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PATCH:ES

Private Adaptation to Climate Change

Case Study Report

Private Adaptation to Climate Change in Agriculture

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Executive Summary

Agricultural experts play an important role in facilitating climate change adaptation in Austria. We aim at investigating their perceptions and future expectations of changes in regional climate conditions, agricultural impacts, and private adaptation measures. Furthermore, we analyze whether and how climate change is addressed in regional agricultural institutions and examine the agricultural experts' level of information, their preferred information sources and media as well as their information needs. Qualitative, semi-structured interviews have been conducted with agricultural experts in two case study regions, i.e. Mostviertel and South-East Styria. The results show that changes in temperature and extreme events as well as high future uncertainties are perceived as most challenging. Perceived impacts are focused but not limited to negative effects on crop production. A broad variety of incremental, systemic and transformational adaptation measures are rated as relevant for the case study regions. Their implementation is driven by farm and regional characteristics as well as by legal, market and policy conditions. Climate change is directly or indirectly addressed in the regional agricultural institutions represented by the interview partners who feel well informed about this topic. They regularly consult print and digital media provided by established agricultural and educational institutions and appreciate discussions with peers. Information needs refer to generalized as well as context-specific data and information which are easily accessible and user-friendly.

Introduction

Agricultural productivity and land use potential are likely to alter under changing climatic conditions. Modelling results for Austria show high regional differences in expected climate change impacts leading to different adaptation potentials (Mitter et al., 2015; Schönhart et al., 2014). A timely recognition of chances and risks is essential for developing and implementing adaptation measures. Although agricultural experts play an important role in facilitating and supporting climate change adaptation in Austria, information on their perceptions and expectations of changes in regional climate conditions, climate change impacts and adaptation is limited. This knowledge gap can constrain the adaption process and may reduce the capacity and willingness to take adaptation decisions (Moser and Ekstrom, 2010).

We present results of a qualitative study focusing on perceptions and future expectations of a broad range of agricultural experts on the subject of climate change. In particular, we are interested in perceived and expected changes in regional climate conditions and induced impacts on the agricultural sector as well as on adequate adaptation measures. Furthermore, we examine the level of information of agricultural experts, their preferred information sources and information needs and how climate change is addressed in regional agricultural institutions in Austria.

Data and method

Two agricultural production regions, the Mostviertel and South-East Styria, have been selected as case study regions. The selection was based on the heterogeneity in pedo-climatic conditions among the regions and on results from integrated modelling studies on the regional vulnerability of the agricultural sector. While grassland production in the Mostviertel is likely to benefit from climate change in the next decades, cropland production may benefit or loose. In South-East Styria, previous model results show adverse impacts on the agricultural sector for most climate change scenarios (see Mitter et al., 2015, 2014; Schönhart et al., 2014)

A focus group discussion with twelve farmers and agricultural experts from extension services has been conducted in the Mostviertel region in May 2015 in order to frame the research questions and develop the qualitative interview guide for data collection.

Twenty-one qualitative, semi-structured interviews have been conducted with agricultural experts in the two case study regions between August and October 2015. The interview partners represent the bandwidth of agricultural institutions in the case study regions and include agricultural extension specialists, people from administration, teachers and heads of farming engineering schools, scientists and engineers at regional research institutes, people from agricultural cooperatives, producer groups and machinery co-operations as well as people working for regional development agencies and environmental organizations.

The interviews lasted between 40 and 90 minutes each. They were digitally recorded and have been transcribed word-for-word. Qualitative content analysis, facilitated by Atlas.ti, has served as a means for narrowing down, coding and interpreting the statements. Deductive and inductive coding has been used. In a first step, codes were defined based on the literature and the interview guide and were finally assigned to relevant text passages. During this procedure additional codes were created for emerging topics (see der beiden Fallstudienregionen Mostviertel und Südoststeiermark Friese, 2012).

Results and discussion

The interviews indicate that perceived changes in regional climate conditions are similar in the two case study regions. The agricultural experts responded that temperature levels and variabilities have increased, precipitation distributions have changed, and the number and intensity of droughts, heat waves and heavy rainfall events has risen. For the future period, the agricultural experts expect further increases in mean temperature and temperature fluctuations, further changes in timing of precipitation as well as more frequent and more severe extreme events.

