

3.1 GENERAL INFORMATION ABOUT THE PROJECT \_B2\_

3.1.1 Title:  
**Resilience of SES from a Resource-Economics Perspective**

3.1.2 Research Areas:  
**Resource and Institutional Economics**

3.1.3 Principal Investigators:

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Do the principal investigators hold permanent positions?

(X) yes ( ) No, limited until \_\_\_\_\_  
( ) further employment is planned until \_\_\_\_\_

3.1.4 The project includes:

- research on human subjects ( ) yes (X) no
- clinical studies in somatic gene therapy ( ) yes (X) no
- experiments involving animals ( ) yes (X) no
- experiments involving recombinant DNA ( ) yes (X) no
- research with human embryonic stem cells ( ) yes (X) no
- legal authorisation has been obtained ( ) yes ( ) no

3.1.5 REQUESTED FUNDING


### 3.2 SUMMARY / ZUSAMMENFASSUNG

#### Zusammenfassung

Massive Transformationen von Nutzergruppen und Landnutzungswandel kennzeichnen heute die sozial-ökologischen Dynamiken in Savannenlandschaften des südlichen und östlichen Afrika. Sich verändernde Marktbedingungen und institutionelle Dynamiken – etwa durch Veränderung von Zugangsrechten – treiben diese Veränderungen wesentlich an. Das Teilprojekt Ressourcenökonomik wird seinen Schwerpunkt auf die Verknüpfung von natur- und sozialwissenschaftlicher Forschung legen, indem die Interaktionen zwischen Ökosystemen und deren produktive Ressourcen sowie den menschlichen Gemeinschaften, die diese Ressourcen nutzen, modelliert werden sollen. Die wichtigsten Analysewerkzeuge werden die numerische Simulation bio-ökonomischer Prozesse sowie die empirische Analyse von relevanten institutionellen Regelungen zur Ressourcennutzung sein. Das Teilprojekt wird in Naivasha/Kenya und Thaba Nchu/Südafrika arbeiten.

#### Short Summary

Massive transformation of user groups and land use change characterise today's social-ecological dynamics in the savannahs of Eastern and Southern Africa. Changing populations and market environments as well as institutional dynamics – for instance altered rights of access to resources – are driving these changes. Resource economics will concentrate on strengthening the link between natural and social sciences by modelling the interaction between ecosystems, the resources that these ecosystems incorporate, and the human communities using and managing these resources in the described SES. The main analytical tools will be bio-economic numerical simulation and the empirical analysis of the formal and informal institutional designs that are relevant for the regulation of resource use. The sub-project will work in Naivasha/Kenya and Thaba Nchu/South Africa.

#### Long Summary

As in almost all ecosystems that serve as a productive resource base for human societies, decisions on resource use in African savannahs are driven to a large extent by economic considerations and pressures. The resulting 'resource-economic behaviour' is determined by knowledge about ecological processes, preferences of individuals and groups, and by the institutional framework governing action and interaction of individuals and groups. Microeconomic theory presupposes that preferences drive economic behaviour in a sense that actors maximise their individual utility. On the other hand, according to the New Institutional Economics (NIE), institutions defined as formal and informal rules of human behaviour and interaction shape the set of choices available to individuals (North 1990). A central hypothesis to be investigated in this context is that the *resilience* or *robustness* of an SES crucially depends on the nature, flexibility, and cross-scale dynamics of the institutions that govern the economic behaviour of members of the relevant actors in a dynamic environment. The *transformation* of an SES – as a consequence of the degradation of its resource base through internal (e.g. population pressure) or external driving forces (climate change, economic growth) – involves an adaptation of both

institutions and the behaviour of individuals within the SES to cope with the effects of driving forces.

The sub-project will carry out investigations in two research sites, the Lake Naivasha region in Kenya (see also sub-projects A2, B1), and in grasslands in South Africa (Thaba Nchu, Mangaung Municipality, see also sub-projects A1, A3, and C1). B2 will directly cooperate with A1 on the emergence of institutions in the context of land reform in South Africa's arid savannas in the Northwestern Province (Kuruman case study). Historical research in C1 and B1 (counterpart project) will directly add to the knowledge base of B2 on institutional stability and change. C2 will inform B2 on the medialisation of conservationist institutions in the Naivasha context. Two analytical tools will be used:

(1) Institutional analysis is the basis for an understanding of the economic significance of various rules for resource use. The most important institutions relevant from the perspective of resource economics are the formal and informal systems of access-and-use rights for land and water resources. Such institutions emanate from various scales in which local systems are embedded, be it international agreements (e.g. the RAMSAR status), national legislation (e.g. land reform programme in South Africa) or local institutions (e.g. customary law for communal pastures in South Africa or rules and regulations of the Lake Naivasha Riparian Association). In most cases institutional structures intersect, and habitually actors may refer to diverse institutions when attempting to tackle challenges in resource use. Moreover, institutions providing or inhibiting effective risk management will be investigated, both informal ones such as traditions relevant for food or production and new, market-oriented institutions such as credit markets or insurance. A special focus will be given to the functioning of existing user or community organisations in two project regions, their mutual relations, and their cross-scale interactions with national and international organisations. In the Kenyan site, for instance, research on the influence of institutions on the acceptance of use restrictions will start from the management plan for the Naivasha catchment and will then focus on the factors influencing the acceptance of rules by different user groups. These preferences not only drive ecologically relevant economic behaviour, but also provide the basis for assessing the robustness of the SES and eventually (in later phases of the RU) for modelling feedbacks from natural resource management to institutional change. In the case of the South African sites, institutional change as a consequence of post-apartheid land reforms will be investigated in particular.

(2) Bio-economic modelling in a dynamic framework will enable the simulation of various driving forces on the social, economic, and ecological buffer capacity of the SES. The modelling approach addresses both land and water use, incorporating a spatially explicit multi-agent framework when appropriate. This will enable a broad variety of participating disciplines to test and simulate propositions on the robustness of the SES in an integrated numerical framework. One bio-economic simulation model will be established for Naivasha/Kenya with a focus on wetland use, the other model will represent the interaction of large farms and smallholders in the area surrounding Thaba Nchu/South Africa. Most importantly, bio-economic modelling will incorporate the results from institutional analysis. Institutions and the actors steering and changing them will be quantitatively formalised and represented in dynamic simulation models, involving transaction costs and specific objective functions. The ultimate goal is to simulate the institutional choices of resource

users and the dynamic consequences of these choices on resource use and thus the resilience of the SES in question.

### 3.3 STARTING POINT OF THE PROJECT

Resource economics seek to link ecology and social sciences by assuming that economic behaviour relevant for natural resource use is driven by individual and group preferences, knowledge, and the institutional framework governing an SES. Preferences of individuals or groups represent utility trade-offs between consumption of different goods at different points in time, alternative levels and modes of production, and between institutional environments such as, for instance, the handling of use rights on resources. Relevant knowledge of actors and groups covers their understanding of ecological processes, but also the technologies available to exploit the resources in a more or less efficient and sustainable way. Such kind of knowledge is differently distributed in heterogeneous groups of resource users, and basic ideas e.g. on degradation may differ from group to group and within groups. The institutional framework, finally, governs action and interaction of individuals and groups. Microeconomic theory presupposes that preferences drive economic behaviour in a sense that actors maximise their individual utility. More specifically, resource economics presupposes that people search for the optimal allocation of their productive resources in order to satisfy their needs and maximise their overall benefit, given the insight of actors into a) the technological constraints determining the productivity of the resources, and b) the additional limitations of their choice sets represented by institutional arrangements.

According to the New Institutional Economics (NIE), institutions defined as formal and informal rules of human behaviour and interaction shape the set of choices available to individuals (North 1990). A central hypothesis and thus starting point of this sub-project is that the *resilience* or *robustness* (Anderies et al. 2004) of an SES crucially depends on the nature *and* the suitability and flexibility of institutions established at different scales and decision levels (local, national, international, see Adger et al. 2006, Berkes 2008) that govern the economic behaviour of members of the relevant actors in a dynamic environment. The *transformation* of an SES – as a consequence of the degradation of its resource base through internal (e.g. population pressure) or external driving forces (climate change, economic growth) – involves an adaptation of both institutions and behaviour of individuals within the SES to cope with the effects of driving forces.

#### *The Kenyan case*

Naivasha can be seen as a place where rapid economic growth, population growth mainly due to immigration and a deterioration of natural resources (e.g. decreasing lake level, pollution) were followed by manifold institutional changes at different organisation scales concerning e.g. access to resources. Since the 1990s water consuming cut-flower industries were settling along the lake's shoreline, employing some 25.000 workers directly and irrigating about 4.000 ha with lake, river or groundwater. This led to falling lake levels and other environmental problems (see sub-project A2, B1). The Lake Naivasha Riparian association (LNRA), originally founded in the 1920ies by white farmers in order to manage the riparian land, now started to engage for a more sustainable resource use. The asso-

ciation became an advocate for the concerns of all owners of land riparian to the lake Naivasha ranging from smallholders to large farmers. In 1995 Lake Naivasha became a RAMSAR site and the management plan elaborated by the LNRA was awarded the 1999 RAMSAR price. The recognition that went with this price was crucial in making Kenyan authorities adopt the management plan as a legislative basis for action, and to push the association of the flower producers (Lake Naivasha Growers Group) to adjust earlier positions and to cooperate within the lake basin management.

By now the population around the lake has increased from 50.000 in the 1970s to almost 300.000, main feeding rivers have stopped flowing or are diverted to other valleys and the threat that the lake as well as the flower industry might be dying in the near future seems very real. In this situation, government as well as private associations (Kenya Water Resources Management Authority WARMA, the municipal council, the lake Naivasha Growers associations, the lake Naivasha Water Users Association) try to get urgent measures implemented which also have to include catchment areas. The Water Trust fund operated by WARMA encourages the foundation of water user associations in the catchment areas and finances conservation measures there. On the other hand, local authorities have asked the national government unsuccessfully to consider revoking licences of farms that do not adhere to extraction regulations.

