Challenges in Integrating Ecosystem Services in Sustainable Land Management

Jürg Altwegg, Adrienne Grêt-Regamey

(Jürg Altwegg, ETH Zurich, IRL Institute for Spatial and Landscape Planning, PLUS Planning of Landscape and Urban Systems, Wolfgang-Pauli-Str. 15, HIL H 53.2, CH-8093 Zurich, altwegg@nsl.ethz.ch)

(Prof. Dr. Adrienne Grêt-Regamey, ETH Zurich, IRL Institute for Spatial and Landscape Planning, PLUS Planning of Landscape and Urban Systems, Wolfgang-Pauli-Str. 15, HIL H 51.4, CH-8093 Zurich, gret@nsl.ethz.ch)

1 ABSTRACT

In Switzerland and worldwide, demand for services provided by periurban areas increases as the world's population becomes urban and life style changes. Beside services provided by the built environment, such as transportation and protection infrastructures, employment, and housing, periurban systems provide a wide range of ecosystem services (ES). Even though knowledge on the importance of ES in sustainable decision-making is rapidly growing, it has not yet been included in spatial planning for selecting optimal land development zones. This paper therefore aims at provideing an overview of the challenges involved in integrating ES quantification and valuation in spatial planning for selecting optimal land development zones and gives suggestions for a practicable framework.We present a spatially explicit multicriteria potential analysis model for evaluating land in ecological, economic and social dimensions. This new approach will provide a base for identifying the location of optimal building zones considering long-term social, economic and ecological aspects, which might thus provide support for local and national spatial development strategies.

2 INTRODUCTION

Demand for land is rapidly increasing, especially at locations suitable for agricultural production, recreational activities, and for infrastructure development. In 1980, the Swiss law of spatial planning prescribed a provident usage of land in Switzerland but, despite these political constraints, urban sprawl continues at a rate of $1m^2$ per second (BFS, 2005). Land resources are used for a variety of purposes, which interact and may compete with one another at the expense of the natural environment. This calls for new approaches integrating the services provided by nature into spatial planning.

ES are resources produced by the natural environmental useful to people. The concept distinguishes four different ES categories, namely provisioning, regulating, cultural and supporting services (MA, 2005). Even though knowledge on the importance of services that ecosystems provide is rapidly growing in sustainable decision-making, they have not yet been included in spatial planning for selecting optimal land development zones. This is in part because flows of ES remain poorly characterized at local to regional scales, and their protection has not generally been made a priority (Chan et al., 2006).

Economic, social and environmental values are measured in different units that make a weighting against each other in land use decisions difficult. Economic concerns often remain the most important point for planners. There is a growing consensus that land use management needs to be supported by accurate and detailed information about the spatial distribution of services and the value land can provide to human wellbeing (e.g. Balmford et al., 2002; MA, 2005; Nelson et al., 2009; De Groot, 2009). Human societies must provide space for ecosystem services for a rapidly growing population but land resources are scarce. The pressure of usage on undeveloped land in Switzerland is very high which aggravates this challenge. So it is important at present to do an in-depth analysis about which spatial pattern of ecosystems we want to retain for which functions in future land management. Ecosystems require space and soil of adequate quality to ensure the ability to provide high quality ecosystem services (Brauman and Daily 2008).

In Switzerland and worldwide, the body of spatially explicit data about ES is growing (BFS, 2011; Fisher et al. 2009). Spatially explicit valuation methods for optimal land-use and management decisions are still lacking (Nelson et al., 2009; ICSU et al., 2008). Tools are needed for better communication in the frame of stakeholder participation processes (ICSU et al., 2008).

The challenge is to develop tools to evaluate a bundle of ES and locational-based-criteria (LBC) in a spatially explicit manner in order to compare and analyze their benefits under different land use development goals.

