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ÖSTERREICHISCHES INSTITUT FÜR WIRTSCHAFTSFORSCHUNG

ADAPT-CATMILK – Adaptation in Austrian Cattle and Milk Production

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Research assistance: Dietmar Weinberger (WIFO)

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AUSTRIAN INSTITUTE OF ECONOMIC RESEARCH

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Austrian Institute of Economic Research
University of Natural Resources and Applied Life Sciences, Vienna, Institute for Sustainable Economic Development

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Abstract

Climate change will pose considerable challenges to Austrian agriculture which will likely be affected by a higher frequency of extreme weather events and more volatile commodity prices. In this project the spatial, economic and social dimension of these threats were explored and expected consequences for the most important agricultural activity in Austria, cattle and dairy farming were evaluated. By aligning scenarios on projections of climate conditions and socio-economic developments with those developed in other EU countries, the results are consistent with state of the art analyses on climate change in Europe. A well established life cycle analysis (LCA) model from the UK was adapted to the Austrian situation in order to quantify upstream emissions which are usually not accounted for in sector analyses of green house gas emissions. The results allow policy makers to base their decisions on evidence that is not limited to the Austrian situation but includes spillover effects to foreign countries as well. Farmers are able to benefit directly from results of this project because stakeholders from the farm sector were involved in the analyses from the beginning. An additional benefit of the project is that it was closely integrated to the activities of the international network of researchers working on climate change and food security in Europe and thus contributed to the capacity on climate change research in the EU.

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A) Projektdaten / Project data

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KoordinatorIn/ ProjekteinreicherIn:	Franz Sinabell
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B) Projektübersicht / Overview of the project

1 Kurzfassung

Problemstellung

Die Rinderhaltung und die Milchproduktion zählen zu den wichtigsten Produktionszweigen der Landwirtschaft in Österreich. Anders als in vielen anderen Ländern der Welt ist die Futtergrundlage vor allem Feldfutter, sowie Gras von Wiesen und Weiden. Die Futterflächen werden nicht beregnet. Im internationalen Vergleich sind die Emissionen von Treibhausgasen gering.

Szenarien zur Entwicklung des Klimas in den kommenden Jahren geben Anlass zur Erwartung, dass vor allem in alpinen Lagen tiefgreifende Änderungen zu erwarten sind. Änderungen im Verlauf der Jahresniederschläge, höhere Temperaturen, eine stärkere Varianz der Regenfälle mit häufigeren Dürren wird zu einer Steigerung der Produktionsrisiken führen. Die in der Produktion eigesetzten Tiere werden wahrscheinlich auch unter höherem Hitzestress zu leiden haben.

Landwirtinnen und Landwirte reagieren auf Änderungen in der Umwelt, wie dem Klimawandel, durch Anpassung der Produktion und der Nutzung der Flächen, um die Ressourcen des Betriebes bestmöglich zu nutzen. Es liegen zahlreiche Untersuchungen darüber vor, mit welchen Maßnahmen es gelingen kann, die Umweltbelastungen in der Rinder- und Milchviehhaltung zu verringern. Weniger bekannt ist, welche Möglichkeiten sich für Betriebe eröffnen, mit den veränderten Witterungsbedingungen im alpinen Raum zurecht zu kommen.

Die Ziele des Forschungsvorhabens waren

- herauszufinden, wie Landwirtinnen und Landwirte in der Rinderhaltung und Milchproduktion mit den veränderten Klimabedingungen umgehen können, um weiterhin wettbewerbsfähig zu sein und die Gesundheit der Nutztiere zu erhalten;
- Möglichkeiten zu finden, die Umweltbelastung zu verringern und politische Anreize zu identifizieren, die ihre Inanspruchnahme ermöglichen;
- quantitative Bewertungen darüber vorzulegen, wie sich umweltpolitisch motivierte Eingriffe und veränderte Produktionsbedingungen aufgrund von Änderungen der Möglichkeiten, der Erträge und Preise auswirken können;
- Forschungskapazitäten in der Forschungsgemeinschaft in Österreich aufzubauen durch die Abhaltung eines Kurses zur Lebenszyklus-Analyse;
- bestehende quantitative Modelle zu erweitern, im Speziellen um ein Lebenszyklus-Analyse-Modul, das im Vereinigten Königreich entwickelt wurde und an die Bedingungen in Österreich angepasst werden sollte;
- die Ergebnisse der Untersuchung in der Forschungsgemeinschaft und darüber hinaus in Plattformen einzubringen, die sich auf den Einsatz in der Praxis ausrichten.

Methoden, Ergebnisse und Schlussfolgerungen des Projekts

Im Rahmen des Projekts ADAPT-CATMILK wurden bestehende Methoden verbessert und erweitert sowie neue methodische Zugänge geschaffen:

- Ein bestehender integrierter Modellverbund mit zwei Varianten eines Modells des österreichischen Agrarsektors (PASMA und PASMA[grid]) wurde weiterentwickelt und es wurden neue Schnittstellen entwickelt, um quantitative Analysen auf unterschiedlichen räumlichen Ebenen durchführen zu können.

- Auf einer sehr detaillierten räumlichen Ebene wurde ein Grünlandmodell entwickelt, um künftigen Ertrag von Gräsern abschätzen zu können.
- Ein innovatives Daten- und Kostenanalyse-Werkzeug wurde entwickelt (index-based costs of agricultural production – INCAP). Damit können landwirtschaftliche Prozesse und die Kostenentwicklungen auf sehr detaillierter Ebene analysiert und prognostiziert werden.
- Ein für das Vereinigte Königreich entwickeltes Lebens-Zyklus-Analyse-Modell wurde an die Produktionsbedingungen in Österreich angepasst. Somit ist es möglich, die beiden bestehenden Agrarsektormodelle PASMA und PASMA[grid] um ein Lebenszyklus-Analyse-Modul zu ergänzen.

Eine wichtige Verbesserung gegenüber der Ausgangslage war die Weiterentwicklung von Schnittstellen und die kohärente Integration weiterer Module in den bereits zu Beginn des Projekts bestehen integrierten Modellverbund-Rahmen. Damit können nun wichtige Fragen im Zusammenhang mit der Anpassung an veränderte Klimabedingungen in der österreichischen Landwirtschaft genauer und besser analysiert werden. Die Implikationen von Maßnahmen zur Verringerung der Treibhausgasemissionen können nunmehr ebenso besser untersucht werden. Es ist somit eine Infrastruktur geschaffen worden, mit der es möglich ist, Auswirkungen und Folgen des Klimaschutzabkommens von Paris im Jahr 2016 in hohem Detailgrad und zeitnah zu untersuchen.

Aus der Zielstellung ist ersichtlich, dass im Zentrum des Projekts nicht ein einzelner Untersuchungsgegenstand war, sondern dass es darum ging, einen bestehenden Werkzeugkasten zu erweitern, um vielfältige Fragen beantworten zu können. Nach Ablauf des Projekts können drei zentrale Schlussfolgerungen gezogen werden:

a) Um die Gefahren und Chancen, denen die Landwirtschaft unter veränderten Klimabedingungen ausgesetzt ist, bestimmen zu können, ist es nötig, der großen Heterogenität der Produktionsbedingungen Rechnung zu tragen.

b) Politische Eingriffe zur Erleichterung der Anpassung bzw. zur Unterstützung von Maßnahmen zur Vermeidung der Klimabelastung müssen in einem breiten Kontext betrachtet werden. Das Augenmerk lediglich auf den Agrarsektor zu richten reicht nicht aus. Es sind die Bedingungen im Produktionsumfeld, die vertikalen Verbindungen zwischen den Sektoren und die Außenhandelsbeziehungen zu berücksichtigen. Die Effektivität einzelner Maßnahmen kann ohne Beachtung dieser Kontexte nicht ausreichend bewertet werden.

c) Die Unterstützung landwirtschaftlicher Betriebe bei der Anpassung an veränderte Klimabedingungen und die Schaffung wirksamer Anreize zur Verringerung der Treibhausgasbelastung durch die Landwirtschaft sollte zur Priorität in der Agrarpolitik werden.

2 Executive Summary

Problem statement

Cattle and dairy farming are the most important farming activities in Austria with respect to the value of production. In contrast to many other systems around the globe, Austrian cattle and dairy farming heavily relies on forage production from rain-fed permanent grasslands and therefore greenhouse gas (GHG) emissions are relatively low compared to other systems.

Climate scenarios indicate that changes are expected to be exceptionally severe in alpine regions. Changing patterns of rainfall and more frequent droughts would impose the risk of significant adverse consequences for forage production in Austria. Cattle and dairy farming may also be affected by increasing heat stress and new livestock diseases.

Farmers usually respond to external changes such as climate variation by adapting production and land use systems to efficiently utilize and manage their farm resource endowments. There is

abundant literature dealing with measures to reduce GHG emissions from cattle and dairy farming, however, there is less evidence on the options livestock farmers have to respond to adverse climate conditions in Alpine regions.

