable volumes can be found now at the urban fringe (peri-urban). It implies even more complicated functional forms. For these people, the landscape is a source of amenities following certain patterns of spread in “use” (stock: [35]. And from delineation of correlation between density of population, migration interest and visits (10) can be derived. In this regard, one could follow Newburn and Berck’s [36] assuming that users are linked to nature prevalence $N(d)$, and a mathematical formula and statistical correlation develop evidence. Observable background serves getting (5) and (6).

3.5 Costs and Procurement of Finance

In principle and formally, Eqs. (7), (8), (9) and (10) are of the same composition: an integrated quadratic function, which gives utility and relates to distance; though the background of receipt is different. Let us commence with version (3) for the moment and then, later, we will elaborate further for empirical analysis on it. From Eqs. (7), (8), (9) and (10)) as utility, we deduct transportation costs (11) to get net catchment welfare which is a pure equivalent of distance, yet if segments are small. That is, we integrate transport costs equivalently over sample distance; this change is in a more circular economy, because visitors will spread in total hinterland (above). Finally as approximation, we see total transportation costs distributed in a circle reckoning distance exponentially (scattering citizens). At the landscape level, one can summarize the travel costs by

$$t_t^* = \int t_a^* \cdot \pi \cdot e^{\mu_3 \cdot d} d\delta
 \tag{11}$$

where t_a are average costs per distance (km) for travel.

To get payments (surcharge), we re-specify Eq. (11). Surcharge (tax) shall be a percentage of travel cost (12). It seems that from this viewpoint, total “private” costs increase by distance.

$$B_t^* = \int t_a^*[1 + s(\delta)] \cdot \pi \cdot e^{\mu_3 \cdot d} d\delta
 \tag{12}$$

For the moment budget B stands alone. In devising surcharge “s,” it is proportional to travel cost, it can be modified along distance, and it has to be optimized. So, it is not uniform because we will follow the logic of difference in importance and flow analysis

of finance; by specification surcharge in projects, costs increase. Overall, we will deduct payment for provision from amended cost (transport plus tax). Finance accumulates over distance and is used up. The limitation is that the segments are to be redefined. We can work with n identical or adjust to terrain.

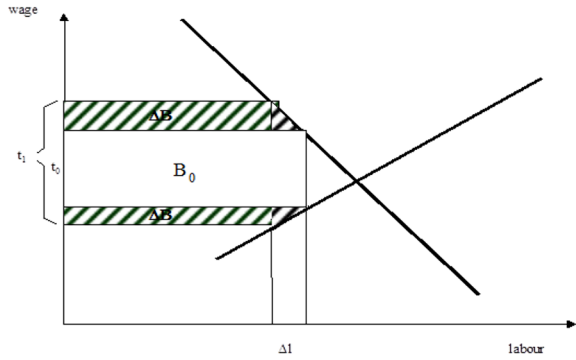
4 Finances vs. Costs in Public Welfare: an Excursion on Excess Burden Modelling

It needs to be further noted that in the above cost for nature provision, which is given as surplus charge, welfare transfers are included. Finance is transferred to farmers, so it is not project cost rather expenses. Finance as award vs. transfer brings the analysis to the question of private welfare vs. public. Benefits are obtained by urban dwellers and generate public interest which is subject to a project analysis for the government. Transfer of money to farmers is not cost; it contains rents. Government taxes citizens and pays for nature. So rents should be deducted.

Yet, in order to explain the difference between costs and payment, we have to clarify what is to be understood as excess burden in public planning. The issue is as follows: are there “excess burdens” [37] in our case? Excess burdens come from changing allocation by introducing payments. Again, we have to be careful with private costs and public costs. In conventional welfare economics which is, as commonly proved, concerned with private goods, government interventions create excess burdens, and interventions are suboptimal [33]. However, we deal with public goods and regional services (amenities, ESS) which are not commodified by straight definition. Nature and ESS are public gains which are spread, in our case in the whole area of nature provision and, as a whole, visited by citizens in bulk. Nature might be only a commodity at a “large scale”, i.e. finally, at the system boundary of a “catchment”, but not tradable as private within a scheme. Within itself, it is not a commodity, rather defined as a share in land use. Expenditures and costs, on the one side, as well as benefits and tax burdens, on the other, are differently associated with services and use: i.e. (i) payments vs. costs matter as government issues, but not as pure private judgments; (ii) making profits from revenues vs. having costs of reallocating land is the farmers’ burden. Payments help farmers think they are better off with nature. (iii) We have to separate payments for achieving a public good vs. spending as private issue. Finally, (iv) net effects of any participant are added.

However, commencing with the citizen perspective, there are private costs which are transport and tax; major money is transferred. In our special case of a specific taxing of travel (here in the transportation system), it generates cash for planning or outreach of nature provision, i.e. finance serves management as a source of area procurement n for nature N . This area is less “productive” than conventional farm land, and this creates the real excess burden; finally, it is funded land use to be justified. In this case, contribution of citizens enabling welfare improvements and taxing is productive. In the envisaged version, however, budgets can (must) be generated (additionally from transport) and must be integrated as deduction from income.

Fig. 6 Excess burden



Source: own design

$$\begin{aligned}
 U(N, n, d) = & \mu_{01}n(d) + .5\mu_{11}n^2(d) + \mu_{02}N(d) + .5\mu_{22}N^2(d) \\
 & + \mu_{12}^*n(d)N(d) + \mu_{31}^*e^{\mu_3 \cdot d}n(d) + \mu_{32}^*e^{\mu_3 \cdot d}N(d) \} d\delta \quad (13) \\
 & - \mu_{23}^*n(d)[y(d) - t(d)] - \mu_{23}^*N(d)[y(d) - t(d)]
 \end{aligned}$$

One question remains: cannot we, alternatively, work with social welfare at primary level and then calculate cash needs at secondary level? We think no, because WTP stands at the centre of traditional welfare analysis with revelation of WRP. Thus, welfare is a monetary issue, and thus, breaking down cash needs for land acquisition and calculating contributions is feasible (Fig. 6).

