ODD PROTOCOL FOR ALUAM-AB

Written by Robert Huber[1], Stefan Lauber[1] ,Adrian Iten[2] and Simon Briner[2]

1 Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zürcherstrasse 111, 8903 Birmensdorf, Switzerland.

2 Swiss Federal Institute of Technology. Institute for Environmental Decisions, Agri-food & Agri-environmental Economics Group, Sonneggstrasse 33, 8092 Zurich.

For correspondence please contact: Simon Briner, briners@ethz.ch

Zurich, 30 January 2012

Purpose

The purpose of ALUAM-AB is to understand agricultural land-use changes triggered by market and policy changes considering individual preferences of the farmers. The consequences of changes in prices and policy measures relating to agricultural land-use activities can be simulated. With respect to the respective study area, spatially explicit information on agricultural activities (spatially explicit grassland and forest yields) allows for a viable linkage with the ecological models WoodPaM[12] (Peringer et al. 2012).

State variables and scale

Agents represent individual farms or groups of identical (with relation to structure and preferences of farmers) farms. Information on preferences for agricultural activities, household composition and available resources (land, capital, labor) were compiled in individual interviews with the farmers. Important parameters with respect to the individual characteristics of the farmers are: the point in time of their retirement (65 years), whether or not they have a successor, their intention to increase farm size, their demand for leisure time, and their preferences concerning specific production activities (e.g. milk production is preferred to meat production despite lower income). The interviews also allowed for a definition of the mosaic of fields per farm and in the whole case study region.

Natural conditions of the different fields and potential fodder production are integrated using results of the vegetation model WoodPaM. In the vegetation model, the following land and soil characteristics are used as input for each field: altitude, slope, aspect, rock outcrops, soil depth, carbon and nutrient cycling rates, past and current vegetation, climatic data and scenarios based on observed data from 1901 to 2000 (interpolated monthly Temperature and Precipitation) and expected driving parameters according to IPCC scenarios.

The smallest landscape unit in ALUAM-AB are the paddocks as they are used by the individual farmer. A higher resolution of the model would not provide additional information since land-use activities are homogenous on these fields and the representation of vegetation dynamics in WoodPaM would not be improved. Since WoodPaM models vegetation on a higher spatial resolution of $25m^2$ these parcels are aggregated to the level of the current

[1] WoodPaM is separate, specialized model and not included in this package.

[2] In this protocol a combination of ALUAM-AB with the landscape model WoodPaM is shown. It is however also possible to combine ALUAM-AB with other forest-landscape models as LandClim (see Briner et al. 2012)

paddocks for a transfer between the models. In contrast, with a lower resolution (e.g. at farm level) important information with respect to land-use intensity would be lost.

Agronomic parameters with respect to fodder intake, nutrient balance and production efficiency (e.g. growth, birth, deaths of animals) are based on Swiss average data (Briner et al. 2012). Production related variables, e.g. the number of livestock or the amount of hay sold, are aggregated at farm level and represent aggregated values over one year. In the optimization process these variables are optimized under the consideration of different balances that link land-use activities with livestock activities: fodder and nutrient balances. As a result, land-use intensities are defined in a spatially explicit manner.

Given the focus on individual farmers, in our approach the temporal scale of the model is limited to 15-25 years. Scenario parameters for prices and costs were derived from project based context scenarios (Briner et al. 2012). These are consistent with base assumptions of the existing set of global greenhouse gas emission scenarios (IPCC SRES) and thus with the climate simulation data used for model-based impact assessment (Walz et al. 2012). The effective data followed the development presented in Abildtrup et al. (2006).

Process overview and scheduling

ALUAM-AB proceeds in annual time steps. The agents allocate their available resources in order to maximize land rent (income from the specific fields). Thereby they consider natural, farm level and individual constraints as well as incentives and regulations from the market and policy instruments. Investments in production capacity done in precedent years are considered as sunk costs representing path dependencies on the individual farms.