The targets of the research project were to

- find out how Austrian cattle and dairy farmers can cope with climate change to maintain livestock well-being and competitive farming;
- identify mitigation options and policy incentives to stimulate their adoption;
- quantitatively evaluate likely changes in milk and cattle production due to policy interventions and changes of production conditions (like changes of capacities, yields, and prices);
- build up research capacities in the Austrian scientific community by offering a course on life cycle assessment (LCA);
- account for production spillovers in the quantitative model by adapting results of an existing life cycle model for the UK agriculture to Austrian conditions;
- make the findings of the research available to stakeholders and the scientific community.

Methods, results and conclusions of the project

Various methods were either developed or further improved and finally applied in ADAPT-CATMILK:

- Integrated economic models of the Austrian agricultural sector (including the models PASMA and PASMA[grid]) were further developed and adapted and new interfaces were used to make quantitative assessments at various spatial scales possible;
- a grassland growth model was used to evaluate observed and expected grassland yields in Austria at fine spatial scale;
- INCAP, a system of "indexed-based costs of agricultural production" calculations, was developed that allows to evaluate agricultural production costs in Austria in a very detailed manner;
- a life-cycle model (LCA model) of UK agriculture was adapted to the Austrian situation and an interface was developed that makes it possible to link LCA results to results of two agricultural sector models of Austria (PASMA and PASMA[grid]).

The main achievements of the project are spatially explicit estimates of grassland yields in Austria and newly (INCAP) and further developed tools (PASMA and PASMA[grid]) for the coherent and comprehensive analysis of adaptation and mitigation measures for the Austrian agricultural sector. These tools can be used to evaluate in great detail the challenges for the Austrian agricultural sector due to climate change. They are designed to explore options for dairy and cattle producers in the context of implementing policies and measures aiming to reach the goals of the Paris Agreement (CMA 1) of 2016.

The aim of the project was to use the tools for a diverse set of research questions and not for just one simulation study. Three major conclusions can be drawn from the analyses that have been carried out in the context of this research project:

a) in order to understand the vulnerability of and the opportunities for agriculture due to climate change and its impact on GHG emission it is necessary to account for the spatial heterogeneity of production conditions;

b) when designing policy measures to attain adaptation or mitigation goals that are focused on agricultural production, it is necessary to consider vertical linkages between sectors and supply chains across international borders; the implementation of national policies without regulation of trade flows likely limit the effectiveness of mitigation policies in livestock production;

c) adaptation of agriculture to climate change hazards and its contribution to reduce GHG emission should become a top priority issue in agricultural policy.

3 Hintergrund und Zielsetzung / Problem Statement and Objectives

Cattle and dairy farming are the most important farming activities in Austria with respect to the value of production. In contrast to many other systems around the globe, Austrian cattle and dairy farming heavily relies on forage production from rain-fed permanent grasslands and therefore GHG emission per unit of product is relatively low compared to other systems. Climate scenarios indicate that changes are expected to be exceptionally severe in alpine regions. Changing patterns of rainfall would impose the risk of significant adverse consequences for forage production. Cattle and dairy farming may also be affected by increasing heat stress and new livestock diseases.

Farmers usually respond to external changes such as climate variation by adapting production and land use systems to efficiently utilize and manage their farm resource endowments. There is an abundant literature dealing with measures to reduce GHG emissions from cattle and dairy farming and recent research projects explored cost-effective strategies for Austrian farms. However, there is less evidence on the options farmers have to respond to adverse climate conditions in Alpine regions and there is less evidence on cost-effectiveness at sector level. If available, most studies on climate change adaptation in agriculture focus on croplands, while adaptation in livestock is less frequently assessed.

Besides its vulnerability to climate change, cattle and dairy farming is among the largest emitters of GHG in agriculture. Austria is among those EU member states that expanded milk production after the abolition of the milk quota system in 2015. It may be even the case that the number of heads of cattle will increase after decades of ever decreasing herd sizes. The trend of continuously lower emissions of the cattle and dairy sector would turn around unless emissions per head of cattle or unit of milk can be reduced significantly. To know more about the quantitative capacities of cattle and dairy farms to mitigate climate change is an important contribution in our understanding how to improve the Austrian climate policy.

Mitigation and adaptation are often analyzed separately due to the nature of the problem. But it is also necessary to consider both areas combined to assess the mutual land use benefits of cost-effective farm mitigation and adaption measures. Changing production conditions and economic incentives in Austria may have adverse effects on global scales. Therefore results from LCA have to be an integral part of adaptation and mitigation studies. By linking a well-established inventory and LCA model with the Austrian agricultural production and land use model PASMA this will be accomplished in the project. In order to evaluate the consequences of such measures in a coherent framework it is necessary to consider spillover effects to other countries. This is done by linking the Austrian model to a global model of agricultural production.

There is clear need for an integrated quantitative assessment of the Austrian cattle and dairy sector with respect to climate change mitigation and adaptation potentials. We contributed to filling the existing research gap by pursuing the following research objectives:

1) find out how Austrian cattle and dairy farmers can cope with climate change – and how the public can support them in the context of the program or rural development and beyond;

2) find out how the Austrian cattle and dairy farmers can respond to climate change mitigation – and which incentives will be needed; the analysis will be carried out at NUTS-3 level and the results will be presented in a quantitative manner at the sector level;

3) to quantitatively evaluate in which foreign regions beef and milk would be produced if Austria would reduce the output of beef and milk assuming a given level of consumption by linking the model results on Austria with a global model of agricultural production;

4) to account for international spillovers in a second way by using parameters in the Austrian model analysis that are based on LCA models specifically tuned to the Austrian livestock systems;

5) the team of the LCA offered a course on this method specifically addressing economic modellers and stakeholders in cattle and dairy production in a dissemination task;

6) finally, it was a goal to make the findings of the research available to Austrian cattle and dairy farmers and to the other relevant stakeholders like breeding organisations.

The results of the analysis were planned to be model based and spatially explicit and farm type specific. Results were intended to serve farmers, extension services and the administration for decision support. The findings of the project were planned to help to build the necessary capacities for a swift adaptation to foreseeable changing conditions. For each of the focus groups, special dissemination strategies were to be developed.

The overarching objective of the study was to shed light on the future exposure of Austrian cattle and milk producers to climate change, such as production risks, and to explore options for responses of farmers and policy makers to adjust to changing market and climate conditions. The scenarios that were analysed for Austria were designed to be consistent with those of international researchers working on similar topics in the MACSUR network (www.macsur.eu). ADAPT-CATMILK results were planned to contribute to a better understanding of European agriculture and food security in the context of climate change. Usually, analyses on Austrian agriculture are based on the small country assumption which implies that measures taken in Austria have no effect on the rest of the world. By evaluating the results with the LCA method, this limitation which prevails in many economic studies, were planned to be overcome.

New insights were attained:

a) In-depth analyses of the future of cattle and dairy farming in Austria – quantification of likely changes of herd sizes and likely changes of milk production.

b) Exploration of the regional dimension of changes: Where will cattle and dairy production take place in future and which kinds of driving forces will be the main causes (market conditions and / climate conditions / policy regulations)?

c) Scenarios on likely levels of GHG emissions of the Austrian cattle and dairy sector. Stakeholders were involved in this task. Measures to reduce emissions from the cattle and dairy sector were identified and the consequences of their implementation were quantified. The effects on the overall emissions based on parameters derived from a LCA were evaluated explicitly.

d) A comparison of the results obtained in this study was compared with results from other countries to contribute to a better understanding of the heterogeneity of European farming.

The analysis was designed not to be restricted to the response of cattle and dairy farmers but to cover the whole Austrian agricultural sector. Because land use changes and changes of intensities are important elements of any LCA, the whole farm sector was under scrutiny and the models used for the analyses cover all land uses in Austria.

A central objective of the research project was to contribute to science. The interdisciplinary team of scientists and researchers involved in this project had already a proven competence in the fields of interest but several elements of the project were designed to expand existing research capacities and to further integrate team members in international scientific networks. A pivotal means to achieving this was identified in international publications and the participation in international scientific events.

The project ADAPT-CATMILK is a piece of applied integrated science. The final purpose is to serve certain means and to address obvious challenges of our society. Considerable resources were therefore set aside in order to get farmers involved in the project and to disseminate results not only in scientific channels. In order to fine-tune research questions to topics that are of interest of the farming community, their active involvement and mutual exchange was identified to be

necessary in this project. The means to achieve this was the plan to organize and to participate in workshops with farmers in the whole country.