WTP becomes available as sharing of costs for any citizen on location d , benefitting area-wise farmers, and we will get benefits in monetary terms as consumer (citizen) surplus. Is that enough? First, the counterargument would be: not everybody would fit into WTP requests, but would have to pay if he travelled; especially, because travel costs are different and some citizen will prefer to defect, is there scope to attain enough money? And what is about those not using amenities? Second, there are overlapping benefits and nature is not paid as private good; i.e. the problem would be how to get the taxing scheme closer to equivalence. Third, citizens could argue that farmers should deliver in a spatially different way; yes, but they do not want pay more for farmers living closer to the city. These are value judgements. Apparently, assessments depend on institutional arrangements. Our pragmatic version of a tax (as added to transport costs) should be that it does not discourage travel, but will still deliver feasible user intensity over distance. Hence, the above formula displays a trade-off choice for regional planning.

Next about nature: for us, the issue of nature as a common in planning explicitly emerges with the connectivity of nature and places of generation within a whole area. As ecologist, who claim that ESS needs large tracks, say, it is almost impossible to get a commodity-oriented benefits on site. Taxing travel as a substitute is an approximation for a joint objective function of societal optimization and ecology. Then, farmers have to shoulder an excess burden, but in turn receive money. Finally, the willingness to contribute depends on opportunity costs based on land rent.

Lastly, let us look at land prices and rents prevalent in a circular economy around cities if nature farming is subsidized; yet as add to already high rents? Land prices seem to be cost units, but mostly they display transfers benefits. Low prices favour nature conservation far away, but citizens have different preferences, and costs to reach peripheral areas will create higher rents close to the city. For planning, land use, intensity, land rent, labour returns, etc., all prices interact. With a lower land price, more land becomes affordable and nature can spread; vice versa, nature close to cities is very (too) expensive. Formally, we follow this outline of a local excess burden concept by a quadrating presentation having a budget:

$$C(B(d)) = \phi_0[B(d) - B_o] + 0.5\phi_1[B(d) - B_o]^2 \tag{14}$$

We will put costs (farmers) and benefits (citizens) in the spatial frame. Equation (14) applies to farm costs. Furthermore, as will soon talk on rent seeking and taxing rents, farmers have to be understood.

5 Decentral Provision of Area for Nature Conservation by Farmers at Farm Level

We now must work on the voluntary provision of nature (willingness to accept WTA) as land use change in favour of farming with nature [4]. This requires land use be changing at distance “*d*” and accepting lower intensity, yields, etc. We look at cost implications and shares obtainable. Our analytical concept works through translation of costs and constraints in land use equivalents (shares). We want to achieve a mathematical treatment of nature provision as land uses shared (15). Nature provision impacts on gross margins. Yet compensation is requested and compensation is built on intensity, distance, and land prices for farm participation.

In extreme cases, one might think about a full change of land use practices. In a more moderate version of cross compliance as ours, means conversion of some land. It can already impact on nature [38]. An outline of specific programs is beyond this contribution. It is assumed that an ecologically conducive scheme exists and farmers contribute land as shares for nature. By the specification of opportunity costs, respectively, compensation asked for by farmers in Eq. (15), we can derive/show the planning from the farm side as land use change:

$$\Pi(d) = p_c(1 - n(d)) + (p_e + m_p(d))n(d) - C((1 - n(d)), n(d), R(d)[1 - m_s(d)], z(d)\alpha_0) \tag{15}$$

(+) (+) (-) (-) (+)

where increase of gross margin: “↑” and decrease “↓” of:

p_c = gross margin per hectare under current practice (↑)

p_e = gross margin per hectare under practice with compliance (↓)

n = nature integrated farming

m_p = monetary payment as compensation for compliance (variable with *d* to be found)

$C(.)$ = cost function (cost \uparrow = $>$ margin \downarrow)
 m_p = transfer payment linked to rent: option to tax farms close to the city (variable with d)
 R = land rent at location d (cost \uparrow = $>$ margin \downarrow) for farmers who have to rent land
 m_s = tax on land rent (\uparrow = $>$ margin \downarrow)
 z = prices of inputs (if \uparrow = $>$ margin \downarrow) and land rent, vector
 α_0 = area coverage
 As remark for nature as a potential element in farming, we abstract and see no impact of nature on farming. Making the analysis mathematically feasible, we apply a quadratic costs function:

$$C((1 - n(d)), n(d), -m_s(d)) = \gamma_0 n(d) + 0.5\gamma_1 [n(d)]^2 + \gamma_2 n(d)(R(d)[1 - m_s(d)]) \tag{16}$$

Prevalence of land scarcity is included. It links to rents. Any rent increase creates costs, and hence, distinct access burdens, here at distance d . With respect to finding a contingent optimum, one must first take derivatives towards land use for nature (Eq. (17)), and land (shares) are supplied as dependent on payments and land rents (varying). Equation (17) translates into “supply” of farmers (18) dependent on instruments m_p . It means that farmers will seek a balance between land for $n(d)$ and payments (in turn, supply can be influenced by tax on the land rent m_s).

$$p_e - p_c + m_p(d) - \gamma_0 - \gamma_1 n(d) + \gamma_2 [R(d) - m_s(d)] = 0 \tag{17}$$

$$\Leftrightarrow n(d) = \gamma_1^{-1} [p_e - p_c - \gamma_0] + \gamma_1^{-1} m_p(d) - \gamma_1^{-1} \gamma_2 [R(d) - m_s(d)] \tag{18}$$

In respect to the design of instruments, supply at area $n(d)$ is now endogenous to payment and tax. Yet we have to recognize the “prevalent” level of land rents (even the pattern from city centre to periphery) which is regionally (at a distance to the city) differentiated by intensity.