The described process is a good example of the increasing significance of cross-scale dynamics that gain relevance for common resource management in SES world-wide: On the one hand local stakeholders (like the LNRA) initiate innovations in resource management, and by teaming up with a global institution (UNDP and the RAMSAR instrument) gain the support of national Kenyan institutions. On the other hand local authorities are hindered at implementing their management plan by the national government with its short term interest in the flower industry. From the point of view of political economy, the presence of these cross-scale dynamics can dramatically change the economic incentives of actors and decision makers on various scales when it comes to resource use, management, and the adoption of institutional innovations. In Kenya, sub-project B2 will focus on relevant institutional arrangements on different levels with a focus on the local level, and look at the (transaction) costs and benefits of alternative settings, in order to eventually incorporate alternative institutional designs into a bio-economic simulation model., and with B1 on the emergence of institutions governing the riparian land-use strategies (Naivasha and Furthermore, C2 will inform B2 on the medialisation of conservationist institutions in the Naivasha context.

### *The South-African case*

The area surrounding Thaba Nchu is a semi-arid grassland landscape. Parts of it are dominated by large-scale farms operated by descendents of European settlers. Indigenous smallholders dwell on communal lands in the area of Thaba Nchu and on a number of resettlement projects brought about by South Africa's ambitious land reform programs, practising subsistence production of crops (maize, sorghum) and livestock on communal pastures. Moreover, indigenous farm workers live on large commercial farms as so-called labour tenants. As a consequence of land reforms initiated at the national level (restitution, redistribution, tenure reform, and legislation to prevent the eviction of labour tenants)

economic preconditions and the local institutional environment facing large and small farms as well as farmers and labour tenants have been subject to rapid change since the end of apartheid. While competing particularly for land, economically, legally, and sometimes violently, different farm types are also likely to increasingly cooperate in labour and capital markets, as for instance by bartering casual labour for machinery services. Whether cooperation or conflict will dominate the relations between farm types and the ethnic groups involved is a common research question across disciplines in the RU. B2 will closely cooperate on this question with the social and cultural anthropology part of subproject A1, analysing the subject from an economic perspective. As to the ecological basis of farming systems in the area, B2 will use the results of soil (A1) as well as cropping and grassland (A3) specialists in the RU to assess the economic productivity of land resources. For instance, soil scientists claim that soils in the region have been degrading over the last hundred years with respect to vegetation cover and organic matter (see subproject A1), partly due to the fact that the rough climate does not allow the cultivation of leguminous crops such as clover. Cropping on degraded land tends to be abandoned in favour of grazing of cattle as soon as a certain degree of profitability cannot be achieved any longer. Grazing by large ruminants, however, may lead to further degradation of grassland.

The ultimate goal of this sub-project is to numerically simulate the complex interaction between resources, resource users with their preferences, as well as choice restricting technologies and institutions. The quantitative tool will allow assessing the resilience of the SES in the context of changing internal and external driving forces and serving as a link between natural and social sciences involved in the RU. The following section gives an overview on the state of the art in the area of quantitative modelling such SES.

### 3.3.1 STATE OF THE ART

Economic models of common pool resources have just started to incorporate the dynamic behaviour of the ecosystems that constitute the resource. Ecologists such as Holling (1973) introduced the term 'resilience' of an ecosystem to characterise its stability against perturbations. Applied to an SES, higher resilience of the ecological part of the SES often means that human actors can rely more safely on a resilient resource during times of perturbations, particularly if the perturbations are caused by human resource use itself, e.g. overgrazing or mishandling of soils. Modelling the interactions of ecosystems and human resource users has been addressed by 'bio-economics', most prominently perhaps in the area of marine resources (see Clark 2005). One of the main challenges that are faced by those models is the modelling of institutions and their changes. For the case study in Naivasha, for instance, the challenge is to model the institutions governing a common pool resource represented by the lake and its catchment and environs.

In his seminal article from 1968, Hardin investigated the stability of a stylised pastoralist SES with an emphasis on 'commons' as 'common pool resources' (CPR). His conclusion that improperly defined property rights under this special institutional arrangement eventually lead to over-use and deterioration of the natural resource may rightly be termed as the starting point of modern resource and ecological economics. As the conclusions from his article appeared to be over-pessimistic and did not fit many apparently stable SES in the real world, the management of common property or common pool resources has

become one of the most important applications of institutional analysis. Ostrom (1990) concludes from a review of numerous case studies on self-governed common property resources that successful common pool regimes are characterised by the following design principles:

1. The boundaries of the resource system and the use rights are clearly defined.
2. There is a proportional equivalence between benefits and costs of resource use.
3. Users subject to rules of resource use are represented in the group who can modify the rules.
4. Resources and their use are monitored; monitoring agents are accountable to users.
5. Violations of rules are sanctioned depending on the seriousness of the violation.
6. Users or their representatives have access to low-cost conflict-resolution mechanisms.
7. Users have the right to organise and devise their own institutions.
8. If resources are part of larger systems, their use is organised in multiple layers of nested enterprises.

Even though these design principles offer a useful guideline for predicting the stability of existing user organisations, they are not broad enough to capture the situation in SESs that do not include all users in one organisation. Moreover, the above design principles mainly fit SESs that are not exposed to major internal or external shocks. Their institutional characteristics are for the most part aimed at dealing with the inherent problems of common pool resources, e.g. the divergence of private and social costs and benefits. Such an institutional design may reach its limits when the SES is exposed to changes of driving forces. There may be shocks to SESs which occur in an unforeseen magnitude (immigrants who are not committed to existing rules, fundamental changes in relative prices of outputs and inputs) that have not been 'foreseen' in the institutional design (e.g. climate change or expansion of invasive species). The uncertainties originating from such external shocks, particularly when they threaten the SES to collapse (Abel et al. 2006), represent additional challenges to the design of the institutional framework of an SES and may necessitate important institutional changes. The emergence and the change of common pool regimes following changes in the environment cannot be addressed by the above framework. Moreover, the above framework has been derived from the observation of smaller, closed collectives of resource users, thus neglecting the co-management of resources across different levels of decision making. Co-management across scales means that local, regional, national, and increasingly international organisations are involved in the regulation of SES.

As the stability of an SES is also determined by the human institutions governing resource use, investigating the 'resilience of institutions' becomes necessary to assess the resilience of the entire SES. In that context, Anderies et al. (2004) point out that the term resilience in its initial meaning is rather oriented at evolved, self-organised systems, whereas the authors suggest to use the term robustness to describe and measure characteristics of an SES that are at least partly designed consciously, and here in particular the capacity to preserve certain desired characteristics (from a human perspective) during the adaptation to extraordinary perturbations and shocks both from within or from outside the system. Dynamic adaptation of designed systems is likely to occur much faster than in unconsciously evolved systems.

As a starting point for a dynamic analysis Anderies et al. (2004) suggest a theoretical framework that is based on the distinction between operational processes (e.g. harvesting

decisions of the resource users) and collective-choice processes (political decisions on the institutional framework and the common physical infrastructure) that have to be analysed simultaneously to assess the robustness of an SES. While resource users are the representative agents in operational processes, infrastructure providers are the representative agents in public-choice processes. Both groups may overlap, particularly when infrastructure providers are recruited from the group of resource users. On the other hand, infrastructure providers can be completely separated from resource users, and may not even be accountable to them in a sense that resource users have no means to influence the behaviour of infrastructure providers from higher organisational levels, e.g. regional or national government bodies. Each organisational level involved in these cross-scale dynamics may possibly promote its own preferred institutional regulation scheme. For example, while water user groups may prefer non-monetary settlement of transactions and conflicts regarding the use of a common water resource, government agencies may try to impose different methods of measurement of use, formal water pricing, and the establishment of markets for water use rights. Resource users in SES are thus often confronted with multiple institutions, possibly allowing them to choose between arrangements. Adger et al. (2006) argue that the distribution of power across scales and the transaction costs of institutional arrangements are the most important determinants of institutional choice. It may be added that also the effectiveness of an institutional arrangement regarding its inherent goals, and particularly its economic efficiency in comparison with other alternatives will impact on choice of individual users and user groups.

Anderies et al. point out that this theoretical framework has to be further developed into more formal theoretical and applied models. We suggest moving in this direction in two steps. One step is to look into the effect of institutions on the behaviour of the resource users. The other one is to work on a more precise characterisation of the providers' behavioural functions and assess their impact on the resilience of SESs by means of simulation models.

Concerning the first step, we suggest addressing the relation of the behaviour of resource users and the (institutional) infrastructure provided. There is evidence that the success of any conservation effort depends on the acceptance of local users (see for example Meinzen-Dick & Di Gregorio 2004; Wiggins et al. 2004, Trakolis 2001). This relates to the distribution of property rights, that is, to the different restrictions that local communities have to face to conserve the resource in question. Comparing satisfaction indices with behaviour is one way to analyse this relation. Satisfaction indices not only allow to evaluate overall satisfaction levels, but also provide insight into the importance of different components (see Guthiga et al. 2008).

Another strand of literature points out the relation of social capital and environmental protection (see for example Lehtonen 2004, Pretty & Ward 2001) with Paavola (2005) emphasizing possibilities to enhance the resilience of an SES by using especially so called bridging and linking capital that helps build up resource user associations and identify and implement management rules. The theoretical and empirical literature available now allows creating hypotheses on the relation of different kinds of social capital and behaviour. As is well known, difficulties in measuring social capital are remarkable, but there are enough empirical investigations to allow some tentative testing of these hy-

potheses. For an overview of possibilities to measure different forms of social capital with ego-centred network studies see Dufhues and Buchenrieder (2006).

Concerning the second step-characterisation of the providers' behavioural functions and their impact in simulation models – we suggest implementing the resource user – infrastructure provider framework into numerical simulation models for two different sites. The current state of ecological-economic modelling is addressed in the following.