4 Projektinhalt und Ergebnisse / Research Objectives and Results

Project outline and objectives

When the project was launched, there was an evident need for an integrated quantitative assessment of the Austrian cattle and dairy sector with respect to climate change mitigation and adaptation potentials. The overarching objective of the study was to shed light on the future exposure of Austrian cattle and milk producers to climate change, such as production risks with a specific focus on extreme weather events like dry or wet periods. In addition, the attempt was made to explore options for responses of farmers and policy makers to adjust to changing market and climate conditions. The project was designed to fill the research gaps listed above by pursuing the following research goals:

1) Deepening the understanding on adaptation options in Austrian dairy and cattle farming: To find out how Austrian cattle and dairy farmers can cope with climate change to maintain livestock well-being and competitive farming – and how the public can support them in the context of the program of rural development and beyond. ADAPT-CATMILK aimed at exploring the effects of different driving forces such as changing market conditions and changing production conditions that have a simultaneous impact on the decisions farmers make.

2) Exploration of mitigation in Austrian dairy and cattle farming at a high spatial resolution: To find out how the Austrian cattle and dairy farmers can contribute to climate change mitigation and which incentives will be needed. The aim was to explore spatial heterogeneity and carry out the analysis at NUTS-3 level and even below.

3) Development of improvements of existing analytical models, in particular to link a model of the Austrian agricultural sector with a global model of agricultural production. With such a model link two benefits can be attained: a) make the price assumptions for Austria consistent with those of international research teams and b) to be able to evaluate the consequences of supply shifts in Austria on global markets.

4) Extension of the scope of results of economic models: Results of a LCA model complement results on economic indicators and quantities of farm commodities derived from the agricultural sector model of Austria. Usually, analyses on Austria's agriculture are based on the small country assumption which implies that measures taken in Austria have no effect on the rest of the world. By evaluating the results with the methodology of LCA, this limitation which prevails in many economic studies, can be overcome.

5) Capacity building: Experts on LCA from the team offered a course on this method specifically addressing economic modelers and stakeholders in cattle and dairy production.

6) Accounting for uncertainty in the quantitative analysis: Because projections about future states of the environment and market conditions are inherently uncertain approaches have to be developed to account for it. One aspect is to communicate uncertainties in the context of presentations of results and another aspect is to analyze uncertainty from the perspective of farmers.

7) Dissemination: Finally, it was a goal to make the findings of the research available to Austrian cattle and dairy farmers and to other relevant stakeholders like public administration and organizations in the value chain.

The research projects aimed to achieve quantitative results that are spatially explicit and therefore can serve farmers in different locations, extension services and the administration for decision support.

The detailed research plan spelled out the following questions to be answered in the project:

a) In depth analysis of the future of cattle and dairy farming in Austria – quantification of likely changes of herd sizes and likely changes of milk production under a new market environment.

b) Exploration of the regional dimension of changes: Where will cattle and dairy production take place in future? Which kinds of driving forces will be the main causes (market conditions and / climate conditions / policy regulations) for changes in the regional pattern of production?

c) Scenarios on the likely emissions of GHG of the Austrian cattle and dairy sector were planned to be made. Measures to reduce emissions in the cattle and dairy sector were planned to be identified and the consequences of their implementation to be quantified. The effects on the overall emissions based on parameters derived from a LCA were planned to be evaluated explicitly.

The scope of the analysis was not restricted to cattle and dairy production but covered the whole Austrian agricultural sector. This approach reflects the fact that most Austrian farms are integrated and not specialized. Nevertheless, the focus of the results was defined to be on beef and milk production and the dissemination efforts were planned to concentrate on stakeholders in this target group.

Among the objectives of the research project was to link researchers from Austria to the international community. All researchers involved in the project have been part of the network of European researchers in the MACSUR project (www.macsur.eu) as well. Within this research network, scenarios, tools and data sets have been developed to attain a better understanding of effects of climate change on food security. The close interaction between team members involved in ADAPT-CATMILK with partners from other countries and projects was planned to contribute to the aims of MACSUR in particular by accounting for perspectives of a small open economy with special geographical challenges. An objective that was developed during the programme period was to work on an Austrian case study that fits into the MACSUR context and thus to contribute to the knowledge how European agriculture will be affected by climate change.

Activities and work packages

The activities carried out in order to achieve the objectives listed above were organized in work packages. Each of the work packages had specific objectives, a designated work package leader and deliverables. The organization of the project and work package specific results are presented below.

WP 0: Project management and completion of the project

Results

The success of this interdisciplinary research projects relied on the development of a common language with respect to the research objects and data. The project coordinator organized five meetings at which team members presented their work and where decisions were made on how to achieve the objectives.

The smooth operation of the communication flows and data flows between the different teams were further result of WP 0.

Milestones reached:

- Kick-Off meeting and other meetings were organized and finished.
- The other work packages were supervised and completed as planned.
- The final meeting was organized and held; final report completed.

WP 1: Policy analysis and scenario analysis

WP 4: Scenario analysis with the land use model on Austrian agriculture

Description:

According to the project plan there were two work packages on scenario analysis (WP1 and WP4) and the model analysis was planned to be carried out in WP4. The results on the policy analyses and scenario analyses of WP1 were published together. The outcomes of WP1 are elements of the model analysis that were carried out in WP4. Therefore the descriptions of WP1 and WP4 are pulled together.

Results (full papers/presentations of references are in the appendix):

The scientific outputs of the two work packages deal with a range of options to mitigate GHG emission and of policy/market/climate change effects on dairy and cattle production. The topics covered in the presentations and (journal) papers are:

- phasing out of the dairy quota system as decided in the Agenda 2000 reform of the Common Agricultural Policy (CAP)
- environmental and economic consequences of the CAP reform of 2014
- mitigation scenarios of the Austrian agricultural sector until 2025
- expected effects of heat stress on Austrian livestock in a climate change scenario
- options to substitute high-protein feed components and production potential of soy beans in Austria
- consequences of climate change on grassland dominated landscapes in a case study region in Austria
- GHG mitigation potential of biomass refineries using grass as feedstock

Milestones reached:

- As presented in the results section, there are several outputs in which scenarios were developed, analyzed, published and /or presented.
- The final report was completed.

WP 2: Cost analysis and development of data set

Description:

According to the plan of the project the results of this work package should serve as an input for PASMA and PASMA[grid]. It turned out that the data would be useful for many other purposes. Therefore, the decision was made, to enhance the value of this work package and to develop a new tool – INCAP (index-based costs of agricultural production) and to make index data and the grassland yield data set publicly available.

Results (full papers/presentations of references are in the appendix):

The scientific outputs of the two activities in the work package deal with descriptions of the data set and the concept of index-based production costs and applications of the tool. The topics covered in the presentations and papers are:

- the concept of index-based production costs
- case studies for crop production activities
- case studies for livestock activities
- exploration of data validation
- application of the data tool in the context of farm risk management
- description of the methodology of grassland yield estimates and presentation of the results

Milestones reached:

- INCAP are developed for the most important agricultural activities. Results of INCAP and the grassland yield data set are published and data are in the public domain and can be accessed from www.landnutzung.at.

WP 3: Life Cycle Assessment

Description:

According to the project plan this work package consisted of two modules:

a) a course on LCA methodology and

b) an LCA tool that can be combined with PASMA and PASMA[grid]

Results:

The team of Cranfield University worked together with the team in Vienna to

- hold a course on the methodology of LCA
- adapt the UK model to the Austrian situation
- develop an interface that links the Cranfield LCA model to PASMA and PASMA[grid]

Milestones reached:

- The LCA course was held and 20 persons from Austria and other countries participated.
- The LCA modeling tool was adapted to the Austrian situation.
- An interface to link the LCA tool to PASMA and PASMA[grid] was completed.

WP 5: Scenario analysis with a global model

Description:

An important prior assumption of models like PASMA or PASMA[grid] is that any changes of the agricultural sector do not have significant effects on the rest of the economy. For a small sector this may be an acceptable assumption but the consequence is that links between the agricultural sector and the rest of the economy are not modelled explicitly. In order to overcome this shortcoming WP5 was designed to link the Austrian agricultural sector model to a model that captures the EU agricultural sector and provides results on world agriculture as well.

Results:

- A link between CAPRI (output) and PASMA (input) was established.
- In the context of MACSUR results from CAPRI simulations have been made available.
- The Thünen Instiute processed data and results from the recent Thünen-baseline simulation study (Offermann et al., 2016).

Milestones reached:

- CAPRI results were made available for MACSUR members and are prepared for further use in PASMA.
- Thünen Institute results of CAPRI were prepared for further use in PASMA.

WP 6: Dissemination and Stakeholder Participation

Description:

The objectives of this work package were to publish scientific output, to make results available for the general public, most importantly for farmers and to take on board the views of farmers and other stakeholders in order to reflect them in the scenarios to be analyzed.

Results:

- 8 papers were published in peer reviewed scientific journals
- 2 papers were submitted for publication to peer reviewed scientific journals and 3 are planned to be submitted in the coming months
- 12 presentations at scientific conferences were made
- 5 papers published in proceedings
- 4 stakeholder workshops
- 7 presentations at farmers' meetings

Milestones reached:

- Presentations at scientific meetings, workshops and congresses.
- Publications in scientific journals are completed.
- Stakeholder workshops were held and protocols are available.
- Dissemination of results at farmers' meetings and in farmers' professional journals.