In the next section we will show an overview of the most important challenges existing in integrating ES in sustainable land management, section 3 will present a spatially explicit multicriteria potential analysis model to overcome these problems, section 4 will give a short discussion and outlook about a successful implementation of ecological and social aspects in land management.

3 OVERVIEW OF CHALLENGES

After groundbreaking research about the value of ecosystems in general (e.g. Costanza et al., 1997; Daily, 1997, MA, 2003; MA, 2005), the way forward is now to include the concept of ecosystem services into daily land management decisions. For Switzerland a clear process has to be defined and incorporated into spatial development. However there are several challenges to overcome:

3.1 Define sustainable spatial development

Spatial development is the result of the interaction between multiple stakeholders with different awarenesses and priorities (Neuenschwander et al., 2011). The definition of sustainability thus depends on the respective views of residents, owners, politicians, economic developers or scientists. Furthermore, focusing on a regional scale will lead to different results than focusing on local scale. Thus, since defining sustainable spatial development is very subjective, expected results will strongly depend on who is carrying out this task.

One way to address the question of differing definitions of sustainability is to set goals for certain services in order to reach the desired sustainable land management, and to define the stakeholders and their scale of view.

3.2 Define a criteria set to measure the suitability of land to provide ecosystem services

After the definition of sustainable spatial development, one has to define criteria for the implementation of the goals formulated by the stakeholders. The suitability of land to support the provision of certain services or reaching certain goals has to be quantified. The challenge here is to define a representative criterion set allowing to measure such suitability with criteria quantified based on todays existing geocoding databases, newly created criteria and even collection of new data. For each study area, a new criteria set has to be defined minimizing computation effort (Figure 1).

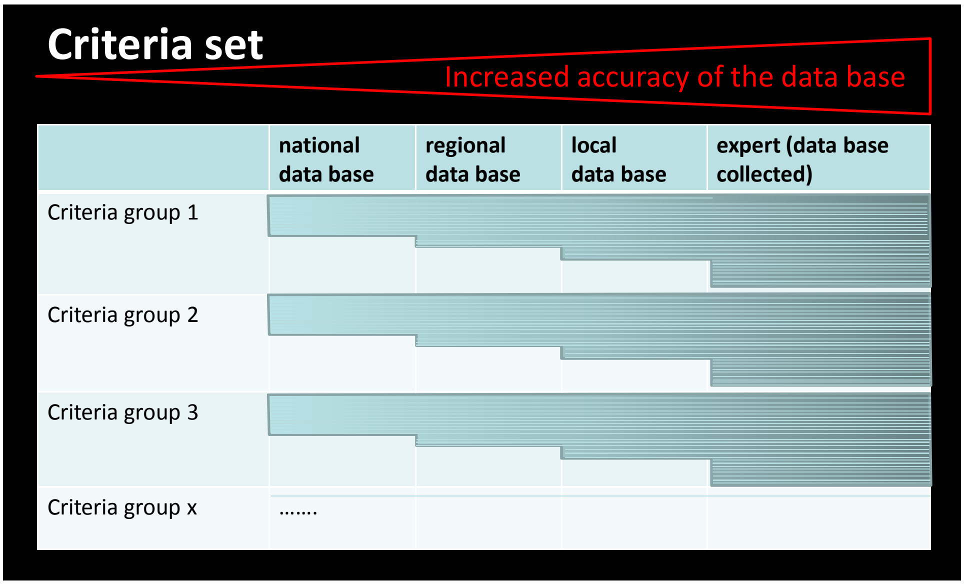

Fig. 1: Criteria set

3.3 Quantification of the criteria

In order to include ES as well as LBC into spatial planning, it is very important to quantify and value them. Depending on the availability of the data and the spatial and temporal scales of assessments different methods are available for quantifying and mapping ES; see Hermann et al. (2011). The biggest challenge here is to do so in a spatially explicit manner, especially on a for land use decisions requested scale of one hectare or even smaller. Some ES can be quantifyied directly based on land cover information using general assumptions from literature reviews. However, a proper quantification of ES requires additional data beyond land cover. One of the solutions to this problem is process-based modelling, even though such models also have their limitations. Process-based models are either detailed or simplified mathematical models, which represent the physical or biological processes based on information such as soil characteristics, geology, topography, land cover etc. Scientific modellers developed simplified spatially explicit process-based models to quantify ES: e.g. InVEST (Nelson et al., 2009); ARIES (Villa et al., 2007), FRAGSTAT (McGarigal et al., 1994), Grêt-Regamey et al. (2008).