As already mentioned above, the interaction between renewable resources, ecosystem dynamics, and resource users has been extensively analysed in recent decades. Based on the theoretical work by Chayanov (1966), Boserup (1965), Binswanger & Rosenzweig (1986) and others, a new class of bio-economic models has emerged which addresses the interaction of subsistence agriculture and natural resource management for developing countries (Holden & Shiferaw 2004). These numerical simulation models are mainly based on linear or non-linear mathematical programming methods to simulate individual farms or aggregate farm sectors within regional economies (see Hazell & Norton 1985; Janssen & Van Ittersum 2007). The distinctive feature of bio-economic models is that they capture the mutual feedback processes of human decisions and natural processes in SES by incorporating endogenous productivity functions for natural resources. This comprises, on the one hand, the impact of management decisions (e.g. use of fertiliser, conservation measures) on agronomic and ecological processes (e.g. yield response but also formation of organic matter in soils). On the other hand, changes in resource productivity due to ecological processes and their impact on management decisions can also be represented by such models, when for example soil degradation induces farmers to adopt an intensification of production (e.g. use of fertiliser) or conservation measures. Barbier & Bergeron (2001) use a recursive-dynamic model for a small river basin in Honduras with a five-year planning horizon. Resource endowment in this model comprises labour, livestock, trees, land of different quality, and ploughs as machine capital. As a biophysical component, yield response is simulated using the EPIC-model.

Barbier & Hazell (2000) concentrate on the interaction between croppers and transhumant herders in a village in Niger, and take the influence of risk from drought on farmer's decisions explicitly into account. Here, modelling the productivity of fallow and savannahs as pasture for livestock as a function of grazing intensity complements endogenous productivity of cropland. Similar models have been used by Okumu et al. (2004), and Holden & Shiferaw (2004). Aspects of decline and collapse are dealt with by researchers investigating so-called 'poverty-traps' using bio-economic simulation models (see Barrett 2003), as the interaction of resource degradation and human development can take completely different paths. SESs may be characterised by multiple equilibria: poverty may coexist with sustainable resource use over long periods, but communities may also be caught in 'poverty traps' characterised by a deteriorating resource base. Economic growth may happen either with or without degrading the resource base of the SES, largely depending on the economic activities that are driving growth. Finally, ecosystems may suffer while people in the SES manage to escape poverty, but eventually people reach a level of wealth that has raised their willingness to pay for resource and nature preservation to sufficient levels such that the ecosystem functions of the SES may be restored or even improved to unknown levels so far.

These bio-economic modelling approaches have in common that they are confined to relatively small areas (villages, small regions, river basins), implying that prices for products and labour are usually exogenous, even though many determinants of resource use are closely related to labour markets and the net trade position of farm households. As to their regional scale, the mentioned simulation models fit well into the scale of the SES case studies suggested in this proposal. The dynamic properties of these models facilitate long-term simulations and thus the investigation of adjustment processes following shocks and disturbances.

While the bio-economic models described so far are dealing with the concept of one aggregate, so-called 'representative' agent per scale unit or do not explicitly capture the interaction between individual actors as governed by institutions, further disaggregation and extension of these concepts may be desirable in our context. Multi-agent systems (MAS) are computationally intensive systems able to simulate the complex interactions of behavioural entities and explicit spatial locations. For economic applications, the term Agent-based Computational Economics (ACE) is used, defined by Tesfatsion (2006) as "[...] the computational study of economic processes modelled as dynamic systems of interacting agents [...]", where 'agents' refer to data and behavioural methods representing an 'entity' that constitutes part of a computationally constructed world. Tesfatsion names examples for human agents such as individuals (e.g. consumers), social groups (households or firms), institutions (markets, regulatory systems), but also non-human agents such as biological or physical entities are possible. Most interestingly, agents can be composed of other agents, thus permitting hierarchical constructs.

According to Axelrod and Tesfatsion (2006), MAS are well suited for studying for systems characterised by a) interacting agents, and b) emergence in the sense that interactions between agents result in system-wide properties or behaviour that cannot be deduced from the aggregated properties or behaviour of the constituting agents. A prominent example for emergent properties of multi-agent systems is the work of Schelling (1978) who showed how a high degree of race-based residential segregation can emerge from the location choices of relatively tolerant individuals. Other important motivations for MAS relevant in the context of this research proposal are:

- Modelling the spatially explicit behaviour of resource users in heterogeneous landscapes is severely constrained in models that assume only one (perhaps immobile) representative agent per spatial unit. Sugden (1989) developed one of the first toy MAS where agents harvest natural resources (driftwood) in continuous, heterogeneous space (a beach) due to rules that emerge without conscious design.
- The diffusion of technical innovations can be simulated by employing the idea of peer networks. Risk-averse adopters of technology will wait until their less risk-averse peer adopt. This process exhibits highly non-linear properties and is prone to path dependence, and is thus difficult to project with statistical models (see Balmann 1997; Berger 2001).
- An important goal of a part of MAS is to replace the assumption of an existing Walrasian equilibrium (with producers/suppliers, consumers, and a 'Walrasian auctioneer') by modelling the *process of procurement* itself. This allows for a direct representation of the consequences of market imperfections such as asymmetric information, strate-

gic interaction, expectations based on limited information, mutual learning, social norms, transaction costs, externalities, and coordination failure (Tefatsion 2006).

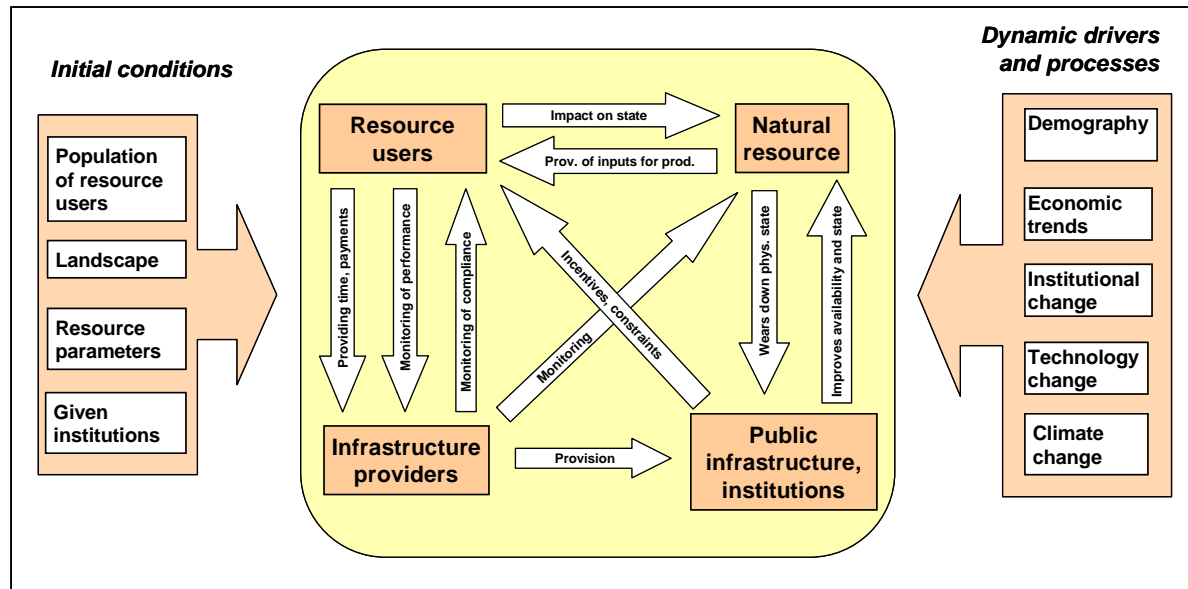
- The latter motive can be extended to the simulation of the institutional environment beyond considerations about the procurement process, particularly if the agents have a choice among different institutional designs, and if these choices are an emergent result of interaction between the relevant agents. As outlined above, sustainable resource use is highly dependent on the institutional design. In the area of common resource management, institutions are very often targeted at regulating the interaction between agents, i.e. resource users and infrastructure providers. Models using highly aggregated representative agents often lack the detail to incorporate and simulate such institutional designs.

Numerically modelling the economic impact of the choice of institutional designs by resource users is a major long-term challenge to be addressed by this sub-project. Institutional design has so far been addressed using MAS by political scientists (see Kollmann & Page 2006), mostly employing heuristic strategies for arriving at decisions rather than assuming optimising behaviour such as in most economic models. In the sphere of resource economics and particularly the governance of SESs, modelling of institutions in both representative and multiple agent systems is still in its infancy (Janssen & Ostrom 2006), probably due to the difficulties in observing and implementing how institutions influence agents' behaviour through incentives and constraints of choice sets.

As to the application of multi-agent models for agriculture and resource use, MAS have recently been used by Happe et al. (2006) to simulate structural change in a western German region as a consequence of changes in the EU's agricultural policy. An illustration of the use of MAS to simulate questions related to resource economics can be found in Schreinemachers et al. (2007) where the authors simulate the interaction of soil fertility dynamics and human behaviour where resource users – subsistence farmers – are affected by severe poverty.

Despite their intuitive attractiveness, MAS should not be regarded per se as superior to models involving representative agents. The degree of differentiation of agents should be decided by following the principle of Occam's razor. Disaggregating representative agents to 'multiple' agents should only be done if a) the model allows these agents to interact within the same agent class and location, and b) if we expect that these interactions will lead to different economic or ecological consequences which cannot be sufficiently described at the aggregate level. Epstein (2006: 1588) claims that only individuals are represented in typical MAS. This approach may be too restrictive, as it is also possible to have agents of a higher aggregation level such as communities, collectives, clubs, NGOs, etc. The appropriate degree of detail or disaggregation first depends on the decision level under consideration. For instance, the consumption decision of a household is the aggregate of individual consumption decisions by the household members. Moreover, as far as the MAS is supposed to provide insights into the possible consequences of interaction among a group of agents, the type of interaction which is of interest has to be specified. This requires detailed theoretical pre-considerations about which kind of social interaction (of which many exist) is relevant for the processes to be simulated with the MAS.

Summarizing the state of the literature to economic aspects of the resilience/robustness of SES, we suggest adopting a modelling approach as depicted in the following flowchart. It attempts to integrate the SES-framework suggested by Anderies et al. (2004) into a numerical bio-economic simulation system with appropriate differentiation of agents.