Activities and results

a) Data sets and data preparation

Throughout the project, the analysis was made in a quantitative manner. Data are

- either based on observations like market prices, production volumes or indices obtained from official statistics (Statistik Austria) or data bases available at WIFO;
- model results like crop yields derived from a growth model (EPIC).

This project benefited from a wide range of data sets that were developed already for other purposes but could be used for analyses of interest in this research project. A large data repository on Austrian climate forecast data and crop yield data for future climate scenarios is available at the website www.landnutzung.at (see Sinabell, 2012). The following data are available there:

- bio-physical information on agricultural land
- yield responses of agricultural crops for different soil and climatic conditions
- land use and land management data for agriculture

- climate change scenario data until 2040

To highlight the value of these data with one example, the repository and data made available by the partners involved in the study were used in order to evaluate how much high-protein feed can be produced in Austria in order to offset imported feed concentrates (Mitter et al., 2015; Sinabell, et al., 2016). The novelty is to link these data in new ways with existing tools in order to provide insights that cannot be reached by using isolated approaches. For every single publication, the challenge was to develop interfaces for making the exchange of quantitative data possible and to establish a coherent framework for the analysis.

For several other outputs of the project, data on resource endowments and observed land use were obtained from the Integrated Administration and Control System (IACS), the digital soil map of Austria (Federal Research and Training Centre for Forests, Natural Hazards and Landscape, BFW), the digital elevation map (Federal Office of Metrology and Surveying, BEV), the farm structure survey, and the Austrian Farm Accountancy Data Network (FADN). These data were complemented by statistics of the Economic Accounts for Agriculture at NUTS3-level (provided by Statistik Austria and published in Sinabell, et al., 2011 and Sinabell et al., 2016). For the published research outputs (see appendix), data on production costs are estimated from standardized gross margin tables for Austrian agriculture (BMLFUW, 2008) and standardized farm labour estimates. Product prices are taken from price statistics of Statistics Austria (www.statcube.at) and price forecasts from the OECD-FAO agricultural outlook (OECD/FAO, various years).

MACSUR developed a coherent set of scenarios for climate change in Europe, policy response and analysed market effects for agricultural commodities with a global model (CAPRI). These results are available in a data inventory for use of the partners in the network. Results from this data set are planned to be used in the ADAPT-CATMILK methodology for a paper that will be presented at the MACSUR science conference in May 2017 (details see appendix).

In ADAPT-CATMILK, a new data set on grassland yields was created (published at www.landnutzung.at). This was necessary because forage from grassland is a major input for milk and beef production and existing data sets were not adequate for the objectives for this research project.

b) Capacity building: offering a course on LCA methods

One milestone of WP3 was a course on the methods of LCA. This capacity building effort was necessary because most of the partners in the research team were not familiar with this methodology when the project started. The course was given by the members of the Cranfield University team who developed the Austrian version of the Cranfield LCA model.

In order to increase the value of this course it was announced nationally and internationally. More than 20 persons attended the course, therefore a large number of persons not directly involved in the project could benefit from ADAPT-CATMILK.

c) Participation in conferences, other scientific events and stakeholder events

The striving for scientific excellence and the production of scientific outputs (enhanced models, data sets, technical coefficients and publications) was given high priority in ADAPT-CATMILK. It is the foundation of any recommendation addressing the wider public beyond the scientific community. During the project, material was prepared for practitioners (i.e. farmers, extension services, breeding organizations, developers of agri-environmental programs) to foster farm and administration decision making with respect to the challenges of climate change. For this purpose, the well-known website www.landnutzung.at was used to publish data sets (grassland yield data), technical papers, and model components (INCAP).

d) Elaboration of scientific papers and on articles for professional journals

Articles for technical journals, which are widely read by Austrian farmers were an integral part of the dissemination strategy in order to bring the results of the research to those who have to make production decisions. Persons working in the public administration, the agricultural chamber, and research institutes were invited to attend the LCA course delivered in the context of this research project. The scientific papers and presentations are collected later in this report for further reading.

e) Development and implementation of methodological enhancements

An important objective of the project was to make use of a set of existing tools and models and to work on improvements and enhancements. The integrative modeling framework that has been developed by one partner was chosen to be further elaborated. More details are presented later in the report (see methodology). The approach chosen in this project was to develop tools that can be used either separate or in combination with other others by using defined interfaces that make it possible to link different tools. Depending on the research question the tools can be combined in a flexible manner.

5 Schlussfolgerungen und Empfehlungen / Conclusions and Rekommandation

General conclusions and recommendations

Many of the resources mobilized in this project have been directed to gain better insights into the heterogeneity of agricultural production conditions in Austrian farming under climate change. The most visible achievements are a new data set of grassland yields under climate change for the whole territory at a very detailed spatial scale, further enhancements of a spatially disaggregated agricultural sector model and a cost analysis tool that is designed to capture the economic aspects of different production and management conditions in Austrian agriculture such as required to analyse climate change mitigation and adaptation strategies.

Austria is a small country but due to topography and a large bandwidth of meteorological conditions agricultural production capacities and production costs are very heterogeneous. An important implication is that the same policy incentives may have very different effects depending on local production conditions. Another implication is that climate change will affect producers of the same commodity in sometimes opposite directions – again depending on local conditions.

These findings lead to one of the main conclusions of the research project: In order to understand the vulnerability of agriculture due to climate change and its contributions to GHG emissions it is necessary to account for the spatial heterogeneity of production conditions. Heterogeneity also matters in the context of potential benefits of warmer weather conditions. The tools developed in this project are a step forward in broadening our understanding and contribute to designing management and policy responses in a better informed manner.

All work in this project dealt with agriculture (specific to Austria) and various aspects of milk and dairy production. The work package that stretched beyond the sectoral focus was the module on LCA. The researchers involved in this study and more than a dozen other scientists were made familiar with the concepts, problems and answers such an approach can offer. Hands-on experience with a working LCA model provided insights that usually cannot be achieved by just listening to course presentations. The course which was combined with modeling exercises

stimulated discussions among the participants and made them think about environmental problems in a more comprehensive manner. A life cycle oriented view on the problems at hand makes clear that to understand the way how agricultural products are made is important, but only one facet of a much bigger picture. To track the provenience of inputs for agricultural production, their logistics, the way agricultural commodities are distributed and processed is likewise very important.

Such a broad view beyond the agricultural production processes let us conclude that when designing policy measures to attain adaptation or mitigation goals that are focused on agricultural production, it is necessary to consider vertical linkages between sectors and supply chains across international borders and most importantly consumption behavior. Eventually consumers make the choice and prefer to buy a certain product over another one. However, the prices they pay do not fully reflect social opportunity costs. LCA could provide rich information for environmentally sensitive consumers to make better informed choices. The project ADAPT-CATMILK did not explore consumer choices and aspects related to consumption. These issues need to be dealt with in a specific analysis.

What is true for consumers is also true for many agents involved in the policy making process. One of the drawbacks of LCA approaches – their static results and the lack to integrate policy instruments into an analysis – can be overcome by combining LCA models with economic models as was done in this project. Work is under way to demonstrate this approach (see next section).

The European agricultural policy's main goals have remained unchanged over the last five decades. Only in the most recent reform (2014) climate change has become a major issue. However, the integration of climate policy goals into the agricultural policy measures has not been achieved without friction. An example of bad policy design is the provision of production-linked support. In many EU Member States farmers are stimulated via specific production premiums to produce beef using suckler cows. However, beef production is emission intensive. This example shows that major adjustments and more so priority changes are needed to make the CAP a tool to steer the EU agricultural sector on a trajectory that is consistent with the emission reduction goals.

This insight leads to the third important conclusion that agriculture's contribution to GHG emissions should become a top priority issue in agricultural policy in the EU. Because agriculture is one of the most heavily exposed sectors to hazards of climate change, agricultural policy should also respond to related challenges.

Target groups specific conclusions

The primary target group of this project was the scientific community working on various aspects related to agriculture and climate change. The major achievements of the project are improved data sets, enhanced models and a new tool to analyse agricultural production costs in Austria.

Farmers:

> Farmers may benefit directly from the results developed in this project, most likely from data on production costs (INCAP) and forecasts on the yield of grassland (see details at http://www.landnutzung.at/Catmilk_karten.html). Given the high spatial resolution for which results are provided, farmers get a much better impression on likely changes of vegetation period length and productivity in the near future in their specific region. General statements on the future development are based on the average of the whole country. As the maps clearly show, geographical conditions make a big difference. Given the large heterogeneity of spatial conditions in Austria due to topography farmers can make better judgements about likely future situations in the specific location where they are operating a farm.

Policy makers:

During the project period the experience was made that the improved modeling framework established by the project turned out to be useful for other purposes as well. One application was the study on the evaluation of the programme of rural development in Austria.[1] For this study, the detailed spatial resolution of PASMA[grid] developed during the project proved to be very useful. It is anticipated that this improved model will be useful in other evaluation studies to come.