6 Financial Needs, Planning, and Analysis of Regional Changes as a Dynamic System

In this section, the discussion of nature provision becomes oriented towards a fit into the “dynamics” of the system (i.e. spatial design of integration of nature in farm land). It includes land rent development, rendered to distance from city “ d ” and budget flows in terms of money spent. It is assumed that central finance exists and it captures money from WTP as prime source. We specify a budget, which is primarily viewed from city dwellers’ ideas on how to “get” nature, and it is based on transport surcharge. Concerning a second source of budget, we suggest taxation of land rents. Observable rent development (i.e. from city to periphery) may be described by an exponential function (differential function in Fig. 3: one can establish it from periphery to city). We assume that there is scope for taxing rents because it is not

in the interest of society that those who own land close to city benefit most from intensity. (Note that we do not argue for justice; rather see potential gains from re-shuffling money for engagements matters.)

6.1 Land Rents

Beside that we have to clarify why rents are important and how they “behave,” we need empirical information on regional development along distance from town? Starting, for instance, from the periphery where rents (land prices) are minimal, where is an increase of intensity and land price surge towards city and the introduction of payments will have an impact on intensity and rents interactively. In fact, farmers add an extra on rent from special crops or farming activities, such as horticulture vs. pasture, for different intensity, etc. Vice versa, it makes nature obsolete if intensity increases due to rent changes, which are not met by payment. This is at farm level. Beyond farm level, for example in the cases of forest or nature reserves, the share of land to be acquired is also important. In principle, any land has to be credited and it competes. Yet competition and need for extra money have an impact beyond individual location, because land use is financial return-related. Farmers, as land owners, will ask for rewards and they will try to substitute losses through land from nearby areas. The search for scarce land has an influence on rent patterns, recursively. We simplify and put it into the following linkage, which is more or less subject to regression analysis or modelling for getting coefficients from function:

$$\dot{R}_s(d) = -\alpha_{00}R_s(d) + \alpha_{10}m_s(d) - \alpha_{20}m_p(d) \quad (19)$$

We suggest spatial regression getting (19). As can be shown, data sets of (i) land use type, (ii) intensity, and (iii) rents deliver coefficients for regional adjustments (for example in econometric analysis on spatial pattern see [39]). In general, we refer to interdisciplinary research of larger land modelling [40] to obtain a spatial dynamic as condensed in Eq. (12). It should also include policy variables. In scenario modelling, for example Verburg et al. [11, 12] looked at interventions by which one can detect linkage, and it delivers data explorable for (19). Triggers for nature provision such as crop choice and intensity force up land prices. Other aspects (such as transport costs and specialization) are also relevant in setting equilibriums between supply and demand for rental land of which payment is part. Essentially, in order to get α_{10} and α_{20} , it has to be distinguished between conventional cropping and cropping with nature (Eq. (19)). Further empirical evidence on infrastructure (i.e. roads, etc. from different locations at inner and outer circles) will enable us to regress better. To model development of rents from the centre, we use exponential functions; yet the function can be translated into a differential equation [24].

6.2 Budget Development

Next, let us assume that major financial contributions are collected in the peri-urban, i.e. from travellers who want to enjoy nature. The budget planning itself is directed

by spending and accumulating over space, and we take the analogy to non-renewable and renewable resources. New spending at any distance is linked to previous spending (increase or declines as for non-renewable resources), and planning must anticipate future spending as well as procuring. Spending, like any financial transaction, is composed of price multiplied by quantity. We approximate spending at the level of instruments “ m_s and m_p a ” and treat money raised from citizens “ s ” first as a “non-renewable” resource. B_t is the total budget. So spending on land procurement for nature and raising tax from land rents with respect to farmers is summed up over distances:

$$B_s^t = \int [\alpha_{120} m_s(\delta) - \alpha_{20} m_p(\delta)] d\delta \tag{20}$$

Earning is at a similar scale. We get it outlined as tax on travelling plus rent levy at distances:

$$B_t^* = \int t_a^* s(\delta) \cdot \pi \cdot e^{\mu_3 \cdot \delta} d\delta \tag{21}$$

In fact, we receive two integrals, yet of functions running over time: procurement and spending. From a method point of view, location-specific procurement of finance, spending, and planning prevails. Integration is complex as well because we work with different functions.

To reduce complexity, a mathematical procedure such as partial integration can apply:

Excursion: there is scope to reduce complexity and make the approach operational, especially if one wants to get budget clearing into a constraint for optimization. For the combination of functions, we can use the mathematical tool of partial integration which reads like this:

$$Z = \int x'(\delta) \cdot y(\delta) d\delta = x(d) \cdot y(d) - \int x(\delta) \cdot y'(\delta) d\delta \tag{22}$$

Applying the mathematical tool (22), i.e. starting point is the centre, the budget decomposes. For explanation: application (22) is preferably linked if a specified function is multiplied with an unspecified. Hence, (22) can be applied to our case. We receive reformulation such as

$$B_t^* = 1/\mu_3 \int t_a^* \cdot \pi \cdot \mu_3 \cdot e^{\mu_3 \cdot \delta} \cdot s(\delta) d\delta \tag{23}$$

For clarity about stock and flow variables, now surcharge $s(d)$ becomes change in stock S since we need the first derivative. The assignment is that $S(d)$ changes in space. We now get

$$B_t^* = 1/\mu_3 \int [t_a^* \cdot \pi \cdot e^{\mu_3 \cdot \delta} \cdot \dot{S}(\delta)] d\delta + S(d) \cdot e^{\mu_3 \cdot d} \tag{24}$$

