**Where have all the meadows gone?**
**Integrated modelling of socio-ecological systems: farm households, agrarian subsidies and land-use change**

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**Abstract**
This paper presents a land-use change model of a small Austrian community integrating an agent based module simulating the social actors with a stock and flow module simulating the carbon and nitrogen stocks and flows of society and ecosystems. The model was constructed in a participatory process and will be used to discus sustainable livelihood options for the municipality.

**Keywords**: Integrative participatory agent-based-modelling, land-use change, socio-ecological system, Upper Austria

## 1. Introduction

Reichraming a small rural community in the Ennstal of Upper Austria has faced a changeful past. Its plentiful forest and water resources powered the energy demands of an early iron industry in the region, which once was one of the European iron producing centres. With the decline and finally disappearance of these industries in the 19th century and the substitution of wood as an important energy source and construction material the importance of the region vanished.
Today the municipality is characterized by a declining population, a high number of commuters and an increasing loss of village infrastructure like local suppliers. For the inhabitants of Reichraming these changes also manifest themselves in an increasing forest cover (today already over 80% of the municipality are covered by forest). This is seen as a consequence of farmers giving up their traditional occupation and replacing their meadows through less work intensive forests.
In this project we developed an agent based model of the municipality which combines aspects of the social and economic systems with aspects of the natural systems with the goal to discuss possible sustainable development paths of the municipality and to gain a better understanding of the linkages between natural and human systems.
Our model combines an agent-based module (ABM) (i.e. Weiss 1999, Ferber 1999) used to simulate farm households and other relevant actors of the region with a system-dynamic module that can simulate changes in land use and substance flows. In this way the model is able to simulate both socio-economic processes and socio-economic and ecological material and substance flows and their interdependency.
Following research questions will be addressed within this project:

- What are the influences of changes in subsidies and agricultural product prices on land use?
- How do political interventions affect the type of agricultural production, farm income and family working time?
- How do socio-economic decisions influence land-use change and how does this change influence the carbon flows of a region?
- What are possibilities and constraints of participatory model building?

## 2. Background Reichraming

The community of Reichraming is situated in the valley of the Enns in Upper Austria. It partly lies in the borders of the national park Kalkalpen. In its past it could draw on the immense wood reserves of the Reichraminger Hintergebirge, the waterpower provided by its streams and the proximity of iron deposits in the region to develop a flourishing industry. At the beginning of the 20th century however most of this industry had collapsed and bit by bit left Reichraming. Wood based industry remained important until the sixties of the last century. Nowadays Reichraming is a typical small rural mountain community, with a high rate of commuters and decreasing population rates.

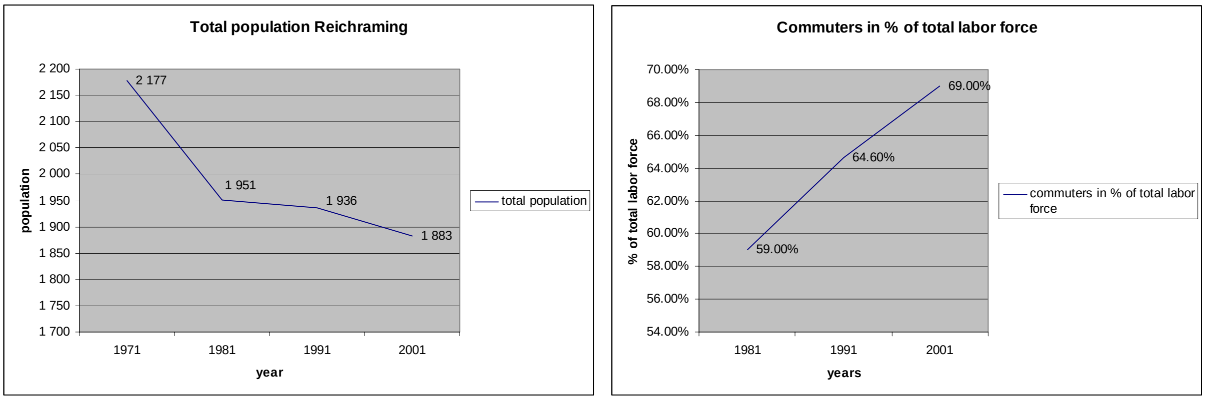



***Figure 1:*** *Population development and number of commuters in Reichraming for the last 40 years. Population is declining whereas the number of commuters is rising.*