Extension services:

One of the outputs of the project is a detailed data set on production costs of agricultural products in Austria. This data set is based on the gross margin data application[2] provided by AWI – Bundesanstalt für Agrarwirtschaft, a government funded research institute) but has many features that make it very useful for extension services. It is possible to derive a detailed overview of production costs of various agricultural activities for a specific region with minimum efforts. Because the time domain is taken explicitly into consideration it is also possible to account for risk parameters. Advice given to farmers can therefore be more specific and more comprehensive.

Insurance industry:

A major topic of this research project was the exploration of adaptation strategies in the context of climate change. It turned out that limiting the focus purely on production risks of the product under consideration (milk or beef) would be too limited in scope. The stochasticity of prices of inputs and outputs is likely to increase if adverse climatic conditions are going to become more frequent. The INCAP data set tool developed in this project is well suited to evaluate the consequences on incomes. It can be used as a tool to design insurance products for a wide range of agricultural products. At the moment INCAP needs to be further developed to meet the full coverage of crops and activities of Austrian agriculture but the most important elements are already included. Therefore, it is already possible to develop prototypes of margin insurance products that can be tested under typical market conditions.

Other research teams:

The models PASMA and PASMA[grid] that were further developed in this project are idiosyncratic and embedded into a framework of tools that cannot be easily transferred to other research teams. Nevertheless, other researchers may benefit from the project directly. Two open data sets have been developed and can be accessed by anyone: the data on grass land yields and the data on production costs. Results on grassland yields are probably relevant mostly for researchers on Austrian topics. The results of INCAP are certainly relevant for all Central European regions. If indices and time series of yields are adjusted to other countries the data can be used in temperate regions throughout the EU.

[1] Sinabell, F., D. Pennerstorfer, G. Streicher und M. Kirchner, 2016. Wirkungen des Programms der Ländlichen Entwicklung 2007/2013 in Österreich auf den Agrarsektor, die Volkswirtschaft und ausgewählte Bereiche der Lebensqualität. Studie des Österreichischen Instituts für Wirtschaftsforschung im Auftrag des Bundesministeriums für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft. Wien 2016.
[2] www.awi.bmlfuw.gv.at/idb

C) Projektdetails / Project Details

6 Methodik / Methods

A central objective of the project was to use a set of existing tools and models and to work on enhancements and improvements. The integrative modeling framework that has been developed by one partner in the past already was chosen to be further developed. In this section the details are presented. As shown in more detail below, the approach chosen in this project was to develop tools that can be used either separately or in combination with other others by using defined interfaces that make it possible to link different tools. Depending on the research question the tools can be combined in a flexible manner in different ways.

The remainder of the section is organized to cover the following topics:

a) Enhancement of existing tools and methods

b) Development of an agricultural production cost analysis tool

d) Creation of a comprehensive and territorially differentiated data set on grassland yields for the present and for the future

d) Results for a set of scenarios from a model on the international agricultural sector that can be used as input for PASMA

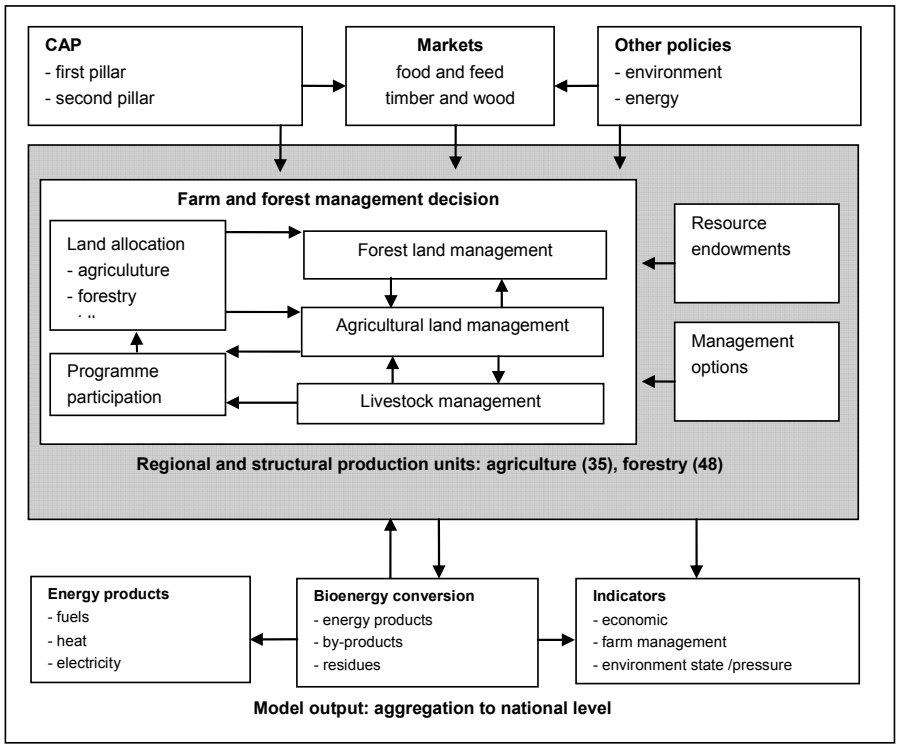
e) Linking the tools employed in the project together for an integrated assessment framework

In each of the following sections methodological enhancements are described in more detail. The presentation includes a motivation to apply a given approach and lists major achievements. How these methodologies are actually used and which results can be obtained by combining them is demonstrated in the publications which are listed in the next chapter.

a) Enhancement of existing tools and methods

PASMA (Positive Agricultural Sector Model Austria) is a land-use model for the quantitative analysis at sector level: For the quantitative analysis of cattle and dairy production the existing model PASMA was further developed. When the ADAPT-CATMILK project started, PASMA was designed to adequately depict the political, natural, and structural complexity of Austrian farming (Figure 1). Land-use decisions between agricultural land and forest land were modelled at a regional level in the current situation. PASMA (Figure 1) is regionally differentiated (NUTS3-level) to account for spatial and structural heterogeneity and the model was used already in many impact studies (e.g. Schmid and Sinabell, 2007; Schmid et al. 2007). Regional results are aggregated at the national scale following the methodology of the Economic Accounts of Agriculture (EAA). In Austria, about 85 % of all payments to farms come from three sources: direct payments, the agri-environmental program ÖPUL, and the program for farmers in Less-Favoured Areas. Agri-environmental policies are of major significance for Austrian farming. Given their importance, not only instruments of the first pillar of the CAP are modelled in detail, but also second pillar policies (see figure 1). The construction of the model ensures a broad representation of production and income possibilities that are essential in comprehensive policy analyses. Data from IACS, EAA, the Agricultural Structural Census (ASC), and the Austrian Farm Accountancy Data Network (FADN) provide the necessary information on resource and production endowments for the 35 NUTS-3 regions in Austria. Consequently, PASMA can estimate production, labour, income, and environmental indicator responses for each of these units.

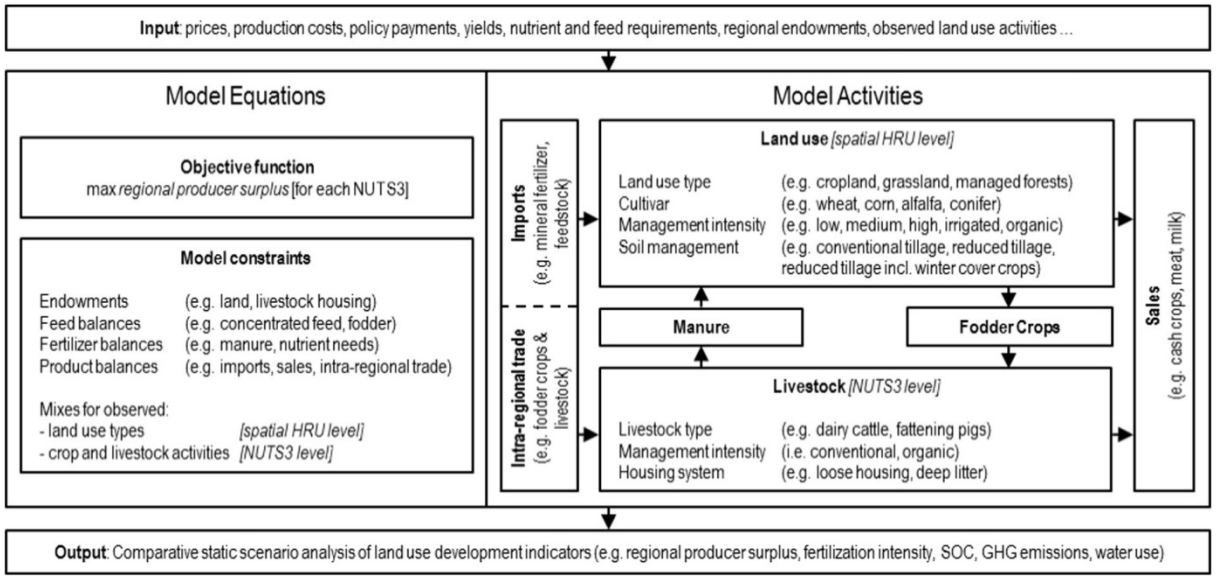
Figure 1: Structure of the agricultural sector and land use model of Austria – PASMA



Source: own construction.