Structural change is modeled using a land market module based on Lauber (2006a). The model determines fields that are no longer cultivated under the existing farm structure. There are mainly 3 reasons why fields go into the land-market: Fields provide a land rent below zero, the corresponding owner of the farm does not reach a minimum wage of 30 kCHF per year that is why the farm is abandoned and all the assigned land enters the land market or the farmer is retired in the simulation year and all his land comes to the market. The land market module randomly assigns the field to one of the other farms. It is then checked if this farm shows the 2 following characteristics: The farmer receiving the field must want to expand the cultivated area and his shadow price of the land must be positive. If these conditions are not met the field is returned to the land market and assigned randomly to another farm. It is then again checked if conditions to assign the field to this farm are fulfilled. This procedure is continued until all parcels are assigned to a farm or none of the farms is willing to take the fields left in the market. Fields that are not transferred to other farms are defined as abandoned. Natural vegetation dynamics get under way on these fields (explicitly modeled in WoodPaM). If land-use allocation at farm level is optimal (both from an economic and individual perspective), farm equipment, capacities and livestock are updated and the next annual time step is initialized using the parameters (prices, costs) of the following year. In this step, the modifications due to climatic and management changes calculated in WoodPaM are used to update the spatially explicit yield potential in ALUAM-AB.

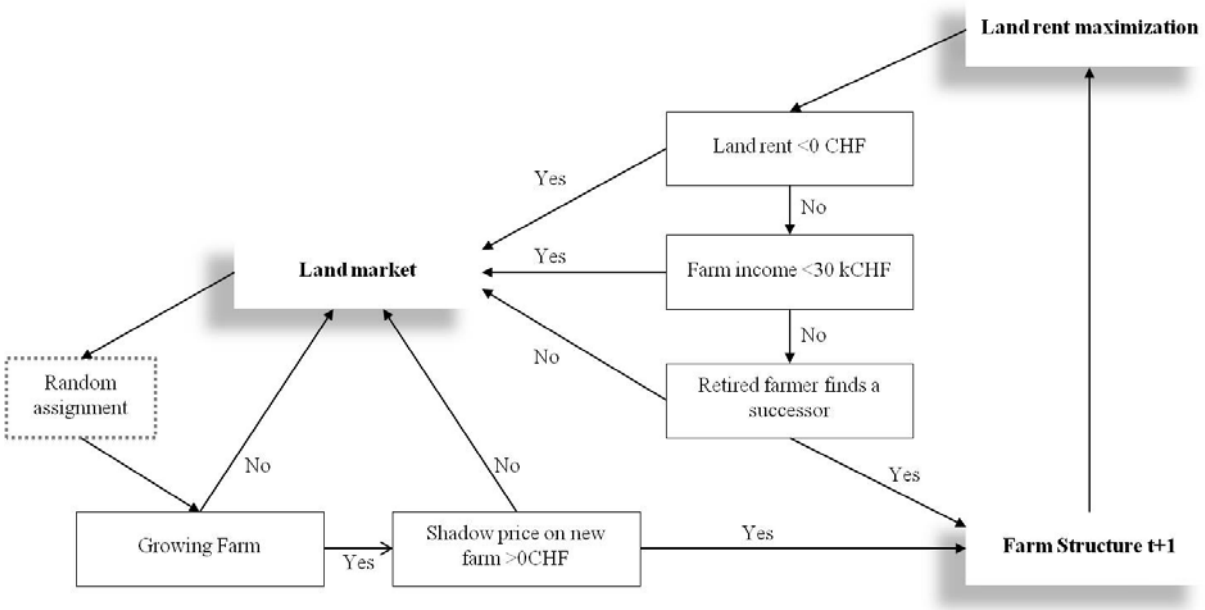

Figure 5: Process of farm structural change in ALUAM-AB

The interaction between ALUAM-AB and WoodPaM is modeled in the following sequence: While each model is driven by (synchronized) time series of climate or agronomic constraints, farm structural change is passed from ALUAM-AB to WoodPaM in terms of stocking density per field and vegetation response is transferred from WoodPaM to ALUAM in terms of forage productivity of the fields. This data exchange happens every 5 years, starting in year 2000.

This results in timely delayed model coupling, according to the following protocol: During each 5-years-period, ALUAM uses the average yearly forage production of fields as simulated by WoodPaM during the period before and simulates yearly livestock allocation per field for 5 years, considering contemporary socio-economic constraints of farms, but timely constant forage productivity. After that, WoodPaM uses the yearly time series of stocking densities per field and simulates vegetation response, from which the average productivity of fields during the current period is calculated, considering climatic variability. Closing the local feedback loop productivity is transferred to ALUAM again as the input variable for the following 5-years-period.

We follow this protocol from 2000 until 2034, where reliable predictions of agronomic developments end. Since ALUAM-AB is based on the characteristics of the current farmers, the model is interrupted in 2035. However, we expect long-term consequences of management decisions due to the slow response of landscape structure. To pinpoint successional trends that have been triggered by today's management decisions, WoodPaM continues its simulation with stocking densities simulated in ALUAM-AB for year 2034 for another 100 years.