Equations (23), (24), (25), and (26) are treatable constraints which have to be equated with the expenditures $B_i = B_s$. The underlying consequence is at the regional scale, budget changes must hold and equalize.

$$\left\{ \frac{1}{\mu_3} \int_d [t_a^* \cdot \pi \cdot e^{\mu_3 \cdot \delta} \cdot \dot{S}(\delta)] - \alpha_{120} m_s(\delta) - \alpha_{20} m_p(\delta) \right\} d\delta + t_a^* \pi S(d) \cdot e^{\mu_3 \cdot d} = 0 \tag{25}$$

Having achieved the equation for (26), it can be differentiated (integral drops), giving us

$$\left\{ \frac{1}{\mu_3} [t_a^* \cdot \pi \cdot e^{\mu_3 \cdot \delta} \cdot \dot{S}(\delta)] - \alpha_{120} m_s(\delta) - \alpha_{20} m_p(\delta) \right\} + t_a^* \pi \dot{S}(d) \cdot e^{\mu_3 \cdot d} + t_a^* \pi S(d) \cdot \frac{1}{\mu_3} e^{\mu_3 \cdot d} = 0 \tag{26}$$

Coefficients can be shorted by variables (which means that they are combined in brackets in front of variables) and deliver a second differential equation dependent on s , m_s , and m_p

$$\dot{S}(d) = \alpha_{22} S(d) - \alpha_{21} m_s(d) - \alpha_{23} m_p(d) + \alpha_{24} t_a^* + \mu_3^* e^{\mu_3 \cdot d} \tag{27}$$

Now, as we elaborate further, the two dynamic economic constraints, so far presented, are to be implemented in a spatial (dynamic) optimization, for instance applying Lagrange and control theory (below). We will supplement it with two more dynamics. Note that there is yet a continuous recognition of the budget constraint telling us how to raise money and how to spend it.

6.3 System Boundaries and Remarks on Scope

In the meantime, we need to make some remarks for spatial planning concerning the system boundaries. We reference to mathematics. Since some aspects of integration and differential equations, i.e. from “where to final,” remain to be clarified and are important, questions to be answered are as follows: (i) where do we start and end? For instance, reversing planning from periphery to city would mean that the city even has to come up with money for the users at the other end. Vice versa, at final distance (at the end of travel), a certain budget is exhausted. The budget is raised as surcharge, and it request an activity. In the end, any budget contribution, raised, must equal/cover total expenditures. Then, (ii) definition of system boundary is relevant for practical reasons. For example, in extreme case, “a high tax may discourage travel,” especially for the poor, and welfare for society is endangered, although farmers receive money for conversion and convert land for ecological reasoning. (iii) This might be appreciated by ecologists, yet it is not the targeted concern of this contribution. We work with human welfare derived as WTP and measure WTP through travel cost. Vice versa, a “low tax” will imply long distance travel.

Later, from optimized payments, we obtain state variables R , N , and S which are subject to interventions in the spatial agro-ecological system; they are built on distance around a city. (Note N still has to be explained, see below). Mathematically,

we are confronted with flow and terminal conditions and all conditions must be met at the side of money raised for outlay.

6.4 Nature Provision and Payment

So far, our spatial system of detecting interventions, finding budgets, and scoping for nature provision as public good and modelling, etc., is built on expenditures and finance for procurement of land under agro-ecological production conditions. The procurement tool is money available from WTP, i.e. from citizens and rent as related to expenditure needs. In the beginning, we additionally said that citizens have preferences for nature N . We still have to include quality of nature as WTP criteria. Again, we follow a system approach in space. Nature prevalence is postulated as a mode/mean of improving WTP (budget, note for provision, “supply,” the issue of quality and connectivity of nature in space have not been addressed yet). We will now amend the underlying bio-spatial system for quality of nature in the catchment [41]. This amendment has implications: (i) in the objective function of citizens, we included the cross-regional aspect of nature expansion as N (stock); (ii) for farming, evenly a system of intersection prevails and it must also be planned by the local authorities. We take a special view and see nature quality as spatially connected. In our view, it is not possible that nature is provided in singular places; rather nature (space) is added at distance; nature “develops.” Development of nature conservation in space is dependent on payment and interaction. We set a differential equation:

$$\dot{N}_s(d) = a_{33}N_s(d) - a_{32}n_s(d) + a_{34}N_s(d)n_s(d) + \alpha_{20}m_s(d) + \mu_{40}e^{\mu_{41} \cdot d} \quad (28)$$

For interpretation, the actual spatial outline can be differently interpreted: clusters (parks, aggregated areas, etc.) close to city vs. clusters in the periphery are a trade-off. In extreme, at the periphery, one can already find natural parks (hundred percentage share of nature: [9], but this is not automatically ecologically justified and we still pursue the idea of integration. For the right appreciation of nature, land procurement by payment, and nature interaction, we have to recognize; is that quality of nature maximum, if only at the periphery? We see N in space in total, and it changes over space. The interaction of factors, especially coefficient a_{34} in (18), is especially important because the latter links area planning and nature. Mathematically, however, it is difficult to treat interaction because it creates non-linearities. There are two ways of dealing with complexity. One can apply the non-linear control theory [24] or approximate linearity. Additionally, there is a special issue. If the supporting systems for nature can be stimulated by investments which impact on connectivity, we prefer and receive (29):

$$\dot{N}_s(d) = a_{33}N_s(d) - a_{32}n_s(d) + [a_{34,o} + a_{34,1}i(d)]N_s^a(d) \cdot n_s^a(d) + \alpha_{20}m_s(d) + \mu_{40}e^{\mu_{41} \cdot d} \quad (29)$$

In this version, we take referenced nature and area optimization of (28), but without any interaction first, and then supplement it by investment to sponsor the interaction (multiplicative).