Due to the steep slopes farming is hard and the profits are marginal. Farming is mainly based on livestock farming for milk and meat and on forestry. Owing to the hard conditions more and more farmers are giving up their occupation. Meadows are turned into forests because of the smaller workloads or are left for natural succession. This leads to an increasing forestation of the community. Today already more then 80% of the total community area are forested. This landscape change is perceived as one of the urgent problems in the community.

In 1997 the National Park Kalkalpen was established in the region. About one third of the municipality area lies within the borders of the national park. Most of the land covered by the national park belongs to the Austrian Federal Forests (ÖBF), which consequently represents the largest landlord of the municipality. The planning phase of the national park was characterized by serve conflicts between farmers, ÖBF, and other local actors fuelled by resentments between different political parties and their local representatives. These conflicts partly have not been resolved until today.

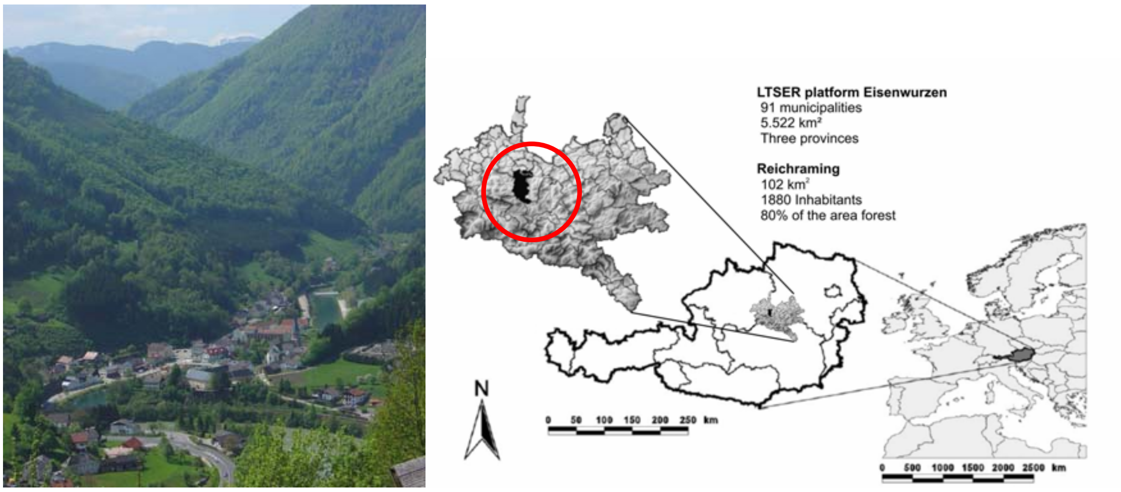



***Figure 2****: Picture of the village and Map showing the location of the municipality of Reichraming.*

Despite its beautiful scenery and proximity to the national park tourism is not strongly developed in Reichraming. Only limited accommodation facilities exist and most of the tourists only stay for a daytrip.

In the recent years some initiatives have been started to make Reichraming more attractive. The most successful being a so-called “innovation centre”, which hosts a national park information centre and provides infrastructure for small to medium sized local businesses. This centre was created in cooperation with one neighbouring municipality.