Due to its partial approach, the model treats the farm sector without any behavioural interaction with other sectors of the economy or the rest of EU's agriculture. Policies and prices are given exogenously and output changes are assumed not to affect equilibrium prices (demand is perfectly elastic). Product prices and other market related model assumptions are derived from Statistik Austria and international sources.

Figure 2: Structure of the agricultural sector and land use model of Austria – PASMA[grid]



Source: Kirchner, et al., 2016.

During the project a major enhancement was made to improve the spatial resolution of the model and to include carbon accounting for the agricultural sector. The enhanced model is dubbed **PASMA[grid]** (see Kirchner et al., 2016). A block diagram is presented in Figure 2. PASMA and PASMA[grid] are very similar models but significantly different in one aspect: in PASMA[grid] land use is modelled at HRU (homogeneous response unit) level which can be as small as 1 km^2. The spatial resolution is therefore much finer than in PASMA. PASMA[grid] is an element of the integrated assessment framework (see Figure 5) for analysing a wide range of agricultural and environmental policy questions at a detailed spatial resolution.

b) Development of an agricultural production cost analysis tool

In most economic models of agriculture, production costs are an essential element. Some models estimate costs assuming specific technologies and/or functional forms from observed data. Others, such as linear or positive mathematical programming models like PASMA or PASMA[grid], use average production costs which are based on gross margin calculations developed for extension services.

Such cost data are usually available for the past and for specific settings, like regions or observed farm sizes, but rarely for scenarios that make projections into the future and/or that need to change underlying settings. A typical example of such a data set is available for Austrian farms on the website www.awi.bmlfuw.gv.at/idb (provided by AWI). In order to retrieve information from there it is necessary to put data into a form by hand and results can be obtained either directly via the website or via a pdf document. However, it is not possible to download the complete data set and to manipulate the data of multiple production activities simultaneously.

To overcome this limitation, a new set of data called 'Index-based Costs of Agricultural Production' (**INCAP**) has been developed. INCAP is a detailed data set on production costs in agriculture. In its current state it is specific to Austria but the method is not country-specific and data for other countries in temperate zones can be easily developed using this approach. INCAP accounts not only for a wide variety of relevant activities (e.g. production of quality wheat) combined with specific attributes (e.g. certain management variants like organic farming), but it is also established as a time series from 2005 to 2013 and is designed to allow future scenarios until 2050.

With its focus on the micro-economic level, costs are specified per unit of output. INCAP is based on a range of existing data repositories that describe agricultural production systems in a detailed manner. Its contribution to the knowledge base is to explicitly represent management variants, various production options, various production regions, and time. The aim is to capture the heterogeneity of agricultural production in a country or region and the production costs of typical farms. Among the reasons to use gross margin data from AWI as the primary data source for INCAP are the wide range of activities, its up-to-date data base, its focus to the Austrian situation and the fact that the data are also widely used in extension services.

c) Creation of a comprehensive and territorially differentiated data set on grassland yields for the present and for the future

As outlined above, the data repository at www.landnutzung.at contains a detailed set of crop yield data for all municipalities in Austria. However, data on the yields of grassland are not included there. Because the main interest of ADAPT-CATMILK was dairy and beef production, it was evident when the project was designed that such a data set needed to be developed in the context of the study. In order to fill this gap, the model **SpatialGRAM** (grassland statistical model) was applied to calculate a data set on grassland yields for the Austrian territory for the past and for future climate situations.

SpatialGRAM consists of a two-step approach and is implemented in a geographical information system (GIS). First, a dynamic daily soil water balance model according to FAO-56 is applied and its outputs are then used to estimate grassland yields. The statistical yield model takes as predictors accumulated temperature, global radiation and water stress. The key procedure of the water balance model is the calculation of the daily reference evapotranspiration as the main soil water balance driver. It is calculated and geo-statistically interpolated from daily values of temperature, wind, relative humidity, and global radiation according to FAO-56-Penman-Monteith (Allen et al., 1998).

Available soil water is determined by the actual soil water content that is driven by the water balance during previous days and precipitation on the given day. If water stress occurs a growth supporting factor will be reduced due to the intensity of stress. The factor affects the summation of daily temperature and global radiation over the period of each growth through a complex function described by Trnka et al. (2006). Thus, temperature and global radiation are not used directly as predictors for the statistical model of yield estimation, but are combined with and changed according to the day-specific value of growth supporting factor.

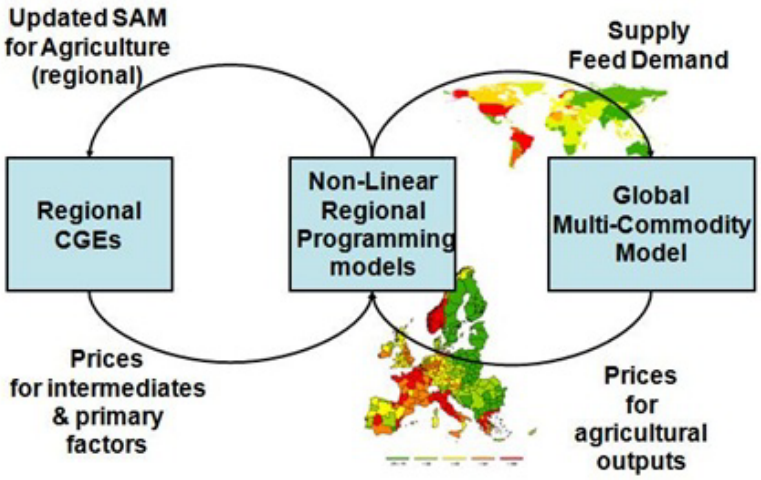
d) Results for a set of scenarios from a model on the international agricultural sector that can be used as input for PASMA

CAPRI (Common Agricultural Policy Regionalised Impact Modelling System) is an economic model developed over more than a decade by an international team of researchers and financed by European Commission research funds. It supports decision making related to the CAP based on sound scientific quantitative analysis. CAPRI is only viable due to its pan-European network of researchers. Based on an open source approach they tender together for projects, develop and maintain the model, apply it for policy impact assessment, write scientific publications and consult clients based on its results (see www.carpri-model.org for more details). CAPRI represents the European agricultural sector in a very detailed manner (NUTS-2 regions) and is widely used in applied research on agricultural policy and food security analyses. Its modules not only cover European agriculture but also global markets (see figure 3).

Among the project team of ADAPT-CATMILK is staff from the Thünen Institute which is located in Braunschweig, Germany. The Thünen Institute is among the network partners of CAPRI and uses the model at a regular basis to model scenarios (e.g. Offermann, 2016). Results derived from

CAPRI are used in order to analyse potential international spillover effects on Austrian agricultural markets. The research question is to identify quantities and regions represented in the CAPRI model which would be affected if Austrian cattle and milk production did change contingent upon the assumption that demand for beef and milk will not be affected. The reason to link the Austrian model PASMA and its variant PASMA[grid] with a model of international markets is to overcome the limitations implied by the small country assumption which is a feature of PASMA.

Figure 3: Overview of the CAPRI model



Source: http://www.capri-model.org/dokuwiki/doku.php?id=start

Development of an interface between an existing LCA model and its adaptation to the Austrian agricultural and forestry sector model PASMA

The **Cranfield AGRI-LCA model** applies systems modeling to environmental LCA studies of alternative agricultural commodity production systems (Williams et al., 2006). The objective is to analyse the system's operation to provide accurate measures of performance and calculate systematically the effect of production alternatives.

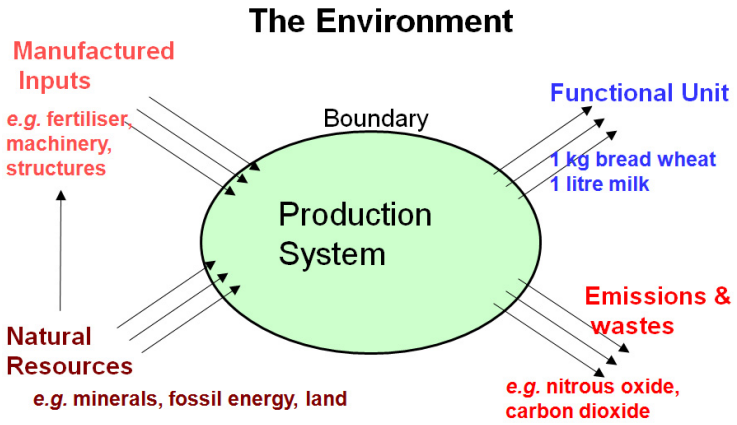
Ten commodities are analysed (wheat, potatoes, oilseed rape, tomatoes, milk, beef, pork, lamb, chicken and eggs) at the national level and resulted in a comprehensive Excel spreadsheet.[3] Unlike previous system comparison analyses, this analysis allows production systems to be defined by parameters from which the inputs and outputs are calculated allowing any number of alternative definitions to be compared.