7 Spatial Optimization of Policy

Having specified utility of urban citizen/consumers (WTP; Eq. (13)), profits of rural land users/farmers (WTA; Eq. (15)), and transaction costs as well as having outlined dynamics (Eqs. 19, 27, and 29 as changes from introducing payment in taxing and feeing scheme), an objective is given. We could add welfare and bundle it into a single representation of social welfare (change) in the landscape. Actually, we will use control theory for that [24], and obtain a system approach. However, there is still the question concerning citizens' distribution. Meaning, first (for mathematical work) we need precision on variables and functions in space.

7.1 Adjustment of Benefit Formulation for Citizens

Subsequent, at system level, benefits refer to integration over space and movement (stock variables). As the circle is divided by a number of segments (Fig. 4), for the implicit function (30), we needed previous steps to obtain explicit movement of stocks including all variables.

$$W = \int_0^d \{ \mu_0 e^{\mu \delta} U(c, m_s, m_p, s, R, N, S, \delta) + \Pi((m_s, m_p, s, R, N, \delta) - T(m_s, m_p, s,)) \} d\delta \tag{30}$$

Also as mentioned above, we suggest using a discounted population distribution, being interested in nature at different distances expressed as exponential function. In this frame, the preference for closeness to city gives the size of the potential movement and interest for sites. It is built in a “discounting” mode of lower value for longer distances and appreciation of short distance which can be verified empirically. Then, the area for nature *N* matters and the choice of payment is considered the focal policy instrument. We actually have four dynamic constraints (below). To solve the model analytically, i.e. for the case of regional shares of nature in land use *n* and nature *N*, one should apply control theory [24]. Control theory serves finding policy instrument *s* and *m* (i.e. for minimal rent seeking *R*). This requires a certain outlay, which will be described next. For the outlay, including movement, it is suggested retrieving coefficients for WTP and WTA functions as regression and using quadratic WTP functions. Yet, some aspects for making the analysis empirically viable are needed in detail, such as.

7.2 Movement of Citizens and Preferences

7.2.1 Intensity of Use

Besides the three dynamic constraints, so far studied in space, the distribution (dynamics in space) of consumer needs (movement) has to be added as fourth constraint and, being part of a spatial preference function. The intention is to qualify

$c(d)$ as citizens ageing at locations d (for nature) as well as getting a stock and flow. Firstly, to get model closure on visiting nature, a cost minimization of the citizens' choice can help. This is supportive of later overall optimization.

Then, we have to understand competition between land for food and nature. We work with density of nature per citizen n/c and initially reckon an optimal overall density. Note that at this level, food provision and nature compete unspecifically for space. We recognize a segment (Fig. 4) given by a transport network and determine intensities by a linear constraint in optimization. Mathematically, the size of angle a in the segments matters; i.e. in that segment multiplied by distance, it gives the sizes of land available. It tells us how much nature is feasible in competition for feeding the population:

$$c = \gamma_1 [a - a_r] \quad (31)$$

The angle represents area “ a ” as percentage in segments. Area already becomes recognizable if we assume that in a first round, equal density is pursued at any distance. However, this changes with costs (below). In the first case, the allocation of land is unspecific, though we get a clue about the potential size of interested citizens and lodging of visitors. Second, most citizens have priorities in space and prefer closeness. It is simple logic; then, we see that land with different priorities can either be used for conventional farming which is prime food source and agriculture. This changes intensity in farming nature, which is the second choice. It prevails

$$l_t = l_c + l_n \quad (32)$$

Then, we divide by c and get

$$l_t/c_t = l_c/c_t + l_n/c_t \quad (33)$$

Now there may be a fixed coefficient which describes land and population as density for a rural–urban nexus spread through radius d ; it means that distance matters in intensity:

$$\phi_0 + \phi_1 d_t = l_c/c_t + l_n/c_t \quad (34)$$

The different parts of land use intensity (n of nature and c for conventional) are characterized by preference and cost functions. We work with cost minimization; this reflects the conflict of having higher costs of food procurement, on the one side, and higher ecological costs in case in case of dominant (conventional) food production, on the other side.

However, for the cost of nature provision at the macro-level, i.e. of city planning, a complex background has to be condensed to a functional approach. It should link to local vs. external food supply and shows distance as related to citizens' movements along preferences (see Newburn and Berck [36]). Also, the demand for food may play a role in different situations. But, we can likewise take a current situation as reference and assume that any conventional land reduction translates into more food from outside which in turn has a price (cost as being

non-regional food supply or land price (ibd.)). For the assessment of citizens' preferences for location and WTP, a reference situation of current vs. demanded nature can be established. The empirical background is a transfer and scaling of WTP, but prices matter. To put the WTP into reference, price and quantity are needed (similar to demand for location) and the elasticities in demand must be referenced. At the generic level, we can roughly take a reference WTP “*p*” from a regression as in (35) which provides calibrated WTP per citizen.

$$p = \varpi_{n,1}n_n + \varpi_{n,2}c_n \tag{35}$$

$$p/c_n = \varpi_{n,1}n_n/c_n + \varpi_{n,2} \tag{36}$$

The outline (36) serves as empirical reference (foundation) in a given case. It reflects a status quo derived from revealed debates on willingness to pay. Knowing the deliberations on land involved, it further includes a referenced percentage of nature as land devoted to nature.

$$p/c_n = \varpi_{n,1}\theta_c l_n/c_n + \varpi_{n,2} \tag{37}$$

Intensity of land use per citizen is reflected by Eq. (37) as well, and it enables WTP per citizen. At the generic level, WTP per citizen and land demand per citizen are retrievable.