## 3. Methods

### *3.1 Integrated Modelling*

Although Agent based models have gained ground in LUCC modelling in the recent years (i.e.: Parker 2002 & 2003; Verburg 2004, McConnell 2001; Koomen 2007) truly integrated models (i.e. Matthews 2006) are still the exceptions. Our model represents a new generation of integrated models. It combines an agent-based module used to simulate farm households and other actors of the system with a system dynamic module that simulates changes in land use and accordingly subsistence flows such as nitrogen or carbon flows. Thus, the model as a whole allows simulating changes in socio-economic structures such as income and workload of farmsteads as well as land use and land cover.Questions about the development paths of complex real world systems can often not be answered with conventional models / scientific approaches. Finding answers to these questions usually implies looking across disciplinary borders and often also the involvement of other actors and therefore requires the use of inter- or transdisciplinary methods. If the system under question is a coupled human and nature system (Liu et al 2007) respectively a socio-ecological system (Fischer-Kowalski und Weisz 1999) approaches including experiments are often ruled out either due to ethical questions or practical reasons. This is especially true if the hypotheses about system development concern elements relevant to society (Schellenhuber1998). Modeling can provide a virtual copy of the system and allow exploration of system linkages and interdependencies thus providing insights on possible and desirable development paths.

### *3.1 Participative Modeling & Stakeholder Process*

Participatory agent based social simulation as used in this project deviates in a number of ways from conventional modeling. The actors themselves whose behavior is simulated in the model have to be involved intensively during all stages of the modeling process from the model design to model parameterization, and discussion of the model results (*figure.3* & *figure. 4*).
To make the most use of a model in a transdiciplinary context an integrative and participative modeling approach (IPM) should be adopted. Traditional modelling often only focuses on the construction of an analytical model and neglects the other building blocks of the modelling process (figure.3). The usability of a model will increase largely when all blocks and the interaction between them (i.e. information flows) are taken into account and are considered during the whole the modelling process. If the stakeholders are part of the model creation (red lines) participative modelling takes place.

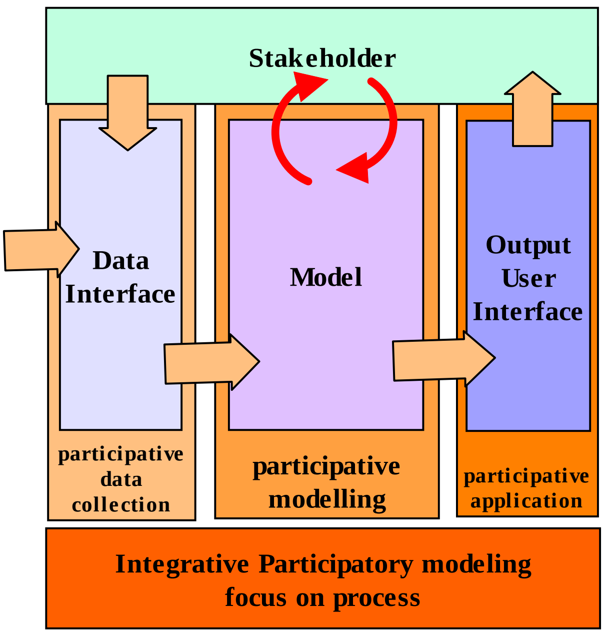



***Figure 3****: The buildings blocks of the modelling process, with arrows representing information flow. If all building blocks and the interaction with the stakeholders are considered integrative participatory modelling takes place.*

The stakeholder process starts right from the beginning to find out the relevant problems and questions of the actors and to discuss the contribution of the model concerning possible problem solutions.
Interviews, focus groups and workshops allow discussing research questions, model assumptions and model design. This guarantees that the model captures issues that are of relevance to the actors involved. In interaction with the stakeholders local knowledge about the system is collected through different methods of participative data collection, which can range from interviews to focus groups, role playing exercises, participative mapping and so on. This local knowledge in combination with available scientific knowledge results in a common understanding of the system. Usually this is done in an iterative process where the heuristic model is changed and

modified when new insights about the system emerge (figure 4). In a second iterative loop the model is formalized to allow for simulation i.e. to test scenarios. The results are fed back and discussed with the stakeholders. Learning is an integral part of participative modeling. It should take place on both sides (science and public / actors). Ideally through the exchange and combination of existing local and scientific knowledge, throughout the modeling process, novel insights of the system are gained.