The challenge here is to reach an accurate quantification of ES on a hectare raster or smaller, clearly differing between functions, services or benefits, as well as defining the time horizon of the assessment.

3.4 Normalization

Economic, social or environmental values are measured in different units. To compare and sum up services of all categories the different values have to be brought to a common scale.

A solution is to calculate monetary values for the considered services. Most of the ES are however not marketed and therefore do not command market price. Although different methods have been developed to calculate monetary values for ES, for an overview see Christie et al. (2008), the economic valuation of ES in a spatially explicit manner is still a big challenge.

Another solution is to quantify every service in his own unit and normalize them between 0 and 1.

3.5 Definition of constraints to reach goals

Stakholders have to set goals for certain services to implement and achieve sustainable spatial development. One has to define constraints to reach goals.

3.6 Priorisation of criteria and goals through stakeholder weighting

The model needs to take into account locally different weightings through stakeholders preferences. Therefore the priorisation of ES and LBC needs to be solved in a participatory process with experts and stakeholders from different fields like specialists from environmental institutions on a national scale, and public authorities on a regional scale as well as public authorities from the villages on local scale.

3.7 Measure trade-offs between the provision of ES and economic development

The principles of sustainable development confront land planners often with a paradox of two apparently contradictory objectives: nature conservation and economic development (vanLier, 1998).

Rodriguez et al. (2006) classified trade-offs in ES along three axes: spatial scale, temporal scale, and reversibility. Spatial scale refers to whether the effects of the trade-off are felt locally or at a distant location. Temporal scale refers to whether the effects take place relatively rapidly or slowly. Reversibility expresses the likelihood that the disturbed ES may return to its original state if the perturbation ceases.

Typical trade-offs are for example between:

- food production and accessibility
- noise and accessibility
- conservation and closeness to existing infrastructure etc

The challenge for planners is to show the trade-offs for sustainable development between ecological impacts and economic growth. The model helps to show trade-offs and support the results with facts.

4 A SPATIALLY EXPLICIT MULTICRITERIA POTENTIAL ANALYSIS MODEL

In many spatial development problems, the decision maker likes to pursue more than one target or consider more than one factor in solving a problem. The multicriteria decision analysis (MCDA) allows to combine these different and often conflicting factors and to come to a compromise in a transparent process (Malczewski 1999).

We us a linear programming (LP) approach to identify the optimal distribution of undeveloped building zones by:

- Minimizing impacts on the provision of ES
- Maximizing economic development

We integrate all the information into a MCDA. Therefore we develop a GIS (Geographic Information System)-based modelling platform to analyze the potential of land for settlement development. The methodical framework (see Figure 2) showes the different steps taken in the process.