A graphical overview of the model is presented in Figure 4. It shows the basic LCA concept which equals inputs to outputs (mass flows measured at the system boundary must balance).

The AGRI-LCA model is a stand-alone application developed in Microsoft Excel. It contains data on technology, LCA coefficients, data on the production structure of the UK agricultural sector, a linear programming module and a user interface for scenario building. One task of ADAPT-CATMILK was to adapt this model to Austrian agriculture (like soil types, livestock management) and to integrate LCA results with PASMA or PASMA[grid].

[3] https://webapps2.cranfield.ac.uk/webforms/form.jsp?formId=12024

Figure 4: Overview of the Cranfield AGRI-LCA model



Source: own construction

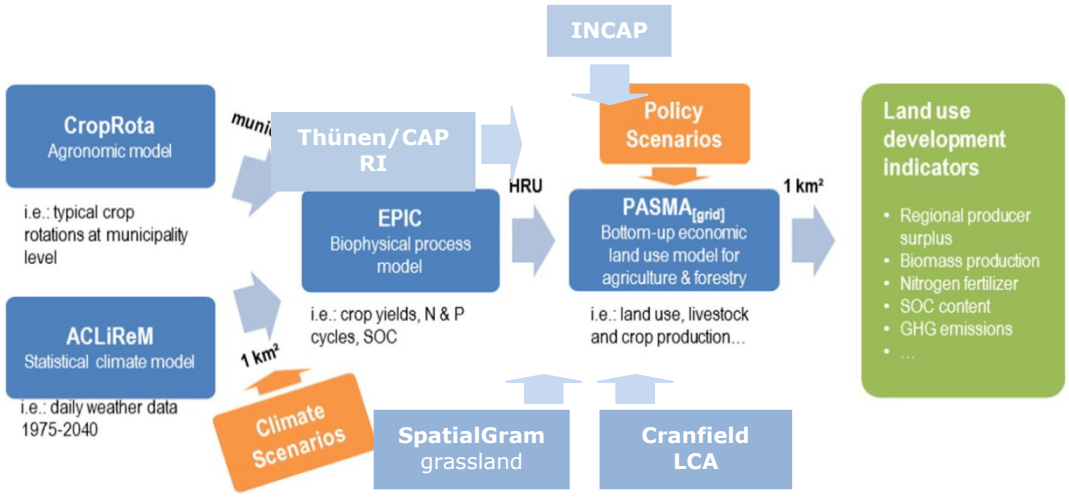
e) Linking the tools employed in the project together for an integrated assessment framework

The methodological framework of the integrated assessment (see Figure 5) used in this research project builds on the experiences and knowledge of previous model frameworks and applications (e.g. Kirchner et al., 2015; Kirchner and Schmid, 2013; Mitter et al., 2014; Schmidt et al., 2012; Schönhart et al., 2014, 2011a; Stürmer et al., 2013). It represents the most important driving factors and processes that affect land use change and management choices in agriculture as well as forestry in Austria.

In the framework, the CropRota model derives typical crop rotations at municipality level, taking into account observed land use and agronomic constraints (Schönhart et al., 2011b). The statistical climate model ACLiReM uses regressions and bootstrapping methods in order to depict temperature trends and to assume precipitation patterns in Austria until 2040 (Strauss et al., 2013). It provides physically consistent daily weather data at a spatial resolution of 1 km. Both models provide input to the biophysical process simulation model EPIC (Williams, 1995; Izaurralde et al., 2006), i.e. crop rotations and weather data respectively. EPIC simulates crop yields and environmental processes (e.g. evapotranspiration, mineralization, nitrification, and erosion) of alternative crop production management systems for different climate–site–soil–crop regimes at a spatial resolution of 1 km. Hence, outputs are differentiated by site-specific topographical, soil, and climate characteristics as well as by agronomic measures (e.g. crop rotations, fertilization intensity, irrigation and crop management measures). Finally, the bottom-up economic land use optimization model PASMA[grid] integrates the biophysical simulation data in order to derive optimal geo-referenced production portfolios of constrained profit-maximizing farmers.

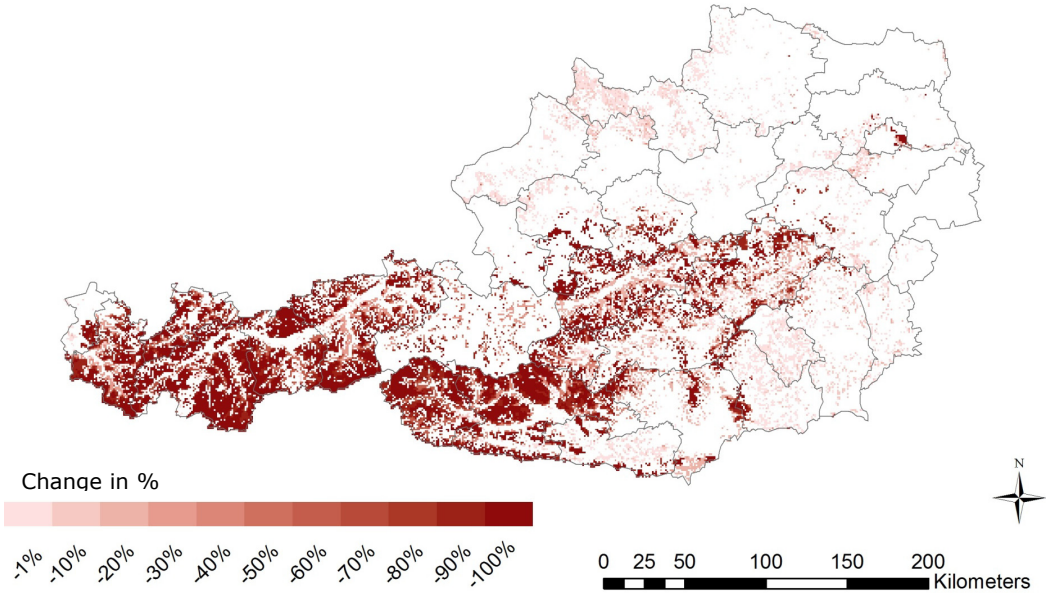
During the project period of ADAPT-CATMILK the integrated modeling framework was further enhanced (Figure 5). The light blue boxes in the graph indicate the modules (presented in more detail below) that were developed during the last 24 months and they indicate how they fit into the tool box: data on the cost of production of agricultural commodities (INCAP), price information from an international agricultural sector model (CAPRI and Thünen Baseline), grassland data (from SpatialGram) and LCA coeffients (from the Cranfield AGRI-LCA model).

Figure 5: Integrated assessment framework for quantifying policy and climate impact chains in Austrian agriculture and forestry



Source: based on Kirchner, et al., 2016; enhancements made during the ADAPT-CATMILK project are indicated in light blue boxes.

Figure 6: An example of PASMA[grid] results – land use change of grassland in a scenario without the programme of rural development



Source: Sinabell, et al., 2016b.

In order to demonstrate the usefulness of the detailed spatial resolution of PASMA[grid] an example of a recent study (Sinabell, et al., 2016) is presented in Figure 5. It shows how – subject to the assumptions made – land use would have changed if the programme of rural development had not been implemented during 2007 to 2013 in Austria. Mainly in Alpine regions the acreage of grassland would have decreased significantly. Consequently, fodder production for ruminants would have shrunk considerably (for further discussion on the results see Sinabell, et al., 2016). Because open grasslands are important characteristics of Austrian landscape it is not only the biomass production that is important. The visual effect of the landscape on visitors is important, as well. To

be able to evaluate land uses changes for typical landscapes is a useful side benefit of the capabilities of PASMA[grid].

7 Arbeits- und Zeitplan / Plan of Work

The Gantt diagram below compares the planned work schedule (coloured cells) with the finally realized work plan (indicated by "x" in cells). Cells with W in row "WP0: management" indicate project workshops. It gives an overview of the duration of the work packages and lists the milestones during the project period which spanned over 24 months.

Work package	**month**																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
WP0: management	x	W	x	x	x	x	x	x	x	W	x	x	x	x	W	x	x	x	x	W	x	x	x	W
WP1: policies /scenarios	x	x	x	x	x	x																	x	x
WP2:cost analysis / data							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
WP3:LCA coefficients	x	x					x	x	x	x	x	x										x	x	x
WP4:scenarios Austria	x	x	x				x	x	x	x	x												x	x
WP5:scenario global	x														x								x	x
WP6:dissemination			x							x	x			x	x	x		x	x		x	x	x	x

The plan was to have project meetings in months 1, 6, 12, 18, and 24. The kick-off meeting was scheduled in month 1 to be arranged in Vienna and attended by all partners. It took finally place in the second month and was held on Sept. 29th and 30th 2014 in Vienna. In this meeting the general structure of the project was decided upon and the plan for the upcoming workshop was made. It was organized by the co-ordinator.