In a holistic modeling exercise all parts of the modeling process (figure 3) are seen as an important contribution to the attempt of influencing or understanding the real system.

Focusing on the modeling process implies considering the whole interaction with the stakeholders as part of the modeling exercise. This requires a careful design of data collection methods (input interface) participative model construction phase and interface for the use of the final model or model results in the local SES right from the beginning. One advantage of this holistic view on modeling is that some parts of the system, which can be difficult to model with some mathematic formulas or computer code, like human behavior, can be included i.e. by letting real people play with the model representing the system of interest (i.e. Antona 2003, Dray 2007). Additionally for the stakeholders themselves the information gained during the modeling process may be as valuable as the final outputs produced by the model.

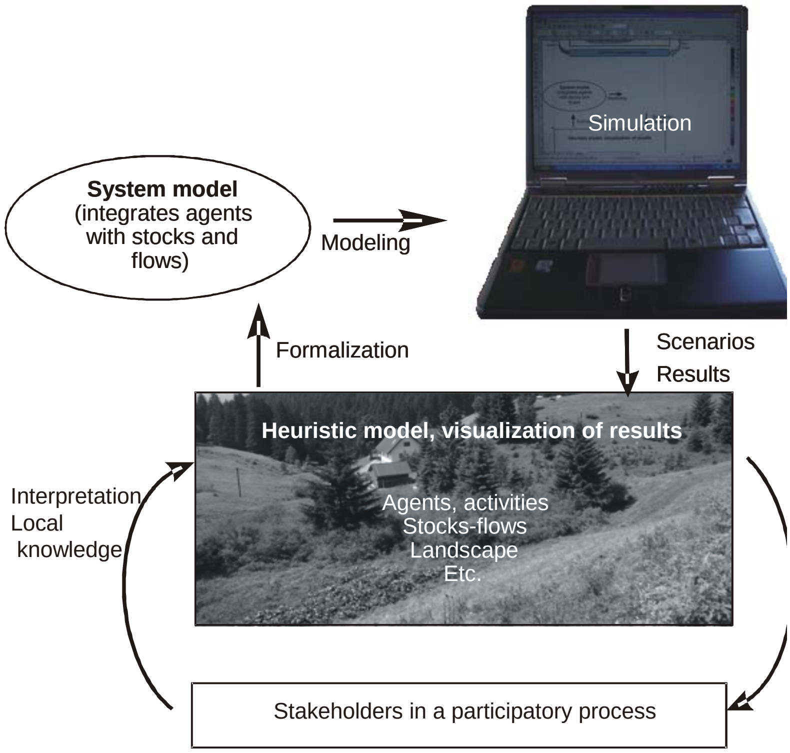



***Figure 4**. Participative modelling and the iterative interaction with the stakeholders*

### *3.3 The Integrated Model of Reichraming*

Right from the beginning, relevant regional actors (farmers as well as politicians, representatives of tourism, industry and manufacturing, and national park) were involved in the modelling process. One major problem identified by the stakeholders in this region is the re-forestation process, which is also seen as a symptom for other underlying problems such as landflucht due to missing infrastructure and opportunities for employment. Communication between different stakeholders in this SES is rather difficult, especially between farmers, municipality and the national park management. This has led to a boycott of rules and lock in situations.

### *3.4 Model structure*

Seven important groups of actors could be identified for Reichraming and were implemented as agents in the model. Three of them namely National Park, ÖBF and Cooperatives do not receive feedback

from the system, as the assumption is that their behaviour is mainly driven by external factors and decisions on higher scales. From the remaining five agents the farms were modelled with most details.
The factors or concepts found to be most relevant to the stakeholders: could be grouped into four fields: Infrastructure (includes social and physical infrastructure), labour market, budget (of municipality) and landscape.