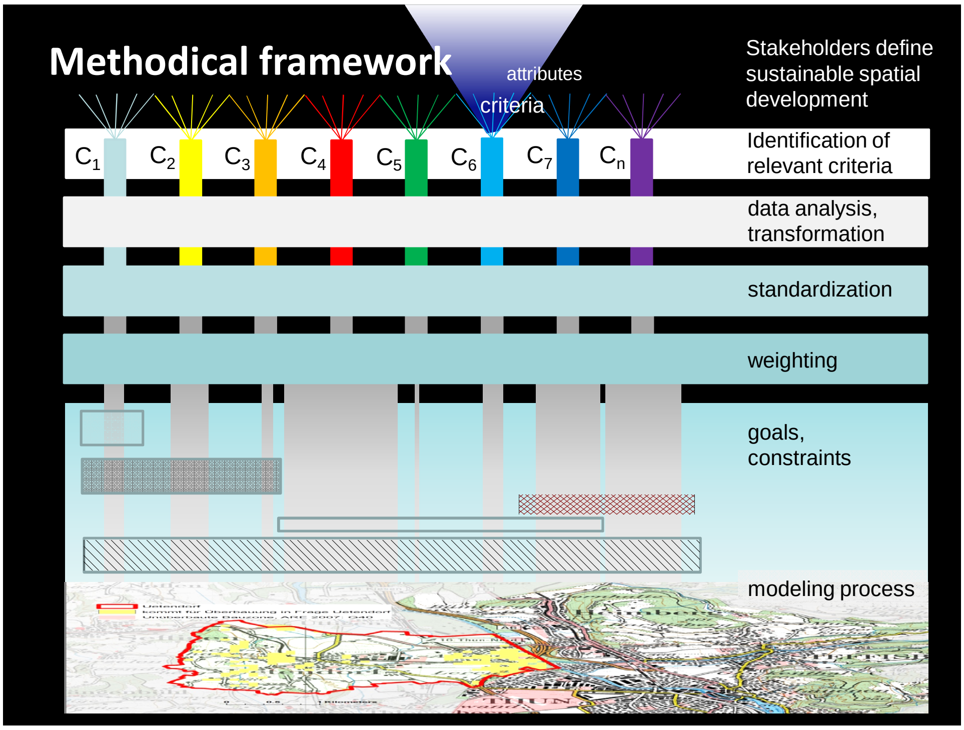

Fig. 2: Methodical framework of the spatially explicit multicriteria potential analysis model.

The result of the LP process is compared with the current situation and optimal trade-offs presented.

5 CONCLUSION

With the Swiss population predicted to grow and the changing lifestyle, it is more crucial than ever that Switzerland's remaining resources are managed in a sustainable way.

Since the Millenium Assessment, efforts to include knowledge about the importance of the ecosystem in sustainable spatial planning have increased. It is now widely recognized that nature conservation does not necessarily pose a trade-off between the "environment" and "development" (De Groot, 2010). Investments in sustainable land management are increasingly seen as a "win-win situation" which generates ecological, social and economic capital as well as human well-being. Land management decisions usually relate to spatially oriented issues. To receive support for adequate problems, information on the spatial distributions of ES and LBS and resulting trade-offs through well planed spatial development are needed.

The multicriteria model presented in this paper allows the integration of economic, ecological and social aspects in spatial planning and facilitates such a process, which is a central concern of sustainable spatial development. The integration of GIS-data and a stakeholder weighting in the modelling approach allows producing spatially explicit scenarios, which can be discussed in spatial and land use planning. The model supports participation in planning processes. A new and challenging issue is to incorporate a mix of ES and LBC in one methodical framework and reduce the values to a common denominator so that they can be equally compared and be accounted for in land management planning and decision making in Switzerland.

Finally, our approach is another step into translating todays wide acceptance for environmental protection into new management tools for sustainable spatial planning processes.

6 REFERENCES

Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R.E., Jenkins, M., Jefferiss, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S., Paavola, J., Rayment, M., Rosendo, S., Roughgarden, J., Trumper, K., Turner, R.K., 2002: Ecology – Economic reasons for conserving wild nature. Science, 297 (5583), 950-953

BFS, 2005: Arealstatistik Schweiz, Zahlen, Fakten, Analysen, Bern.

Boyd, J. and Banzhaf, S. 2007: What are ecosystem services? The need for standardized environmental accounting units. In: Ecological Economics, Vol. 63, Issue 2-3, pp. 616-626. Ecological Economics of Coastal Disasters - Coastal Disasters Special Section.