**Figure 1: Conceptual framework for simulating resilience of SES – Interaction of agents, resources, and public infrastructure.** Source: own illustration involving concepts by Schreinemachers et al. (2007) and Anderies et al. (2004)

The modelling concept portrayed consists of three parts. In the centre, the interactions between resources, users, infrastructure and institutions, and the providers from various levels of the latter two, are explained in stylised examples, constituting a complex system of coupled processes representing the SES. The system is thought to be dynamic over multiple periods, starting with initial conditions which may have a lasting resonance of the dynamic cycle. Moreover, the system's development path is driven by exogenous parameters such as population change, economic growth of the country where the system is located, but also changes in the institutional, technological and ecological environment. The SES will endogenously develop given internal functionalities and external drivers; partly it will evolve (e.g. the ecosystem), partly it will consciously adapt to change (e.g. change in resource use strategies by users, different choices of institutional designs by infrastructure providers). We expect that in the longer perspective of the RU, the most relevant of these entities, dependencies and interactions can be incorporated into a numerical model, enabling the simulation of resilience of the SES to internal or external disturbances or shocks.

## Bibliography

ABEL, N., CUMMING, D.H.M. & ANDERIES, J.M. (2006) Collapse and Reorganisation in Social-Ecological Systems: Questions, Some Ideas, and Policy Implications. In: *Ecology and Society* 11 (1): 17.

- ADGER, W.N, BROWN, K. & TOMPKINS, E.L. (2006) The Political Economy of Cross-Scale Networks in Resource Co-Management. In: *Ecology and Society* 10 (2): 9.
- ANDERIES, J.M., JANSSEN, M.A. & OSTROM, E. (2004) A Framework to Analyze the Robustness of Social-Ecological Systems from an Institutional Perspective. In: *Ecology and Society* 9 (1): 18.
- AXELROD, R. and TEFATSION, L. (2006) A Guide for Newcomers to Agent-Based Modeling in the Social Sciences. In: Tesfatsion, L. and Judd, K.L. [eds.], *Handbook of Computational Economics, Vol. 2*, Elsevier, pp. 1648-1659.
- BARBIER B. and BERGERON G. (2001) *Natural Resource Management in the Hillside of Honduras – Bio-economic Modeling at the Microwatershed Level*. IFPRI – Research Report 123.
- BALMANN, A. (1997) Farm-based modelling of regional structural change: A cellular automata approach. *European Review of Agricultural Economics* (24): 85-108.
- BARBIER B. and HAZELL P. (2000) Implications of Population Growth and Declining Access to Transhumant Grazing Area for Sustainability of Agropastoral Systems in the Semi-Arid Area of Niger. In: McCarthy, N. Swallow, B., Kirk, M. and Hazell, P.: *Property Rights, Risk and Livestock Development in Africa*. IFPRI and ILRI, Washington D.C. S.371-395. Available online at <http://www.ifpri.org/pubs/books/proprights.htm>
- BARRETT, C. (2003) *Rural Poverty Dynamics: Development Policy Implications*. Paper presented at the 25th International Conference of Agricultural Economists, Durban.
- BERGER, T. (2001) Agent-based spatial models applied to agriculture: a simulation tool for technology diffusion, resource use changes and policy analysis. *Agricultural Economics* 25 (2/3), 245-260.
- BERKES, F. (2008) Commons in a Multi-Level World. In: *International Journal of the Commons* 2(1), 1-6.
- BINSWANGER, H. and ROSENZWEIG, M. R. (1986) Behavioral and Material Determinants of Production Relations in Agriculture. *Journal of Development Studies* 22: 503-539.
- BOSERUP, E. (1965) *The conditions of agricultural growth. The economics of agrarian change under population pressure*. London: Earthscan Publications Ltd.
- CHAYANOV A. V. (1966) *The Theory of Peasant Economy*. D. Thorner, B. Kerblay and R. E. F. Smith [eds.] Irwin: Homewood.
- CLARK, C.W. (2005) *Mathematical Bio-economics: The Optimal Management of Renewable Resources*. 2<sup>nd</sup> edition. New York: Wiley & Sons.
- DUFHUES, T. and BUCHENRIEDER, G. (2006) Open issues and implications for measuring individual social capital in developing countries, in: Buchenrieder, G. and Th. Dufhues., *Making rural households' livelihoods more resilient: the importance of social capital and the underlying social networks*. [26th International Conference of Agricultural Economists (IAAE), Brisbane/Queensland, Australia, August 12 -18, 2006]. IAMO, Leibniz-Institut für Agrarentwicklung in Mittel- und Osteuropa]. Halle (Saale), 24 – 42.

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- EPSTEIN, J.M. (2006) Remarks on the Foundations of Agent-Based Generative Social Science. In: Tesfatsion, L. and Judd, K.L. [eds.], *Handbook of Computational Economics*, Vol. 2, Elsevier, pp. 1585-1604.
- GUTHIGA, P., MBURU, J. and HOLM-MÜLLER, K. (2008) Factors Influencing Local Communities' Satisfaction Levels with Different Forest Management Approaches of Kakamega Forest, Kenya. *Environmental Management* 41 (5): 696-706.
- HAPPE, K., KELLERMANN, K. and BALMANN, A. (2006) Agent-based Analysis of Agricultural Policies: an Illustration of the Agricultural Policy Simulator AgriPoliS, its Adaptation and Behavior. *Ecology and Society* 11: 49.
- HARDIN, G. (1968) The Tragedy of the Commons. *Science* 162 (3859): 1243-1248.
- HAZELL, P.B.R. and NORTON, R. (1985) *Mathematical Programming for Economic Analysis in Agriculture*. London: Macmillan.
- HOLDEN S. T. und SHIFERAW B. (2004) Land Degradation, Drought and Food Security in a Less-favoured Area in the Ethiopian Highlands: A Bio-economic Model with Market Imperfections. *Agricultural Economics* 30, 1, 31-49.
- HOLLING, C.S. (1973) Resilience and Stability of Ecological Systems. *Annual Review of Ecology and Systematics* (4): 2-23.
- JANSSEN, S. and VAN ITTERSUM, M.K. (2007) Assessing farm innovations and responses to policies: A review of bio-economic farm models. *Agricultural Systems*, 94 (3): 622-636.
- JANSSEN, M.A. and OSTROM, E. (2006) Governing Social-Ecological Systems. In: Tesfatsion, L. and Judd, K.L. [eds.], *Handbook of Computational Economics*, Vol. 2, Elsevier, pp. 1465-1509.
- KOLLMAN, K. and PAGE, S.E. (2006) Computational Methods and Models of Politics. In: Tesfatsion, L. and Judd, K.L. [eds.], *Handbook of Computational Economics*, Vol. 2, Elsevier, pp. 1433-1463.
- LEHTONEN, M. (2004) The environmental–social interface of sustainable development: capabilities, social capital, institutions, *Ecological Economics* 49, 199-214
- MEINZEN-DICK, R. and DI GREGORIO, M. (2004) *Collective Action and Property Rights for Sustainable Development: Overview*. IFPRI Brief no. 1 of 16.
- NORTH, D.C. (1990) *Institutions, Institutional Change and Economic Performance*. Cambridge: Cambridge University Press.
- OKUMU B.N., RUSELL N., JABBAR M.A., COMAN D., SALEEM M., PENDER J. (2004) Economic Impacts of Technology, Population Growth and Soil erosion at Watershed Level: The Case of the Ginchi in Ethiopia. *Agricultural Economics* 30, 3, 503-523.
- OSTROM, E. (1990) *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge: Cambridge University Press.
- PAAVOLAA, J. and ADGE, W. N. (2005) Institutional ecological economics, *Ecological Economics* 53: 353-368.
- PRETTY, J. and WARD, H. (2001) Social Capital and the Environment, *World Development* 29(2): 209-227,

- SCHELLING, T. (1978) Economics, or the Art of Self-Management. *American Economic Review* 68(2): 290-294.
- SCHREINEMACHERS, P., BERGER, T. and J.B. AUNE (2007) Simulating soil fertility and poverty dynamics in Uganda: A bio-economic multi-agent systems approach. *Ecological Economics* 64: 387-401.
- SUDGEN, R. (1989) Spontaneous order. *Journal of Economic Perspectives* 3 (4) 85-97.
- TESFATSION, L. (2006) Agent-Based Computational Economics: A Constructive Approach to Economic Theory. In: Tesfatsion, L. and Judd, K.L. [eds.], *Handbook of Computational Economics, Vol. 2*. Elsevier, pp. 831-880.
- TRAKOLIS, D. (2001) Perceptions, Preferences and Reactions of Local Inhabitants in Vikos-Aoos National Park, Greece. *Environmental Management* 28 (5), 665-676.
- WIGGINS, S., MARFO, K. and ANCHIRINAH, V. (2004) Protecting the Forest or the People? Environmental policies and livelihoods in the forest margins of Southern Ghana. *World Development* 32 (11): 1939-1955.

### 3.3.2 PREVIOUS RELEVANT WORK BY THIS RESEARCH GROUP

**Prof. Dr. Karin Holm-Müller** and her group have been working on the identification of environmental preferences since 1987. Some of the studies have been conducted in Africa. Guthiga, Mburu, & Holm-Müller (2008) address the factors influencing local communities' satisfaction levels with different forest management approaches in Kenya. Wale, Holm-Müller, Mburu & Zeller (2005) analyse farmers' preferences for coffee variety attributes in Ethiopia and draw conclusions for on-farm conservation and variety adoption. Zander & Holm-Müller (2007) carry out choice experiments for valuing farm animal genetic resources. The effect of institutions on resource use in the context of a water user association in Uzbekistan is treated in Zavgorodnyaya & Holm-Müller (2003).

Other work has been dealing with an application of Ostrom's design principles on performance payments for the conservation of wildlife paid collectively to Sami villages in Sweden (Zabel & Holm-Müller 2008). In the framework of the IMPETUS project, jointly carried out by the Universities of Cologne and Bonn, Gruber (2007) has carried out long-term projections of land use in Benin with special regard to transhumant pastoralists facing weak property rights on required grazing lands which leads to dysfunctional traditional land sharing arrangements when population pressure increases. In the same project, institutional arrangements in the area of water management, comparing unregulated distribution, optimised distribution via rationing schemes, and different water pricing policies in a multidisciplinary simulation model have been investigated for Morocco (see Heidecke, Kuhn, & Klose 2008).