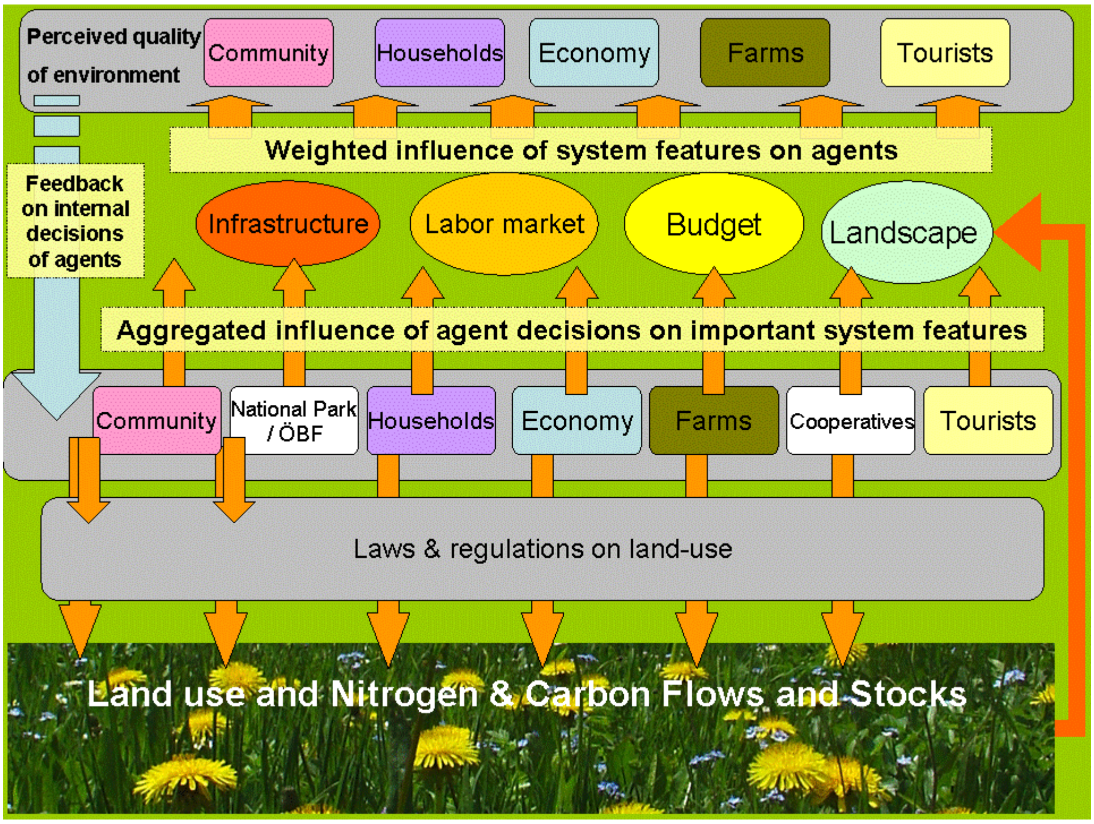


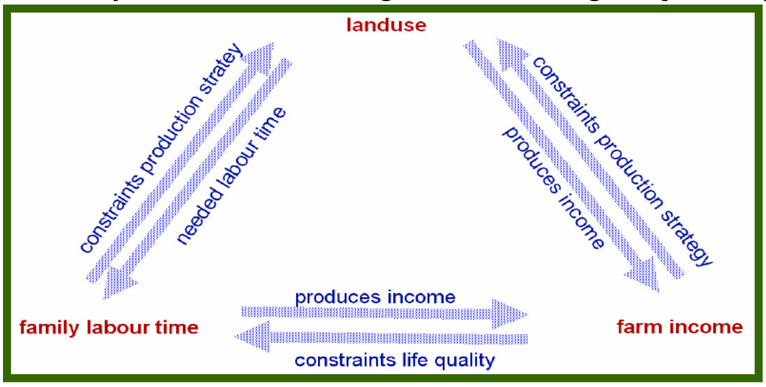

***Figure 5**: Conceptualisation of the Reichraming model. The decisions of the agents influence the environment (Infrastructure, Labour market, Budget, Landscape) the agents react to changes in their environment according to their decision rules.*