Brauman, K. and Daily, G. 2008: Ecosystem Services. In: Jorgensen, S. E. and Fath, B., editors, Encyclopedia of Ecology, pp. 1148-1154. Academic Press, Oxford.

Chan, K. M.A., Shaw M. R., Cameron, D. R., Underwood, E. C., Daily, G. C. 2006: Conservation planning for ecosystem services. 4(11): e379. DOI: 10.1371/journal.pbio.0040379.

Christie, M., Fazey, I., Cooper, R., Hyde, T., Deri, A., Hughes, L., Bush, G., Brander, L., Nahman, A., de Lange, W., Reyers, B., 2008. An Evaluation of Economic and Non-Economic Techniques for Assessing the Importance of Biodiversity to People in Developing Countries. Defra, London.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997: The value of the world's ecosystem services and natural capital. Nature 387, 253–260.

Daily, G.C. (Ed.), 1997: Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, DC, 392 pp.

De Groot, R., Alkemade, R., Braat, L., Hein, L., and Willemen, L. 2010: Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. In: Ecological Complexity, Vol. 7, pp. 260-272.

De Groot, R.S.; Alkemade, R.; Braat, L.; Hein, L.; Willemen, L., 2009: Challenges in integrating the concept of ecosys-tem services and values in landscape planning, management and decision making. Ecol. Complex. AIP.

Fisher, B., Turner, R. K., and Morling, P. 2009: Defining and classifying ecosystem services for decision making. In: Ecological Economics, Vol. 68, Issue 3, pp. 643-653.

Grêt-Regamey, A., 2008: Spatially explicit valuation of ecosystem goods and services in the Alps as a support tool for regional decision making. ETH. doi:10.3929/ethz-a-005410762.

Hermann, A., Schleifer, S., Wrbka, T. 2011: The Concept of Ecosystem Services Regarding Landscape Research: A Review. Living Rev. Landscape Res., 5,(2011), 1.

ICSU, UNESCO, UNU, 2008: Ecosystem Change and Human Wellbeing. Research and Monitoring. Report, ICSU, UNESCO and UNU, Paris.

MA, 2005: Ecosystems and Human Well-Being: Current State and Trends. Island Press, Washington, DC.

MA, 2003: Ecosystems and Human Well-being: A Framework for Assessment. Island Press, Washington.

MALCZEWSKI, J. 1999: GIS and multicriteria decision analysis. John Wiley & Sons, Inc.

McGarigal, K., Marks, B.J., 1994: FRAGSTATS—spatial pattern analysis program for quantifying landscape structure, version 2. Forest Science Department. Oregon States University, 67pp. +3 appendices.

Nelson E., Mendoza, G., Regetz, J., Polasky S., Tallis, H., Cameron, R., MA Chan K., C Daily G., Goldstein, J., M Kareiva, P., Lonsdorf, E., Naidoo, R., Ricketts, T., and Shaw, R., 2009: Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. Frontiers in Ecology and the Environment: Vol. 7, No. 1.

Neuenschwander, N., Wissen Hayek, U., Grêt-Regamey, A. (2011): Participatory modelling platform for generating procedural 3D urban development patterns taking into account the value of ecosystem services. In: Schrenk, M., REAL CORP 2011 „Change for Stability: Lifecycles of Cities and Regions“, Peer-reviewed Proceedings/Tagungsband, Essen, Germany.

Rodríguez, J. P., Beard, T. D., Bennett, E. M., Cumming, G. S., Cork, S., Agard, J., Dobson, A. P., Peterson, G. D., 2006: Trade-offs across space, time, and ecosystem services. Ecology and Society 11(1): 28.

VanLier, H., 1998: The role of land-use planning in sustainable rural systems. Landscape and Urban Plan., 41, 83-91.

Villa, F., Athanasiadis, I.N., Rizzoli, A.E., 2007: Modelling with knowledge: a review of emerging semantic approaches to environmental modeling. Environ. Modell. Software 24 (5), 577–587.