Perceived climate change impacts are focused but not limited to crop production. This emphasis can be explained by the direct link between changes in regional climate conditions and crop growth rates. Furthermore, extension activities traditionally concentrate on production-related aspects which may amplify their dominance in the interviews. The agricultural experts mostly address negative impacts such as crop damages, problems with animal welfare, additional management-related expenses and soil loss. Perceived positive impacts comprise increases in yield levels and yield quality due to higher temperatures. Expected future impacts refer to reductions in crop, grassland and livestock yields and to harmful effects on natural resources, i.e. soil and water.

The agricultural experts reported on private, public, and natural adaptation, depending on the main ‘actor’ taking the respective adaptation measure. Private adaptation measures are mostly implemented for private benefit but may also exert beneficial or adverse effects on public goods. Incremental, systemic and transformational private adaptation measures have been perceived in the case study regions. Incremental adaptation relates to land and livestock management decisions, which are taken at sub-system level in order to ‘preserve’ the existing farm. They include, for instance, changes in timing of cultivation, changes in stocking densities, and adjustments in feeding ratios. Systemic adaptation is linked to management decisions at farm level, land use and land cover change, and investment decisions. Examples are the expansion of cropland, fruit and wine growing areas, and the investment in water reservoirs and new technologies. Transformational adaptation refers to the strategic orientation of the farm and includes, for instance, converting from full-time to part-time farming, changing the farm type, farm withdrawal and engaging in non-agricultural secondary activities. Several incremental and systemic adaptation measures are perceived to gain in importance in the future. They comprise of the implementation of new technologies, changes in land use and land cover, and the adoption of more sophisticated financial and risk management strategies.

Climate change, related impacts or adaptation strategies are directly or indirectly addressed in all institutions represented by the agricultural experts, though for different purposes (e.g. education and training, strategic orientation of the institution) and with different priorities. The majority of the agricultural experts feel very well or well informed about changes in climate conditions and well or moderately informed about latest developments in adaptation measures. Almost all are actively seeking for information related to changing climate conditions and they rate the available information generally as good. However, they expressed various information needs which can be summarized in two major categories, (i) generalized data and information which are easily accessible and user-friendly, and (ii) context-specific data and information with high practical relevance.

Conclusions

Feedback from agricultural experts shows that higher temperatures and an increase in frequency and duration of extreme events (i.e. droughts, heat waves and heavy rainfall events) are the main climatic parameters affecting agricultural production. Although perceived climate signals and dominating

chances and challenges are similar in the case study regions, observed impacts are influenced by the prevalent agro-ecosystems and the socio-economic conditions. Similarly, regional climate change is one of many drivers for implementing private adaptation measures. The agricultural experts perceive market and agricultural policy changes as well as the legal framework as equally important at least. Furthermore, available resources (such as land, water and infrastructure) as well as farmers' and farms' characteristics shape adaptation decisions. This highlights the need to put climate-related chances and risks in the context of the farm, the region and the legal, market and policy conditions.

Keywords: regional climate change, private adaptation, drivers of private adaption, external effects, agricultural experts' perceptions, qualitative interviews

Ausführliche Zusammenfassung

AgrarexpertInnen spielen bei der Förderung von Klimawandelanpassung in Österreich eine wichtige Rolle. Wir untersuchen ihre Wahrnehmungen und zukünftigen Erwartungen von regionalen Klimaveränderungen, Auswirkungen auf die Landwirtschaft und privaten Anpassungsmaßnahmen. Weiteres prüfen wir, ob und wie Klimawandel in regional verankerten Agrarinstitutionen thematisiert wird und analysieren den Informationsstand, die bevorzugten Informationsquellen und -medien sowie den Informationsbedarf der AgrarexpertInnen. Qualitative, Leitfaden-gestützte Interviews wurden in zwei Fallstudienregion – Mostviertel und Südost-Steiermark – mit AgrarexpertInnen geführt. Die Ergebnisse zeigen, dass Veränderungen der Temperatur und von Extremwetterereignissen sowie hohe erwartete Unsicherheiten als größte Herausforderungen gesehen werden. Die wahrgenommenen Auswirkungen umfassen vor allem negative Effekte auf die Pflanzenproduktion, sind aber nicht hierauf beschränkt. Eine Bandbreite an inkrementellen, systemischen und transformativen Anpassungsmaßnahmen werden für die Fallstudienregionen als relevant eingeschätzt. Ihre Umsetzung wird angetrieben von betriebs- und regionsspezifischen Charakteristika sowie von gesetzlichen, politisch-administrativen und marktwirtschaftlichen Rahmenbedingungen. Klimawandel wird in den regional verankerten Agrarinstitutionen direkt oder indirekt thematisiert. Die interviewten AgrarexpertInnen greifen regelmäßig auf Print- und digitale Medien etablierter Agrarinstitutionen und Bildungseinrichtungen zurück und schätzen Diskussionen mit FachkollegInnen. Ihr Informationsbedarf konzentriert sich auf allgemeine und kontextspezifische Daten und Informationen, die leicht zugänglich und nutzerfreundlich sind.