The group of **Prof. Dr. Thomas Heckelei** has a long standing tradition in quantitative bio-economic modelling. A series of large scale European research projects developed quantitative simulation tools to assess impacts of EU market and agri-environmental policies on agricultural production systems and markets (Heckelei & Britz 2001; Van Ittersum et al. 2007). Specific emphasis was put on the interaction of agricultural management and the environment by linking production systems and structure to environmental indicators (for example Holm-Müller & Pérez 2007). During the last years, spatially explicit modelling tools have been added to improve the resolution and quality of simula-

tion results (Kempen et al. 2005; Britz 2008; Leip et al. 2008). Furthermore, innovative methodologies for the statistical specification of aggregate and farm level optimisation models have been introduced improving the empirical content of the behavioural models (Heckelei & Wolff 2003; Britz et al. 2003).

Apart from these Europe-oriented modelling activities and general methodological developments, the group has been involved in projects dealing with the management of natural resources in developing countries. In the framework of the above mentioned IMPETUS project, aspects of agricultural land use are addressed using a newly developed multi-regional, recursive-dynamic agricultural sector model BenIMPACT (Benin Integrated Modelling System for Policy Analysis, Climate and Technology Change). This spatial simulation model comprises features of farm-household models representing simultaneous decision making on production and consumption by rural households. A detailed description of the most important features of BenIMPACT can be found in Jansson (2005a, 2005b). In Morocco, the interdisciplinary analysis of the Drâa river basin is carried out on the basis of the integrated river basin model MIVAD (Modèle Intégrée du Vallée du Drâa) involving the main water resources and users (see Heidecke & Kuhn 2006, Heidecke & Kuhn 2007). This simulation model is designed as a hydrologic-economic optimization model in which spatial relations are represented in a node network representing points of withdrawal along the river, water reservoirs, groundwater bodies, and agricultural water demand sites.

Due to its high degree of spatial differentiation, the river basin modelling for Morocco is already quite close to an agent-based model. This is useful when it comes to simulating endogenous choice of institutional designs – be it as rules, constraints, or as ‘social technologies’ – where it is almost certain that interactions among agents are crucial to arrive at a satisfying model structure. An example taken from the area of water management and pricing shall illustrate this point. The MIVAD river basin model simulates agricultural production by using representative farms that are aggregates of several hundred individual farms in several villages along the Drâa river in Morocco. The locations of the representative farms are each endowed with a groundwater aquifer, but are also provided with river water through centralised distribution. Recursive-dynamic simulations of alternative water pricing schemes reveal that groundwater pricing would be a reasonable option to preserve water resources in the Drâa valley provided that transaction costs of implementation are sufficiently low (Heidecke, Kuhn & Klose 2008). The level of these transaction costs, and thus the feasibility of groundwater pricing, however, can only be assessed when the concrete institutional design of the water pricing scheme is analysed, and alternative designs compared via simulations. Modelling the details of institutional design (such as rules, constraints, interactions, benefits and costs, additional agents representing infrastructure providers) requires the disaggregation of representative farms into spatially explicit smaller units, be it individual farms or groups of farms, or even a nested multi-agent structure. This modelling decision depends on who will be charged (individuals or groups) and how these individuals or groups react to the new institutional rules.

### 3.3.3 List of relevant publications

#### I. Peer-reviewed publications

**a) in scientific journals**

- BRIAND, G., HECKELEI, T., MATULICH, S. C. and MITTELHAMMER, R.C. (2004) Managing Fishing Power: The Case of Alaska Red King Crab. *Canadian Journal of Fisheries and Aquatic Sciences* 61(1): 43-53.
- BRITZ, W., HECKELEI, T. and PÉREZ, I. (2006) Effects of Decoupling on Land Use: An EU wide, Regionally Differentiated Analysis. *Agrarwirtschaft* 55(5/6): 215-226.
- BRITZ, W., HECKELEI, T. and WOLFF, H. (2003) Symmetric Positive Equilibrium Problem, A Framework for Rationalizing Economic Behavior with Limited Information: Comment, *American Journal of Agricultural Economics* 85, S. 1078-1081
- KEMPEN, M., HECKELEI, T. and BRITZ W. (2005) A Statistical Approach for Spatial Disaggregation of Crop Production in the EU, in: *Modelling Agricultural Policies: State of the Art and New Challenges*, Proceedings of the 89th European Seminar of the EAAE, Parma, Italy, February 3-5, 2005, S. 810-830
- CHADDAD, F., COOK, M. L. and HECKELEI, T. (2005) Testing for the Presence of Financial Constraints in U.S. Agricultural Cooperatives: An Investment Behavior Approach. *Journal of Agricultural Economics* 56(3), 385-97.
- CHOUINARD, H., HUFFAKER, R., HECKELEI, T. and WAHL T.I. (2004) The Marriage between Humanitarian Assistance and Agricultural Interests in U.S. Overseas Aid Programs: Reconcilable Differences? *Journal of Humanitarian Assistance*, <http://www.jha.ac/articles/a136.htm>.
- DEGNET, A., HOLM-MÜLLER, K. and MBURU, J. (2006) Understanding the Perceived Importance of Risk for Coffee Growers: Empirical Evidence from Ethiopia, in: *Quarterly Journal of International Agriculture*, p. 253-267
- GUTHIGA, P., MBURU, J. and HOLM-MÜLLER, K. (2008) Factors Influencing Local Communities' Satisfaction Levels with Different Forest Management Approaches of Kakamega Forest, Kenya. *Environmental Management* Volume: 41 Issue: 5 Pages: 696-706
- HECKELEI, T. and WOLFF, H. (2003) Estimation of Constrained Optimisation Models for Agricultural Supply Analysis Based on Generalised Maximum Entropy. *European Review of Agricultural Economics*, 30, p. 27-50
- HEIDECHE, C. and KUHN, A. (2006) Simulating Groundwater Charges for the Moroccan Drâa River Basin. In: *Journal of Agriculture and Marine Science*. Oman.
- HEIDECHE, C., KUHN, A., and KLOSE, S. (2008) Water Pricing Options for the Middle Drâa River Basin in Morocco. In: *African Journal of Agricultural and Resource Economics* (forthcoming).
- LEIP, A., G. MARCHI, KOEBLE, R., KEMPEN, M., BRITZ, W. and LI, C. (2008) Linking an economic model for European agriculture with a mechanistic model to estimate nitrogen and carbon losses from arable soils in Europe. *Biogeosciences*, 5, 73-94.

- MUTHKE, T. and HOLM-MÜLLER, K. (2004) Benefit Transfer Testing With Revised Requirements - National And International Benefit Transfer Testing With A Rigorous Test Procedure. *Environmental and Resource Economics*, Vol. 29, Nr.3, p. 323-336.
- RICHERZHAGEN, C. and HOLM-MÜLLER, K. (2005) The effectiveness of access and benefit sharing in Costa Rica: Implications for national and international regimes, in: *Ecological Economics* 53, S. 445-460.
- VAN ITTERSUM, M.K., EWERT, F., HECKELEI, T., WERY, J., ALKAN OLSSON, J., ANDERSEN, E., BEZLEPINKA, I., BROUWER, F., DONATELLI, M., FLICHMANN, G., OLSSON, L., RIZZOLI, A. E., VAN DER WAL, T., WIEN, J. E., and WOLF, J. (2008) Integrated assessment of agricultural systems – A component-based framework for the European Union (SEAMLESS), *Agricultural Systems* 96, 150-165.
- WALE, E., HOLM-MÜLLER, K. MBURU, J. and ZELLER, M. (2005) Economic analysis of farmers' preferences for coffee variety attributes: lessons for on-farm conservation and variety adoption in Ethiopia, in: *Quarterly Journal of International Agriculture* 44. Nr. 2, p. 121-139.
- WIECK, C. and HECKELEI, T. (2007) Determinants, Differentiation, and Development of Short-term Marginal Costs in Dairy production: An Empirical Analysis for Selected Regions of the EU. *Agricultural Economics* 36(2): 202-220
- ZABEL, A. and HOLM-MÜLLER, K. (2008) Performance payments for carnivore conservation in Sweden, *Conservation Biology*, Volume 22, No. 2, S. 247-251
- Zander K., Simianer, H., Holm-Müller, K. (2009), Choosing the "cargo" for Noah's Ark - applying Weitzman's approach to Borana cattle in East Africa. *Ecological Economics* (68), S. 2051-2057

#### **b) at major scientific conferences**

- BRITZ, W. (2008) *EU-wide spatial down-scaling of results of regional economic models to analyze environmental impacts*, in: Proceedings of the 107th EAAE Seminar "Modeling of Agricultural and Rural Development Policies". Sevilla, Spain, January 29th -February 1st, 2008
- GRUBER, I., JANSSON, T. and KUHN, A. (2005) *Projecting Benin's Food Gap for 2025*. Deutscher Tropentag 2005: The Global Food and Product Chain - Dynamics, Innovations, Conflicts, Strategies University of Hohenheim, Stuttgart, October 11 – 13. [www.tropentag.de/2005/proceedings/node104.html](http://www.tropentag.de/2005/proceedings/node104.html)
- KUHN, A. and GRUBER, I. (2006) *The Impact of Increasing Land Scarcity on Food Production in Benin*. Conference 'Economics of Poverty Environment and Natural Resource Use', ENR, Wageningen.
- KUHN, A., SCHMIDT, T. and HEIDECKE, C. (2005) *Economic Aspects of Water Management in the Drâa Region (Southeast Morocco)*. Deutscher Tropentag 2005: The Global Food and Product Chain - Dynamics, Innovations, Conflicts, Strategies University of Hohenheim, Stuttgart, October 11 - 13. [www.tropentag.de/2005/proceedings/node68.html](http://www.tropentag.de/2005/proceedings/node68.html)

KUHN A., GRUBER I., DOEVENSPECK M. and PAETH, H. (2005) *The Impact of Resources Pressure and Rainfall Variability on Land Use and Food Supply in Benin*. Vortrag zur GLOWA-Statuskonferenz 18./19.05.2005, Universität zu Köln.