Design concepts

Emergence
Structural change on farm level emerges from an endogenous development determined by prices, policies and individual preferences which are given exogenously. In addition, land-use

patterns (intensity levels of land-use) emerge from the main outcome of the structural changes on farm level.

Adaptation
Farmers respond to climatic and socio-economic as well as policy changes by adjusting their production activities, applying new production technologies, increase (or decrease) land size, and adjust land-use intensities. In addition, farmers also exit the sector if their income falls below a certain limit (30 kCHF).

Objectives and prediction
Agents maximize their net agricultural income based on yearly price and cost parameters. However, the maximal income is constrained by individual preferences and attitudes towards production activities and individual expectations concerning leisure time and well-being. Thus, the fundamental concept behind our approach is rational economic behavior (land rent maximization). However, the consideration of individual constraints leads to a consideration of non-economic goals in the decision making process as well (see Lauber 2006b).

Agent-environment interaction and observation
The interaction between the farmers and the environment is based on the model linkage of WoodPaM and ALUAM-AB. Detailed information on spatially explicit natural conditions (e.g. grassland yields) are provided by the WoodPaM model (see: Gillet 2008, Peringer et al. 2012).The corresponding maps are used as an input for ALUAM-AB. The spatially explicit information following the optimization procedure is then re-entered into the vegetation model. These maps can be used to illustrate the changes in land-use dynamics.

Initialization
Initial attributes for households were set using the information from the interviews along with farm census data of the FOAG. In addition, the modeling results from WoodPaM were used to calibrate existing land-use intensities on field level. The corresponding results were verified with local experts (Chételat et al. 2012). The validation of the ALUAM-AB model showed satisfying results with respect to livestock numbers, farm structures and income.

Input
Information with respect to natural conditions are derived from the WoodPaM model. Price and cost developments are derived from scenarios for the European agricultural sector (Abildtrup et al. 2006). Policy and climate changes follow from an interdisciplinary development of scenarios for our case study region (Walz et al. 2012).

Submodels
ALUAM-AB consists of individual farms which again are modeled using different submodels for plant activities and livestock activities. A detailed description of these modules can be found in Briner et al. 2012.

If you would like to receive more detailed information about ALUAM-AB please contact Simon Briner, briners@ethz.ch

References

Abildtrup, J., E. Audsley, M. Fekete-Farkas, C. Giupponi, M. Gylling, P. Rosato, and M. Rounsevell. 2006. Socio-economic scenario development for the assessment of climate change impacts on agricultural land use: a pairwise comparison approach. Environmental Science & Policy **9**:101-115.

Briner, S., R. Huber, C. Elkin, and A. Grêt-Regamey. 2012. Assessing the impacts of economic and climate changes on land-use in mountain regions: A spatial dynamic modeling approach. Agriculture, Ecosystems & Environment (accepted**)**.

Chételat, J., T. Kalbermatten, T. Spiegelberger, F. Gillet, J.-B. Wettstein, A. Peringer, and A. Buttler. 2012. A contextual analysis of observed land-use and vegetation changes applied to two wooded pastures in the Swiss Jura Mountains. Ecology and Society (Submitted to Ecology and Society).

Gillet, F. 2008. Modelling vegetation dynamics in heterogeneous pasture-woodland landscapes. Ecological Modelling **217**:1-18.

Lauber, S. 2006. Path-Dependent Change in Agricultural Structure in Two Mountain Areas in Switzerland. A Spatially Explicit Modelling Approach. . In: Mann, S. (Hrsg.). Causes and Impacts of Agricultural Structures. Nova Science Publishers, New York: 77-97.

Lauber, S. 2006a. Agrarstrukturwandel im Berggebiet. Ein agentenbasiertes, räumlich explizites Agrarstruktur- und Landnutzungsmodell für zwei Regionen Mittelbündens. Dissertation ETH Zürich. ART-Schriftenreihe 2. Agroscope Reckenholz-Tänikon ART, Ettenhausen. 216 pp. .

Peringer, A., J. Chételat, K. Gavazov, T. Spiegelberger, F. Gillet, and A. Buttler. 2012. Past and future landscape dynamics in wooded pastures of the Jura under land use and climate change. Ecology and Society (Submitted to Ecology and Society).

Walz, A., J. Braendle, D. J. Lang, F. Brand, S. Briner, C. Elkin, C. Hirschi, R. Huber, H. Lischke, and D. R. Schmatz. 2012. Experience from customising IPCC scenarios to specific national-level focus scenarios for ecosystem service management. Technological Forecasting and Social Change (accepted).