7.2.2 Movement as WTP

In parallel to the question of the size of city and movement of citizens, referenced by radius, i.e. number of divisions in transport corridors and intensity, we must obtain a depiction of WTP as function. Our first step was a rough outline for WTP on intensity of nature (above). The coefficients in functions (35) and (36) allow a transfer from projects, which gives us “elasticity” of demand [29]. Now we have to translate WTP into land use (request) per citizen. Equation (38) serves for reference of citizens' WTP and will give movement as integrated over demand. (Note from WTP, as demand, welfare parallels integral: Just et al. [33]):

$$WTP_{c_n} = [0.5\varpi_{n,1}\theta_c l_n/c_n + \varpi_{n,2}]l_n/c_n \tag{38}$$

The next step is to introduce transport costs (separately mentioned before). We can follow a similar outline of an exponential function. The idea is getting the optimal density at each point, and it will give us an approximated objective function. In terms of meeting the overall number of citizens, the integral over distances delivers a differential equation which shall fit the distribution of citizens as potential WTP in space. For optimization, we can apply Euler's rule and receive a distribution of citizen “flocking.” Note, it does not include the mean of finance and location-specific preferences; i.e. if excess burdens change, this has to be recognized. Yet, the revised version will enable us to modify citizens' choice. We take derivations as referenced.

Then, the costs of change in land use, i.e. from conventional food provision to nature provision, can be equally appreciated if we condense information from cost benefit analysis of nature provision projects (on cost and methods, [26] and [42].

$$CST_{ff} = [0.5\varpi_{f1}[l_f/c_c - l'_f/c'_c] + \varpi_{f2}][l_f/c_c - l'_f/c'_c] \quad (39)$$

For now, inserting the constraint of land (32–34), we get a function to be optimized for l_n/c_n :

$$\varpi_{f1}[l_f/c_c - l'_f/c'_c] + \varpi_{f2} = \varpi_{n1}\theta_c[\phi_0 + \phi_1d_t - l_c/c_t l_f/c_f] + \varpi_{n2} \quad (40)$$

and we get an “optimal intensity” defined as land use for nature per citizen, yet parallel to food production intensity. With total land and size of the circle, we get the number of citizens or vice versa the land needed for citizens. It goes beyond pure preference. Both nature and citizens can be retrieved from the system boundaries. Note that the size of operation is not determined by the total number of inhabitants, but by WTP (those paying). Also, we obtain a shadow price which offers us the opportunity to ask for public payments and environment apart from private purchases for food. This shadow price may serve as per unit payment reference (like price) for nature as per land use (volume) intensity. It gives a hint as to the potential of finance and is equally useable for the taxation of citizens per unit of nature for grounding coefficients.

Through cost–benefit analysis, outlined so far for getting coefficients in WTP, we again are confronted with the issue of clarifying on excess burden, expenditures, and revenues minus costs of public planning. A suggestion is to take “net benefits,” which means that we take the integral above shadow price (i.e. we deduct the “costs” represented as shadow price from the integral). This applies to both citizens’ welfare (which increases because multifunctionality is delivered: [43] and farmers’ costs (which are land use change based). That is, if costs are partly compensated [44] welfare is with consumers, where, as farmers are already compensated more than necessary, a win–win situation prevails. In that case, the transfer element needs to be eliminated. So, what are costs and benefits for society? Anyway one should attribute payments to participants, how? Additionally, the issue of transportation costs may change the net-benefits and distribution of costs and benefits for participants (farmers and citizens) as well as the pattern for movement and nature share in the landscape. In our case, consumers pay for transport. In the concurrent procedure of establishing citizens’ movements to destinations, farmers are identified as units looking for revenue and cost compensation.

7.2.3 Citizens’ Movement as Spatial Optimization

The next step, in order to obtain citizen movement, is to correlate land use intensity with transport costs. Citizens’ interest is so far expressed as intensity of nature (land under use with nature elements). As simplification we stick to constant intensity and just change the numbers of citizens. Then, travel costs are deducted from net benefits. As we have derived the total net-benefit, we can divide it by the willing citizens, and then, the citizens’ occupation is integrated over distance. In the logic of flow

and stocks, the total number of citizens to be allocated to different distances is $c(d)$ and any distance. Then, the first derivative is (41):

$$C(D) = \int_0^D c(d)d\delta \Leftrightarrow \dot{C} = c(D) \tag{41}$$

For the objective function the scaling matters and by some respecification, we get.

$$W = \int_0^D e^{\mu_{51} \cdot d} [\varpi_{f0}^* - 0.5\varpi_{f1}^* c_f] c_f(d) \tag{42}$$

Finally, transportation costs are specifically assumed as an exponential function $\mu_{60}e^{\mu_{61} \cdot d}$ and we get social welfare:

$$NW = \int_0^D e^{\mu_{51} \cdot d} [\varpi_{f0}^* - 0.5\varpi_{f1}^* c_f(d)] c_f(d) - \mu_{60}e^{\mu_{61} \cdot d} c_f(d) + \lambda(d)[\dot{C}(d) - c(d)] dd \tag{43}$$

The variables $c(d)$ and $\lambda(d)$ are control variables, and $C(d)$ is the state variable. Mathematically, the Euler condition (on math; see [24]) can be applied and we get a first-order differential equation for $c(d)$. The control optimization actually gives three equations:

$$e^{\mu_{51} \cdot d} [\varpi_{f0}^* - \varpi_{f1}^* c_f(d)] - \mu_{60}e^{\mu_{61} \cdot d} - \lambda(d) = 0 \tag{44}$$

$$\dot{\lambda}(d) = 0 \tag{45}$$

$$\dot{C}(d) - c(d) = 0 \tag{46}$$

From these conditions, the first Eq. (44) can again be differentiated and we get

$$\mu_{51}e^{\mu_{51} \cdot d} [\varpi_{f0}^* - \varpi_{f1}^* c_f(d)] + \mu_{51}e^{\mu_{51} \cdot d} \varpi_{f1}^* \dot{c}_f(d) - \mu_{60}^2e^{\mu_{61} \cdot d} - \dot{\lambda}(d) = 0 \tag{47}$$