All agents except the tourist agent influence the landscape via land use and land-use change and consequently the nitrogen and carbon stocks and flows according to internal decisions and some predefined rules and regulations provided by external policy. The agent community has the possibility to influence some of these rules and regulations i.e. through re-zoning.
The other concepts are influenced by all agents. Changes in these concepts trigger changes in the behaviour of the agents and link their decisions to each other.
I.e. low income for farmers may lead to an increasing forestation as the farmers need engage in of farm work and opt for the less time consuming forestry. This in turn may lead to a less attractive landscape for households (more forests), which will reduce the number of households. Fewer households have an effect on the budget of the municipality and may result in a reduced infrastructure – which again reduces the quality for the households.

### *3.5 Structure of the farm agents*

Each farmer agent is implemented with land and a set of livestock corresponding to the spatially explicit data available. The decision-finding process of each farm is analysed along a ‘sustainability triangle’ (figure 6) in which each corner represents one of the core sustainability corners (social / ecological / economic dimension). To apply this so-called ‘magic triangle of sustainability’ (Fischer-Kowalski 1997) for farms, we have chosen following three dimensions:
1) Agricultural production, such as land use and livestock (ecological dimension)
2) Income of all family members, living on the farm (economic dimension)3) Family labour time (social dimension)

The interactions between the three corners can be described as follows:
Land use and time use: Every strategy of using land requires a specific amount of working hours. According to the number of people living on a farm only a certain amount of working hours is available.
Land use and income: Each square meter and each agricultural activity needs and creates a certain amount of income.
Time use and income: Time used as working time determines the amount of income. In turn, income constraints activities in leisure time or require working time.
The analysis of decision-making within this triangle requires implementing each agent with its internal




structure in terms of family structure such as family members living on the farm, their age, task on the farm (i.e. agricultural working time), etc. The actors themselves whose behavior is simulated in the model have to be involved intensively during all stages of the modeling process.

### *3.5 The Interface*

The interface is an important – yet often underestimated – part of every model. It should fulfill following requests:

- Easily understandable
- Showing just the most relevant (for the respective stakeholder) information on the surface
- Allowing to play with the model