The second project workshop was linked to the capacity building event of the project, the 'Course on LCA applied to agriculture'. It took place from 6th to 7th May 2015 in Vienna at the premises of WIFO. It was organized by the co-ordinator.

The third project workshop was linked to a MACSUR workshop which took place in Braunschweig on 26th of October 2015. It was organized by the Thünen Institute and the focus of the workshop dealt with options how to link the Thünen model infrastructure to the needs of the project.

The fourth project workshop was linked to the International Crop Modelling Symposium which took place from 15th to 17th March 2016 in Berlin in Germany. This workshop was organized by the project co-ordinator and the location was chosen because many of the partners involved in the project attended the symposium. Therefore time and travel related emission could be saved.

The fifth project workshop was linked to the annual meeting of ÖGA (Austrian Society of Agricultural Economists) and organized by the partner INWE-BOKU. The workshop took place in

Vienna and it was attended only by the Austrian partners to save travel costs from abroad. Contacts to the other partners were established beforehand via skype.

8 Publikationen und Disseminierungsaktivitäten / Publications and Dissemination

- **Journal Articles**

Heinschink, K., F. Sinabell, C. Tribl, 2016, An index-based production costs system to evaluate costs of adaptation and mitigation in dairy and cattle farming. Advances in Animal Biosciences, (2016), 7:3, pp 242–244 © The Animal Consortium 2016. doi:10.1017/S2040470016000285

Heinschink, K., F. Sinabell, C. Tribl, 2016, Differentiation of variable costs in the Austrian agricultural production. Erschienen im Jahrbuch der Österreichischen Gesellschaft für Agrarökonomie, Band 25: 231-240, 2016. Online available at: http://oega.boku.ac.at.

Kirchner, M., M. Schönhart and E. Schmid, 2016, Spatial impacts of the CAP post-2013 and climate change scenarios on agricultural intensification and environment in Austria. Ecol. Econ. 123, 35–56. doi:10.1016/j.ecolecon.2015.12.009

Larcher, M., M. Schönhart, E. Schmid und St. Vogel, 2015, Intensivierungspläne österreichischer MilchproduzentInnen angesichts der auslaufenden Milchquotenregelung 2015 – ein empirisches Modell zur Erklärung von Verhaltensintentionen. German Journal of Agricultural Economics, (3) 148-162.

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Sinabell, F., T. Url, and K. Heinschink, 2016, An index-based margin insurance for wheat and milk production in Austria. Paper submitted for publication in Agricultural Finance Review.

- ***Proceedings***

Heinschink, F. Lembacher, F. Sinabell and C. Tribl, 2016, Crop production costs in Austria: Validation of simulated results using farm observations. Proceedings of the 26. Jahrestagung der Österreichischen Gesellschaft für Agrarökonomie am 15. und 16. September 2016, Wien.

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Heinschink, K., F. Sinabell, C. Tribl, 2016, Index-based Costs of Agricultural Production' (INCAP) – a new risk analysis tool for Austria. Paper presented at the Agricultural Economics Society Annual Conference 2016, 4 April 2016, University of Warwick, England.

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- **Presentations**

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Sinabell, F., 2015, Wirtschaftliche Herausforderungen für Österreichs Landwirtschaft. Präsentiert beim 5. Umweltökologischen Symposium. Landwirtschaft 2030 - Auswirkungen auf Boden, Wasser und Luft, 5. April 2015, HBLA Raumberg-Gumpenstein, Irdning-Donnersbachtal.

Sinabell, F., K. Heinschink, M. Kirchner, E. Audsley, A. Schaumberger, V. Danieu, E. Schmid, B. Amon, M. Schönhart, N. Röder, P. Salamon and A. Williams, 2016, Adaptation and mitigation in Austrian cattle and milk production – scenarios for 2050. Paper presented at 17. Österreichischer Klimatag, Graz, Austria, April 7, 2016.

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Sinabell, F., Th. Url, K. Heinschink, 2016, Adaptation to climate change in the European agriculture: A new tool for explicit cost accounting. Paper presented at MACSUR TradeM Workshop, Oslo, Norway, October 10-12, 2016.

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- **Poster**

Sinabell, F., K. Heinschink, K. Mechtler, H. Mitter, E. Schmid, A. Zimmermann, 2016, Yield potentials and yield gaps of soybeans in Austria – a biophysical and economic assessment. Poster presented at International Crop Modeling Symposium ICropM 2016, Berlin, 16 March 2016, Berlin.

- **Research Report**

Schaumberger, A., 2015, ADAPT-CATMILK: Adaptation in Austrian cattle and milk production. Report on WP2: Grassland Yield and Grassland Yield Risk. Available at: http://www.landnutzung.at/dokumente/CATMILK/2015_Schaumberger-etal.pdf

- **Website**

http://www.landnutzung.at/Catmilk_info.html

- **Concepts for planned project outputs**

Sinabell, F. B. Amon, E. Audsley, M. Kirchner, K. Heinschink, N. Röder, P. Salamon, Schönhart, M., E. Schmid , A. Williams, forthcoming, Implications of Cattle and Restricting Dairy and Cattle Production in Austria – implications from a live cycle assessment point of view. Paper to be submitted to the Journal of Environmental Management or to Science of the Total Environment.

Heinschink, K., and F. Sinabell, forthcoming, The economic cost of eco-system provision by agriculture. Paper to be submitted to Environmental Modeling and Software.

Sinabell, F. B. Amon, E. Audsley, K. Heinschink, N. Röder, P. Salamon, Schönhart, M., E. Schmid, A. Williams, forthcoming, Life Cycle Assesment Implications of GHG reduction policies for Austrian Agriculture. Paper submitted for the Joint Meeting of the Austrian Agricultural Association and GEWISOLA, Munich, 13. bis 15. September 2017, at Technische Universität München in Freising-Weihenstephan.

- **Articles in professional journals**

Sinabell, F., 2016, Ohne Investitionen kommen wir nicht weiter!, dlz magazin, Dezember, Seite 27, 2016

Sinabell, F., Evaluierbar? In: LandInForm. Deutsche Vernetzungsstelle Ländliche Räume, Bundesanstalt für Landwirtschaft und Ernährung. Ausgabe 2/2016, Seite 29.

Sinabell , F., M. Kirchner, D. Pennerstorfer und G. Streicher, 2016, Die Wirkungen des Programms LE 07-13 auf Wertschöpfung, Beschäftigung und Indikatoren zur Lebensqualität. Ländlicher Raum, März 2016

Sinabell, F., 2016, Der Österreichbonus kommt bei den Bauern nicht an 16. Okt. 2015, Kärntner Bauer.

Sinabell, F., 2016, Preisfaktoren im Überblick. Die Landwirtschaft, August 2015.

Sinabell, F., 2016, Wer profitiert von internationalen Handelsabkommen und warum sind so viele dagegen? VÖS Magazin 3 2015

Sinabell, F., 2014, Mögliche Modelle zur Berechnung von Umwelt- und Ressourcenkosten im Bereich Wasser. In: factum 2014.

- **Doctoral dissertations**

  Mathias Kirchner: The dissertation "Integrated impact modelling of climate change and policy scenarios on agriculture, land use change, and environment in Austria" was accepted by Universität für Bodenkultur Wien in 2015 (see http://permalink.obvsg.at/bok/AC10777779). This dissertation earned the *ÖGA-Preis* for excellence in young scientists' achievement (see http://oega.boku.ac.at/oega-preis/oega-preis-2016.html).

  Stefan Höltinger: The work on his dissertation is ongoing.

- **Contributions at stakeholder workshops**:

  Dairy production and dairy cow breeding, Vienna, 22nd April 2016

  Beef production, sheep and goats, Salzburg, 3rd May 2016

  Pork, poultry, egg production, Linz, 27th April 2016

  Organic Farming, Vienna, 30th May 2016

- **Dissemination activities at seminars for farmers:**

  Regionale Wirtschaft – Chancen für land- und forstwirtschaftliche Betriebe, Landjugend Wien, 19. Nov. 2016

  Optionen und Perspektiven für die österreichische Landwirtschaft, Bauernbund, Pamhagen, 3. Nov. 2016

  Bedeutung Tierhaltung in der Landwirtschaft und der Gesamtwirtschaft, Landwirtschaftskammer St. Pölten, 25. Nov. 2015

  Agrarpolitik in der EU und in Österreich, Fachschule Warth, 8. Juni 2016

  Perspektiven und Herausforderungen für Österreichs Landwirtschaft im kommenden Jahrzehnt, Arge Meister in St. Pölten, 19. Jän. 2015

  Zukunft der agrarischen Märkte – Wie kann es weitergehen, ARGE Bergbauern Weiz, 6. Feber 2015

  Zukunftsaussichten der Landwirtschaft, Landwirtschaftskammer Burgenland, Podler, 4. Dez. 2014