HECKELEI, T. and BRITZ, W. (2001) *Concept and Explorative Application of an EU-wide Regional Agricultural Sector Model (CAPRI-Projekt)*. in Heckelei, T., H.P. Witzke, and W. Henrichsmeyer (Eds.): *Agricultural Sector Modelling and Policy Information Systems*. Proceedings of the 65th EAAE Seminar, March 29-31, 2000 at Bonn University , S. 281-290 , Vauk Verlag Kiel

### c) in monographs

ZANDER, K. and HOLM-MÜLLER, K. (2007) Valuing farm animal genetic resources by using a choice ranking method, in: Meyerhoff, Lienhoop and Elsasser (eds.) *Stated Preference Methods for Environmental Valuation: Applications form Austria and Germany*, p. 105 - 137

GRUBER, I. (2007) *The impact of socio-economic development and climate change on livestock management in Benin*. Dissertation, Institute for Food and Resource Economics, University of Bonn.

HEIDECKE, C. and KUHN, A. (2007): Considering salinity effects on crop yields in hydro-economic modelling- the case of a semi-arid river basin in Morocco. In: Brebbia, C.A., Kungolos, A.G. [eds.]: *Water Resources Management (IV)*. Wessex Institute of Technology Press.

ZAVGORODNYAYA, D. and HOLM-MÜLLER, K. (2003) *Conflict-resolution mechanisms in Uzbek Water Users' Associations: one of the important institutional criteria*, 20th European Conference of ICID, Montpellier, 17.-19. September 2003.

## II. Non peer-reviewed publications

### a) at major scientific conferences

M'BAREK R., GRUBER, I., HEIDECKE C., and KUHN, A. (2005) *Optimising the Use of Scarce Resources - a Decision Support System for Benin*. Book of Abstracts, Conference of Integrated Assessment of Water Resources and Global Change: A North-South Analysis, ZEF Bonn.

**b) Working papers**

JANSSON T. (2005a) *A demand system for the BenIMPACT model. Department for Economic and Agricultural Policy, Bonn University. Technical Paper, March 2005.*  
Download: [http://www.agp.uni-bonn.de/agpo/rsrch/impetus/A4\\_publi\\_e.htm](http://www.agp.uni-bonn.de/agpo/rsrch/impetus/A4_publi_e.htm)

JANSSON T. (2005b) *The Economic Model BenIMPACT. Technical Paper, May 2005.*  
Download: [http://www.agp.uni-bonn.de/agpo/rsrch/impetus/A4\\_publi\\_e.htm](http://www.agp.uni-bonn.de/agpo/rsrch/impetus/A4_publi_e.htm)

**3.4 PROJECT DESCRIPTION (GOALS, METHODS, WORK PROGRAMME)****3.4.1 Goals**

The long term goal of this research project is to identify the resource-economic and institutional properties determining the resilience of an SES employing a dynamic numerical bio-economic modelling approach able to represent the relevant resource users, infrastructure providers, and institutions (coupling processes) to internal and external shocks.

In the first project phase we aim at generating basic bio-economic models for two very distinct regions, one in Naivasha (Kenya) and one in Free State (Republic of South Africa), to be used as analytical tools to assess the robustness of the desirable traits of these SES. For the existing situations we will, with these models, try to numerically describe the link between human action, the situation of the natural system, and the influence of feedback mechanisms from a changed natural system on the actions chosen by the actors. These simulation models should be spatially explicit, multi-sector, dynamic, and bio-economic. We will also analyse the prevailing – possibly multiple – institutions in both regions and strive to gain first insights into the influence of the dominant institutions on behaviour. A more theoretically based in-depth institutional analysis will be confined to the Kenyan case. For South Africa the information on the institutional environment necessary for the bio-economic model will be gathered in cooperation with subproject A1.

In a second phase, the bio-economic model will be modified in order to account for the influence of alternative institutional designs, which we deem crucial for the robustness of an SES, and thus look into the relation between preferences, knowledge, institutions and behaviour. Nevertheless, we feel it is too early to look into the factors which may bring about a change in institutions within the first phase of the RU. The specific goals of research in the two sites (Kenya and South Africa) are described in the following.

**Naivasha/Kenya**

The wider Lake Naivasha region is characterised by competition of various user groups for both land and water. Issues of land ownership and access rights to resources are contested between various stakeholders. The most significant economic activity is intensive irrigated greenhouse floriculture and horticulture by larger companies (organised in the Lake Naivasha Growers Group). Its intensive use of chemical inputs, removal of fringing swamps, and excessive withdrawal of water poses a threat to the area's integrity. On the other hand, rapid population growth around the lake has led to the encroachment of wetlands by smallholders, who converted them into agricultural lands. Harvesting of

papyrus, fishing, and tourism are additional economic activities that heavily rely on the local ecosystem. As the region's population is growing due to high fertility rates and immigration, the long-term productivity and stability of the SES is threatened as long as non-resource-based job opportunities are not sufficiently available. The Lake Naivasha Riparian association, an association of commercial farmers and tourist entrepreneurs with deep historical roots (topic of counterpart project in B1), as well as Maasai herders organised in various NGOs are further stakeholders impacting on resource use in the basin.

Designing a bio-economic simulation model for the region has to take the land and water resources into account, as well as the biophysical interrelations between these resources. Moreover, several typical resource users will have to be incorporated, each with a specific set of choices as to production mode and commodities produced, including tourism services. The model would thus have to rely heavily on the results of remote sensing, soil science, and agronomy. It would have to be spatially explicit as far as possible, and have dynamic features to produce future scenarios.

For the institutional analysis we will make use of the dominant position of the Lake Naivasha Riparian association (LNRA) for the management of natural resources as described above under „starting point“ as they are an excellent example for infrastructure providers within the robustness framework.

It seems clear from the start that the LNRA as a major infrastructure provider cannot be characterized as a successful common pool regime because only part of the factors influencing on the quantity and quality of lake water under the responsibility of its members. Moreover, many of the regulations affect people that are not (direct) beneficiaries of the lake. This will probably negatively affect their acceptance of restrictions in the management plan and necessitate additional incentives stemming from lake water users or others. On the other hand, the existence of a powerful user group that has vital interests in a sustainable use of the lake is a crucial asset for enhancing the resilience of the whole system as it can function as a core group for adaptation of use restriction etc. and voicing of ecological aspects. In the Naivasha case this group exists parallel to the governmental authority WARMA leading to different forms of interactions.

Thus, a first goal of the institutional analysis will be to describe the relevant institutions and their interactions. We will then have a deeper look into the LNRA as a long standing user association at place and assess what aspects of the organisation and its embeddedness in the institutional environment at the different scales are favourable for a successful common pool regime. This should result in the identification of necessary traits of a more successful regime. As the elements necessary to evaluate successful common pool regimes applicable to the LNRA are outlined clearly in the literature, this could be done with a Master thesis directed by our partners in Nairobi. In a second phase of the RU these results could be a good starting point for assessing dynamic properties of the existing user group associations and the factors that influence on the emergence of such groups as well as on changes in their goals and measures.

The aim of the PhD research conducted at the Naivasha side will be to investigate into the hypothesis that institutions influence behaviour or in this case the acceptance of environmentally friendly regulations. To do so, we will take some prominent measures from the management plan and do a survey with individuals of different user groups in the Na-

ivasha catchment that are negatively affected by the regulation. We will choose regulations that inflict a reduction of immediate advantages to the individuals and then we will investigate into the reasons of acceptance or rejection of these regulations. We assume that endowments, substitution possibilities and risk mitigating institutions as well as expected own long-term benefits, together with some notions of fairness will influence on the acceptance of the regulations.

### **Thaba Nchu (Mangaung/South Africa)**

The goal of the research work in the South African case is modelling land use by various users in the area surrounding Thaba Nchu as an SES would focus on the competition of large and small farms for land under different assumptions of technology use. Large farms have formally recognised property rights to land, which is why they can lease land out. They are supposed to use capital-intensive production modes with zero increases in family labour endowments, high opportunity costs of family labour, and a focus on cash crops and large ruminants. Large farms have access to new technologies and develop the capacity to use these technologies (fertiliser, pesticides, advanced machinery and facilities, etc.) through training. Besides input use, technical progress occurs in the form of labour-saving growth of the capital stock, which is financed by access to long-term credit at relatively low interest rates. Large farms also have access to various kinds of formal insurance (droughts, floods, pests, health insurance) which makes them less vulnerable to risk.

By contrast, indigenous small farmers outside the Thaba Nchu Homeland (see a description of the special situation in Thaba Nchu in the chapter by A1) are supposed to hold rather informal land use rights, often in the form of oral tenure agreements or use rights within a commons. They use labour-intensive production modes. Their household labour pool tends to increase over time according to population growth among squatters. As a consequence of low education and lacking local job opportunities, reservation wages – i.e. the lowest wage rate at which a worker would be willing to accept a particular type of job – among subsistence farmers are considered to be much lower than those of members of large farm households. Small farms focus on subsistence crops and small livestock. They have only limited access to fertiliser and only few skills to make use of pesticides or advanced machinery. Moreover, they only have access to short-term credit at relatively high interest rates. On small farms, credit finances input use and consumption during times of scarcity. They have no access to formal insurance and are thus more vulnerable to risk than large farms.

From a modelling point of view, the interactions between small and large farms that constitute the SES are most interesting. Since the end of apartheid, large farms are allowed to rent out land to squatters, and employ squatters as farm hands temporary or permanently since centuries. Subsistence farmers face thus a trade-off between renting more land from large farms and accepting employment on the large farm. Moreover, small farms might hire machinery services from large farms, and buy feed grains. All these transactions might be carried out on a non-monetary barter basis.