Since the first differentiation of $d\lambda/dt$ is zero, $c(d)$ remains as differential equation. The system can be outlined as an exponential description of incurred transport costs (charged to citizens) and can systematically be modified by the transport cost; yet, that effectively is the case with a surcharge. For empirical and straightforward work, we condense and get the citizens' movement as a differential equation which gives an exponential result or is another constraint.

$$\dot{c}_f(d) = \mu_{50}^* + \mu_{51}^* c_f(d) + \mu_{53} s(d) + \mu_{54} e^{\mu_{51} \cdot d} \tag{48}$$

This function expressing movement of citizens (32, dependent on spatial surcharge “s”) is our fourth dynamic constraint for system optimization (with instruments below). It is sufficient, as it does contain the grouping of citizen for amenity by payments and costs. However, for that meta-system optimization, we need all stocks and flows being part of the complex constraints.

8 System Optimization

Finally, we will sketch how a regional model can be composed of objectives and (dynamic) constraints. All of them have been identified (being now four). The objective functions were synthesized along stock and flow variables. Also, the mechanism of payment was identified as surcharge on transport costs and land rent fee. A common version is to add up and cancel transfers [33]. The mathematical outline is a combination of stocks and flows, so see relations. We got parts systematically and say: let us look at constraints first and then reckon the objective function. For solving we need a linear differential and quadratic objective system.

8.1 Constraint System

To clarify, we have got four differential equations (in space) composed of four stock variables $R, D, N,$ and D and equally four instrument variables $m_p, m_s, s_c,$ and $n_p,$ to meeting system needs.

$$\begin{bmatrix} \dot{R}(d) \\ \dot{S}(d) \\ \dot{N}(d) \\ \dot{C}(d) \end{bmatrix} = \begin{bmatrix} 11 & & & \\ & & & \\ & & & \\ & & 44 & \end{bmatrix} \begin{bmatrix} R(d) \\ S(d) \\ N(d) \\ C(d) \end{bmatrix} + \begin{bmatrix} 11 & & & \\ & & & \\ & & & \\ & & 44 & \end{bmatrix} \begin{bmatrix} m_p(d) \\ m_p(d) \\ s_c(d) \\ n_p(d) \end{bmatrix} = M_{s1}^1 y_d(d) + M_{d-1}^2 u_g(d) + h_d \tag{49}$$

For constraint (49), we get shadow prices. Shadow price gives a numeration of cost for com-promise of intensity. In this respect, size and composition for individual distances are derived.

8.2 Objective Function

On aggregation we can add the objective functions of citizens and farmers (i.e. presumably so that a win-win situation prevails). Then, social welfare is total welfare minus transport costs and government expenditures and finance must be included. Tax collection and expenditures by and of the government have to be included because they represent transfers or they are to be equalized. For a general appreciation, we again take a version where citizen movement and their per capita interest are distinguished from movements. The whole set-up is captured in and by the overall benefit function (50). The farm side is defined as area under the scheme multiplied with the hectare (area) costs. It says that farmers work along change in revenue plus subsidy because they are paid for land under nature provision multiplied by the coding per hectare.

$$W = \int_o^d \{ \mu_0 e^{\mu^* \delta} U_c(c, f_c(m_s, m_p, s, R, N, S, \delta)) + \Pi_f(n_s(m_s, m_p, s) \cdot f_{f1}(R, N, \delta)) \} d\delta \tag{50}$$

Moreover, as said, expenditure and subsidy as retrieved from tax/fees have to be acknowledged. Finally, we reckon them as a constraint which is not dynamic in space but totalized:

$$\int \{t_a^*(\delta) \cdot \pi \cdot e^{\mu_3 \cdot \delta} \cdot c(\delta) - n(\delta)[\alpha_{120}m_s(\delta) + \alpha_{20}m_p(\delta) - t_a]\}d\delta = 0 \quad (51)$$

Then, we must include the transaction section by element per unit of visit and corresponding land: t_a . It shall be neutral and does not create income for the government which is neutral.

The inclusion of all system elements (objectives, constraints, spatial definitions, variables, etc. per se) is in mathematical terms; it can be accomplished by a Lagrange approach. Further, the outline of objective function (50 and 51) is quadratic due to choice of a functional form. We can most easily take a quadratic approximation, which enables us to get an analytical version such as

$$O_s = y_s'(d)[H_{10} + .5H_{11}y_s(d) + H_{12}u_g(d)] + \lambda_s(d)[A_{11}u_g(d) - A_{12}y_s(d)] \quad (52)$$

Finishing the process of getting the objective functions and constraints mathematically ready as well as constructing it in vector depiction, the model shall fit into the Hamiltonian version for an optimization of a dynamic system [45]. In this optimization, there is the position of a government to establish optimal provision by instruments. Instruments are optimized.