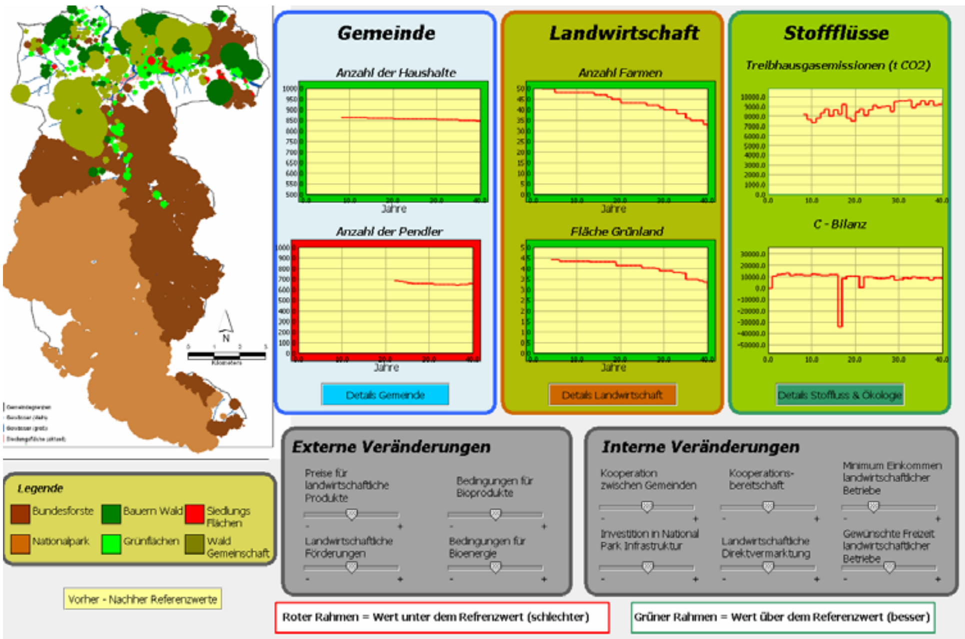



***Figure 6**: The main interface screen of the model with a map, sliders, and output graphics.*

The Interface of the Model displays a map showing changes in land-use and land-cover (settlement, grassland, forest, national park) in run-time with a distinction between land tenure regarding the federal forest agency (ÖBF). The model provides more detailed information on land use land-use

changes, which are not displayed at run-time but will be used to produce more detailed maps with GIS software.
Further 15 important indicators and variables are displayed in graphs. They cover economic, social and ecological realms, indicated by the different colors used. They are organized in one main screen displaying six graphs and three thematic screens (agriculture, municipality, ecology) displaying the remaining graphs. On a fourth screen a comparison between start and end values of the run and a comparison with results of the reference run can be made.
Ten sliders provide the possibility to influence some exogenous and indigenous parameters of the model during run-time. Some sliders influence more then one parameter as they already represent certain development paths / scenarios i.e. the slider affecting the conditions of organic farming influences subsidies as well as prices.

Sliders can be differentiated between sliders that influence endogenous parameters such as:
- Willingness to cooperate in the system
- Willingness to cooperate with other (external) municipalities.
- Desired minimum income in the farming sector
- Minimum recreational time in the farming sector
- Investments in the national park infrastructure

and external parameters such as:
- Prices for agricultural products
- Agricultural subsidies
- Conditions for organic farming
- Conditions for bio-energy

**4. First results of the participatory modeling process and model runs**

Our experience with participatory modelling shows the ability of models to structure the information coming out of a participatory process. The different stakeholder groups could be involved in the discussion and delivered information on their view of the system. Through observing the interactions between stakeholders and comparing their views of the system, information about conflicts and contradictions between them could be gained. It became clear how important the modelling process itself is in the context of problem oriented modelling. However the participatory process had to be designed carefully to be effective.

First results from the model itself suggest that the decline of farms will go on, not so much influenced by changes in agricultural policies but more through the social situation i.e. regarding the availability of successors.
Area based subsidies do not influence the number of farms surviving to such a big extend. More important are socially and demographic determined factors i.e. availability of a successor, desired minimum working times - or minimum incomes.
Organizations conveying cooperation like the ”Maschinen Ring” enable the farmers to remain their traditional occupation and avert that privately owned forest is incorporated into the federal forest agency (ÖBF).
An increase in bioenergy demand would bring benefits for municipality and households in terms of job possibilities and also for farmers as additional income would be available.

**5. Conclusion**

The aim of providing a model of the local Socio ecological system (SES) (including the human agents and biophysical flows in human- and ecosystems) acceptable by all stakeholders could be achieved by involving all relevant actors in the modeling process right from the beginning. The model can be used as starting point for discussions on the future development of the SES making clear the direct and indirect links between the different stakeholders and the opportunities of cooperation and communication vs. conflicts and stillness.

Benefits for the stakeholders already arose during the modeling process as they could compare and discuss their different views on the system. It became clear that many of their problems were connected to each other and could only be solved if they worked together.
The last phase of the project – presenting and discussing the model results in Reichraming and developing scenarios – is not completed yet, but will be presented on the conference.

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