The envisioned land use simulation model will have to be based on empirical investigations in different areas. The different user groups have to be identified and their use

modes to be described quantitatively. This information will be gathered by means of a large survey among the different groups of land users. Moreover, the suitability of the resource system to serve different regimes of use (cropping, grazing, large-scale versus small-scale farming) will have to be assessed with the assistance of the soil scientists and agronomists within the RU (A1, A3). The institutional framework governing land use and transactions of use rights will be investigated in close cooperation with the cultural anthropologists of sub-projects A1 and C2.

### 3.4.2 Methods

The choice of the methodology serves the overall research goal to integrate the SES-framework suggested by Anderies et al. (2004) into an empirical bio-economic simulation system with appropriate differentiation of agents and institutions (see figure 1 above). The purpose of this numerical model is to simulate the resilience of the SES that are studied by B2 in Kenya and South Africa. As our models are supposed to incorporate the influence of the prevailing institutions on decisions taken by the different actors detailed analysis of institutional economics of resource use will be necessary at both research sites and thus be the first methodological pillar of the work of B2. The second methodological focus is setting up the simulation model itself which involves developing its theoretical structure and collecting necessary data beyond the institutional environment such as resource endowments, productivity of different production modes, and own-consumption versus trade of products. Moreover, bio-economic modelling will have to find ways to incorporate institutions and their relevant actors into the bio-economic model. The two methodological foci are explained in more detail below.

(1) Institutional analysis of selected SES cases is the basis for an understanding of the economic significance of customary and official regulations for resource use. It will start with an extended literature review on the way institutions are modelled in bio-economic models as well as on the relation between institutions, social capital and resilience (see state of the art for first information). Expert and actor interviews will accompany the literature review to help us learn more about the existing formal and informal institutions and help to construct the main hypotheses for subsequent research. Moreover, we will participate in the census conducted in subproject B1 by adding questions on endowments, the availability of social capital and perceived restrictions on the use of natural resources.

An in-depth survey with a smaller group of respondents will give us the possibility to identify relations between satisfaction levels with the management of natural resources in the catchment and users' endowments, the availability of social capital, perceived benefit sharing, and other relevant aspects. In masters theses to be prepared by local young scientists, focus groups and expert interviews will be accompanied by small surveys among members of representative resource user groups concerning the most important design principles.

(2) Bio-economic modelling in a dynamic framework will simulate the economic aspects of resilience and transformation in complex SES numerically. By modelling feedback

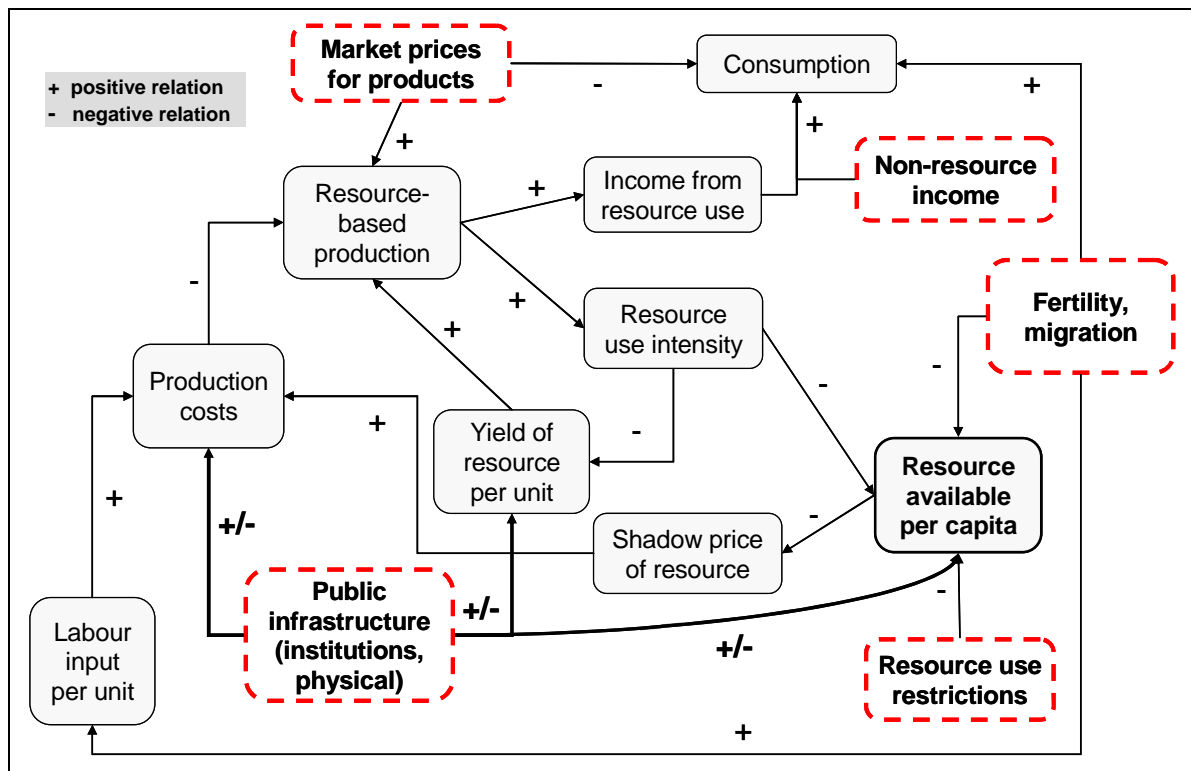
mechanisms between the state of the resource and resource use intensity, bio-economic models offer the possibility to simulate both vicious and virtuous circles as dynamic, non-equilibrium processes. In particular, the impact of various driving forces can be assessed with respect to the economic and ecological buffer capacity of the SES. Modelling approaches would involve the representation of both land and water use. The results of the analysis on preferences and institutions will be incorporated into the bio-economic model as behavioural options. This can then also be used to simulate the resilience or robustness of the SES under different institutional set-ups. As an SES consists of numerous economic and institutional agents, the envisioned simulation model should incorporate elements of agent-based models to capture interactions between agents.

As the ultimate goal of the sub-project B2 is to represent the economic aspects of the resilience of two SES (in Kenya and in the Republic of South Africa) in detailed numerical simulation models, these models should have the following decisive properties:

- **Spatially explicit:** This approach facilitates the representation of heterogeneous land and water resources in space. Moreover, many land use decisions are dependent on the distance of the plot to the homestead of the farmer, other plots, a nearby forest or water body, certain infrastructure such as irrigation facilities, or the road leading to the next market.
- **Multi-sector:** Natural resources in an SES can be used for multiple purposes. Wetlands, for instance, may be used for fishery, hunting, harvesting of reed, crop production, grazing of livestock, as source for freshwater, for cleaning wastewater, and for tourism. Forests may be used as pasture, for extracting timber, charcoal, hunting, or for recreational purposes.
- **Dynamic:** the models should be multi-periodical to capture intra-annual events such as rainy seasons. In order to reflect long-term trends such as climate change, growth of off-farm wages, or population growth, the models should encompass roughly two decades. Finally, the impact of expectations of resource users about future trends of driving forces on resource use have to be addressed in the dynamic design.
- **Bio-economic:** the physical or biological properties of the eco-resources on which the SES is built upon will have to be modelled such that the productivity of the resources and their degradation can be simulated. The state of the resources should be a function of the mode and intensity of their use. As such, productivity functions of resources have to be implemented.

We suggest establishing the basis of the bio-economic models for both the Kenyan and South African sites first by focusing on the interaction between the resources and resource users, i.e. only part of the framework suggested by Anderies et al. (2004). The following figure (figure 2) illustrates in simplified form the causal relationships that this first version of the integrated simulation model would take into account. The elements with a red-dashed border are exogenous parameters, mostly external drivers that are not endogenously determined in the system such as market prices, fertility and immigration, or economic development of the nation-state resulting in changed opportunity costs of

labour time. Other parameters represent constants governing the system, in particular the element of public infrastructure comprising institutions. The grey-shaded elements, on the contrary, are endogenous variables which are involved in system-wide feedback mechanisms through well-defined causal relationships with other variables or the previously mentioned parameters. All variables assume quantifiable levels. Changes of these levels will positively or negatively influence the levels of variables that are causally dependent, as indicated by the arrows. Pluses and minuses indicate positive or negative changes of dependent variables.



**Figure 2: Economic interactions in an SES - functional relations between exogenous and endogenous variables**

As compared to figure 1 at the end of the literature review, the above flowchart is not focusing on entities, but on the quantitative variables that are determined by the properties and behaviour of these entities. For instance, resource-based production (a quantifiable variable) is carried out by resource users (numerous entities that will be aggregated into just a few representative agents in the first model versions) who also consume part of their production. The resource itself is characterised by the quantitative variables 'resource availability' (or 'endowment', e.g. hectares of land available) and yield (e.g. harvest in tons per hectare).

The chart illustrates the causal relationships of parameters and variables in a stylised model reflecting the relation between resources and resource users. In this model concept for the first phase, institutions are treated as exogenous conditions. Moreover, the figure does not contain information on aspects of dynamic properties or interaction of agents. These aspects, as well as endogenous choice of institutions, will be implemented in the following phases of the RU.

It is obvious that switching to an empirically well-based multi-agent structure – which means disintegrating the representative agents mentioned above – tremendously increases the demands for detailed farm level data, but also about the resources (terrain, properties of field plots or water sources), physical infrastructure, and preferences of agents. We suggest pursuing a strategy of inter-disciplinary data collection, which will be further discussed as part of the work programme and in the section describing the role of this sub-project within the entire RU.

### 3.4.3 Work Programme

The work programme is illustrated in the following table. In 2010, an in-depth literature review will be at the beginning, followed by first field missions in both research sites to team up with local academic partners, collect existing secondary data, and conduct exploratory interviews with experts and key actors.

2010 will continue with the development of a questionnaire related to the institutional environment in the Lake Naivasha site. As a by-product, questions will be developed that are meant to become part of the census questionnaire to be used in subproject B1. Besides, two groups of important resource users negatively affected by the management plan for the Naivasha catchment will be identified.