8.3 Optimization

For the above analytics, in our case, a regional system of nature provision along the von Thünen model as segments, a control system prevails in which 4 stock and control variables prevail. The objective function O_{SH} (52) and dynamics (49) can be combined as a Hamilton function (with dynamic constraint), and hence, a control problem can be stated as a rule [24]:

$$O_{s,H} = y_s'(d)[H_{10} + .5H_{11}y_s(d) + H_{12}u_g(d)] + \lambda_s(d)[A_{11}u_g(d) - A_{12}y_s(d)] + \lambda_d(d)[M_{11}y_s(d) - M_{12}u_s(d)] \quad (53)$$

Note the constraint is dynamic in terms of accepting distance, and has a different feature from static optimality conditions. This is expressed by the Hamilton condition, with the first derivative being equal to the dynamics of the state variable, and indeed three conditions prevail.

$$\begin{aligned} \partial O_s / \partial y_s &= H_{10} + H_{11}y_s(d) + H_{12}u_g(d) + A_{12}\lambda_s(d) + M_{11}\lambda_d(d) = \dot{\lambda}_d(d) \\ \partial O_s / \partial u_g &= H_{12}y_s + A_{11}\lambda_s(d) + M_{12}\lambda_d(d) = 0 \end{aligned} \quad (54)$$

$$\partial O_s / \partial \lambda_d = M_{11} y_s(d) - M_{12} u_s(d) = \dot{y}(d)$$

$$\partial O_s / \partial \lambda_s = A_{11} u_g(d) - A_{12} y_s(d) = 0$$

Since we are now in a well-known frame of dynamic optimization, then by taking derivatives (preferably in continuous space), it remains a technical question of stating and calculating conditions for nature provision in space. System (54) can be solved as differential equations for shares of nature at distance “ d .” As is usually done, one can also offer a steady state solution for the periphery. Furthermore, other specifications are possible, for instance a discrete version. In any case, one can technically work equivalently with discrete or continuous control [45] and get stepwise adjusted shares and payment/taxes in space by sequencing them. For example, one can work at a scale of 5 km and have total distances of 500 km given 100 steps.

9 Limitations

A major limitation is that the model does not reckon land quality, only nature quality. Land quality is presumed, at any location, the same, and it is thought that the sole major driving force for spatial landscape shaping is access to nature and intensity in farming. However, intensity in farming also depends on soil quality (sediments, organic matter, etc.), terrain (altitude, slope, micro-climate, etc.), and local cost as well as price conditions (wages, transport cost of inputs, etc.). To a certain extent, such conditions can be partially included if they show systematic movements. For example, cities are frequently located in fertile hotspots and a transect occurs, though it might be not concentric. Similar things happen to prices and density of population along transects. Indeed, they are part of an existing transport system and hence can be investigated. Dynamics of urbanizing and detection of indicators could be used for keys [46].

A further limitation can be seen in simplifying agriculture and its practices as well as options and strategies. Regard to the complexity of farming systems in reality, the model just assumes a version in which distinct responses to payments are included for categories of production. In reality, farming systems and their promotion in landscapes is a matter of a strategic distinction and orientation towards amenity provision and measures. Nature provision seems to be classified by the categories of nature envisioned by the planner or not. In regard, a big problem is the addressing of organism for ESS in special landscapes at location in transects [47]. There is need for linkages. Fine-tuning may help to select for more specific types of nature provision and local embedding; but it is beyond for the moment, here finance matters.

Moreover, network opportunities play a role [48]. It relates to transport and nature. In order to capture the impact of the current situation of a transport network on financing of nature provision and to check current settings vs. improvements (possibly generated by public investment of a city), simulations can be built on linkages of nature prevalence and price performance. What matters is

scarcity in space. An option is the hinterland can be divided into more segments (in the circle), which in turn reflect different investments. What matters is the number of segments because it defines structure and design of rural–urban systems and linkage.

10 Further Aspects for Planning and Policy as well as Summary and Conclusions

Our analysis served to attain insight into optimal use and provision of nature for conservation in a spatial framework. We took the concept of a central city and rural outlay as a basis for a spatial optimization of money and service flows, as exchange. Some farmers received compensation for nature provision; others pay a fee on land rent and citizens' pay by a surcharge to travel costs. In that regard, the modelling shows that the government plays a role as finance collector and stimulant of nature provision for farmers. It does planning, assures finance, and finally it is responsible for payments. Citizens document their willingness to pay by travel costs and farmers their willingness to accept. In that frame, the job of policy is money generation and optimal redistribution in space. However, there might be an additional job of policy. As the analysis so far depends on a given infrastructure and this infrastructure might not be conducive to close the city-nature-provision, we have to reiterate what can be investments of government to stimulate lower transportation costs. Public service depends on the transport networks. These networks can be loose or tight. A tight network (smaller segments) enables lower transport (transaction) costs, and lower transport costs will have impacts on the competitiveness of regional and preferred outlays of nature, especially with respect to the touched issue of integrative provision. By shadow prices, we get an indication of scarcity. Food prices also matter in regards, and the explicitly modelled land rent profile is essential. If prices are high, for instance because horticultural and organic foods are the preferred in regional farming, a region has a different land rent profile. In comparison, long-distance transactions are for staple foods and this shows a preference for distance. How can we capture these aspects and how can competitiveness of integrated nature provision improve in space? Even more specifically, how can we capture the effects and discuss them in modelling? We have to think what simulations are we aiming for.

As an outlook in terms of plea for more networks, a suggestion is seeing transport networks as accumulation along transport lines; we may need more and different lines to work together, for example like in a river system. In this river system, we have mainlines, those of a second order, and tertiary lines which form different nature types. For instance, forests, landscapes with hedges, and extensive farming areas for mixed grazing may matter in networks. Bigger areas are to be covered (at angles of segments) and, segmentwise, more complex interactions evolve. Yet, there might be an operational research answer to an optimal network of different nature types. In this study, we simplified and just checked segments of a potential network, separately. At that level, segments are added and perhaps do not fully cover potentials for nature.

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Declarations

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Authors and Affiliations

Ernst-August Nuppenau¹ 

¹ Department of Agricultural Economics, Justus-Liebig-University, Senckenbergstr. 3, 35390 Giessen, Germany