In parallel, the theoretical and conceptual model development will start for both research sites based on existing in-house models and other relevant modelling approaches. The early start of the design of bio-economic models is crucial, as the model structure will determine the content of the questionnaires related to physical and economic aspects of resource use for Kenya and South Africa. These questionnaires will cover all relevant resource users in both sites investigating their production systems, use of technology, and interactions between categories of users. Endowed with the questionnaires, researchers will return to the field in the second half of 2010 and start the preparation of a sampling frame and other necessary preparations for the survey as for instance pre-tests and interviewer training.

With the beginning of 2011, researchers will start the resource-use and institutions-related survey. This work will require roughly three months. After finishing the survey, data analysis will start in Germany. The researchers dealing with the institutional aspects of resource use will carry out in-depth interviews on-site as follow-up in March 2012.

In the next step the detailed numerical specification of the existing conceptual bio-economic simulation models will be carried out. For the Kenyan model, we expect to incorporate the most relevant institutions at that stage already. The rest of 2012 will be used for sensitivity analyses and the simulation of the functioning of the modelled SES, as well as to preparing publications and doctoral theses.

As to the tasks of individual researchers involved in the sub-project, Karin Holm-Mueller will focus her supervision and contributions on the institutional aspects of work, whereas Thomas Heckelei concentrates on the concept and methodological implementation of the bio-economic models. The post-doctoral researcher, Arnim Kuhn, will coordinate field work, data collection, and will implement the designed simulation models in the modelling language GAMS. Two dissertation projects will be carried out: the one in Kenya will concentrate on the institutional analysis of resource use and regulation in the Lake Na-

ivasha region, while the stipendiary working in the Thaba Nchu grassland region will focus on the bio-economic modelling of land use in this marginal area.

## 3.4.3.1 Schedule (3 years programme)

B2 KENYA					B2 SOUTH AFRICA						
Year	Month	Work-programme	Partici-pants	Vehic-les	Year	Month	Work-programme	Partici-pants	Vehic-les		
2010	1	Literature review			2010	1	Literature review				
	2					Exploratory Field-work		2			
	3		1	1			3		1	1	
	4	Development of questionnaires, theoretical and technical model development				4	Development of questionnaire, theoretical and technical model development				
	5					5					
	6					6					
	7					7					
	8					8					
	9	Preparatory Fieldwork	2	1		9	Preparatory Fieldwork	2	1		
	10		1	1		10		1	1		
	11	Drafting of conceptual papers				11	Drafting of conceptual paper				
	12					12					
2011	1	Fieldwork for Surveys in Kenya			2011	1	Fieldwork for Surveys in RSA				
	2		2	1		2					
	3		1	1		3		2	1		
	4		1	1		4		1	1		
	5		1	1		5		1	1		
	6	Analysis of survey data				6	Analysis of survey data	1	1		
	7					7					
	8					8					
	9					9					
	10					10					
	11					11					
	12			12							
2012	1	Preparation of in-depth interviews			2012	1	Preparation of in-depth interviews				
	2					2		In-depth interviews	2	1	
	3	In-depth inter-views	2	1		3	In-depth interviews		1	1	
	4		1	1		4		Writing of papers on survey results			
	5			5							
	6			6							
	7	Detailed specifica-tion of first bio-economic model including most relevant institu-tional features				7	Detailed specification of first bio-economic model				
	8					8					
	9					9					
	10					10					
	11					11					
	12					12					

Field Research – highlighted in grey

### **Work programme for extensions beyond the first project phase**

In the longer perspective of the RU, it is planned to incorporate the institutional framework depicted in figure 1 (chapter 3.3.1) into the numerical model. This requires a formalisation of the information on relevant institutions that is going to be collected in the first phase of the RU. The basic idea is to represent institutions as 'social technologies' to which benefits and costs can be attributed. It is envisioned to offer resource users choices between alternative institutional designs. Moreover, the 'infrastructure providers' which are suggested within this analytical framework will be represented as agents with behavioural functions, assuming that they follow their own optimisation concerns. The role of infrastructure providers will to a large extent depend on whether they share the interests of resource users or are accountable to them. Sub-project B2 is directly linked with the social-anthropological parts of sub-projects A1, B1 and C3 in its interest in institutional analysis. It is intended to prepare common research designs for institutional analysis (not withholding disciplinary specialisations in the sub-projects), so that methods applied to institutional analysis in the Thaba Nchu and Naivasha cases will also be applied in the Kuruman and Baringo case.

### **3.5 ROLE WITHIN THE RESEARCH UNIT**

Details of the methods of investigation, particularly for field data collection, will inevitably have to be developed in close cooperation with other sub-projects, both from the natural sciences and humanities. The methodological advantage of integrated numerical approaches such as bio-economic modelling is that it enables a broad variety of participating disciplines to share their results with other scientists, and to be able to have their own propositions and hypotheses numerically simulated.

For instance, social and cultural anthropologists will contribute to the identification of preferences and institutions. For that purpose, all survey work planned by B2 will be conceptualised jointly with sub-projects B1 and C3. The economic and ecological impact of these preferences and institutions will be simulated in the bio-economic framework (which is why this label for the envisaged modelling approach is still too narrow). The same holds for natural sciences and geography. The estimation of yield functions as for instance of rangeland soils is a challenging inter-disciplinary endeavour and requires proper planning particularly of the choice of sites and of data collection strategies. Agronomists (A2), grassland (A3) and soil scientists (A1) will contribute simplified versions of their data, specialised simulation models, and results – either as parameters or complete sub-modules – to be integrated in the bio-economic modelling framework. Such a multidisciplinary approach will enable to participate in simulating the interplay of environment and human agents.

### **3.6 Demarcation from other funded projects of the principal investigators**

Karin Holm-Müller is currently involved in a project (BIOTA East, BMBF) on the acceptance of auctions in Kakamega forest, Kenya. This project also focuses on institutional analysis and will look into factors affecting the acceptance of certain policy instruments. The time horizon of the analysis, however, is not long enough to address questions of

resilience, and the policy instruments analysed will be different from those relevant in this proposal.

Since 2004, Thomas Heckelei has been participating in the IMPETUS project (GLOWA programme, BMBF) which is dealing with water and land use in Benin and Morocco. IMPETUS will finish in 7/2009. The proposed sub-project is likely to benefit extensively from the experience in modelling land and water resource use that were gained in IMPETUS.

### **Job description of staff paid from core support for the funding period requested – Research-Assistants**

#### **1. Principal investigator: Prof. Dr. Karin Holm-Müller**

Karin Holm-Mueller will focus her research on the resource-economic and institutional aspects of the work programme. She will supervise the PhD-student responsible for institutional analysis particularly in methodological issues, devise and participate in relevant publications, and team up with Kenyan counterparts.

#### **2. Prof. Dr. Thomas Heckelei**

Thomas Heckelei will support conceptualisation and methodological implementation of the bio-economic models. In this context, he will provide assistance for the statistical processing of survey data, the specification of behavioural functions of model agents, and the calibration and validation of simulation models.

#### **3.7.1.1. Job description of staff paid from core support for the funding period requested – Non-scientific Assistants**

None

#### **3.7.1.2. Job description of staff paid from auxiliary support for the funding period requested – Research Assistants**

##### **1. Post-doctoral research assistant: Dr. Arnim Kuhn**

Dr. Arnim Kuhn will be responsible for the design and programming of the bio-economic simulation models for both research areas in Kenya and RSA. Moreover, he will plan and supervise the fieldwork of the two PhD students, and draft reports and publications of the sub-project.

##### **2. Research assistant, PhD-student for Naivasha/Kenya: N.N.**

The research assistant will focus on the institutional structures and regulations that are relevant for land and water use in the research site in Kenya. He/she will carry out surveys among land and water users, draft publications on survey results, and will contribute to data collection serving the bio-economic modelling project in Naivasha.

##### **3. Stipendiary, PhD-student for Thaba Nchu/RSA: N.N.**

The research assistant will focus on the resource-economic aspects of land use in the research site in South Africa. He/she will carry out surveys among land users, split be-

tween large and small farms, draft publications on survey results, and will contribute to data collection serving the bio-economic model planned for Thaba Nchu.

#### 4. Student assistant: N.N.

The student assistants will provide support to both PhD-student in the area of data processing and data analysis. Moreover, the assistants will be involved in literature research, and will support the drafting of publications. Ideally the student assistants will also contribute to the publication record of the sub-project by choosing relevant Master thesis topics related to the sub-project.

#### 3.7.1.3. Job description of staff paid from auxiliary support for the funding period requested – Non-scientific Assistants

None

#### 3.7.1.4. Counterparts

**Dr. Paul Maina Guthiga**, Post-Doc Researcher at the Environment for Development Initiative (EfD-Kenya) and the Kenya Institute for Public Policy Research and Analysis (KIPPRA) the initiative belongs to are also interested in collaboration with our project. Paul Guthiga, who was born in Naivasha, obtained his PhD in Agricultural Economics at the ZEF, University of Bonn, with the thesis “Economic Assessment of Different Management Approaches of Kakamega Forest in Kenya: Cost –Benefit and Local Community Satisfaction Analysis” . As a lecturer at Nairobi University Paul Guthiga is interested in supervising a MSc thesis on assessing certain characteristics of the LNRA with respect to exclusion and inclusion of different stakeholders that will decide on whether the organisation can in the long run be successful in setting up a sustainable common pool regime.

**Stephen Mailu** at KARI is very much supportive of our planned research and ready to provide information and contacts. He has a Masters degree in Environmental Studies (Environmental Economics) from the School of Environmental Studies, Moi University. His MPhil thesis was on the “Household Welfare Impacts of water hyacinth (*Eichhornia crassipes*) in the Kenyan side of Lake Victoria. The programme was supported by the Regional Lake Victoria Environmental Management Program in collaboration with the School of Environmental Studies, Moi University. Stephen has accumulated over 10 years working experience at the Kenya Agricultural Research Institute in various research and management capacities and has coauthored more than 10 publications over this period. Stephen has also lectured resource and environmental economics and entrepreneurship to students of wildlife, tourism, fisheries and environmental management at the Kenya Wildlife Service Training Institute. In addition, he has been involved in several taskforces including the team preparing the Protocol on Environment and Natural Resources under the auspices of The East African Community Secretariat.