Einleitung

Die landwirtschaftliche Produktivität und das Landnutzungspotenzial werden sich mit dem Klimawandel voraussichtlich verändern. Modellergebnisse zeigen für Österreich hohe räumliche Unterschiede bei den erwarteten Klimawandel-Auswirkungen die zu diversen Anpassungspotenzialen führen (Mitter et al., 2015; Schönhart et al., 2014). Ein zeitgerechtes Erkennen von Chancen und Risiken ist ausschlaggebend für die Entwicklung und Implementierung von Anpassungsmaßnahmen. Obwohl AgrarexpertInnen bei der Förderung von Klimawandelanpassung in Österreich eine wichtige Rolle spielen, sind Informationen über ihre Wahrnehmungen und Erwartungen von regionalen Klimabedingungen, Auswirkungen des Klimawandels und Anpassung limitiert. Diese Wissenslücke kann den Anpassungsprozess beeinträchtigen und die Anpassungskapazität und die Bereitschaft zur Umsetzung von Anpassungsmaßnahmen reduzieren (Moser und Ekstrom, 2010).

Wir präsentieren Ergebnisse einer qualitativen Studie mit dem Fokus auf Wahrnehmungen und zukünftigen Erwartungen einer Bandbreite an AgrarexpertInnen zum Thema Klimawandel. Im Speziellen interessieren wir uns für die wahrgenommenen und erwarteten Veränderungen regionaler Klimabedingungen und die dadurch hervorgerufenen Auswirkungen auf den Sektor Landwirtschaft sowie für adäquate Anpassungsmaßnahmen. Zudem untersuchen wir den Informationsstand der AgrarexpertInnen, ihre bevorzugten Informationsquellen, ihren Informationsbedarf und wie Klimawandel in regionalen landwirtschaftlichen Institutionen in Österreich thematisiert wird.

Daten und Methode

Zwei agrarische Produktionsgebiete, das Mostviertel und die Südost-Steiermark, wurden als Fallstudienregionen ausgewählt. Die Auswahl erfolgte auf Grund heterogener pedo-klimatischen Bedingungen in den Regionen und basierte auf den Ergebnissen integrativer Modellstudien zur regionalen Vulnerabilität des Agrarsektors. Während das Grünland im Mostviertel in den nächsten Jahrzehnten wahrscheinlich vom Klimawandel profitieren kann, wird das Ackerland entweder gewinnen oder verlieren. In der Südost-Steiermark zeigten bisherige Modellergebnisse für die meisten Klimaszenarien nachteilige Auswirkungen für den Sektor Landwirtschaft (siehe Mitter et al., 2015, 2014; Schönhart et al., 2014).

Eine Fokusgruppendiskussion wurde im Mostviertel im Mai 2015 mit zwölf Landwirten und AgrarexpertInnen der Landwirtschaftskammer geführt, um die Forschungsfragen und den qualitativen Interviewleitfaden gemeinsam weiterzuentwickeln.

21 qualitative, Leitfaden-gestützte Interviews wurden mit AgrarexpertInnen in den beiden Fallstudienregionen von August bis Oktober 2015 geführt. Die InterviewpartnerInnen repräsentierten die Bandbreite landwirtschaftlicher Institutionen in den Fallstudienregionen und umfassen BeraterInnen der Landwirtschaftskammern, Angestellte der Verwaltung, LehrerInnen und Direktoren von Landwirtschaftsschulen, Wissenschaftler und Techniker in regionalen Forschungseinrichtungen, Mitarbeiter in landwirtschaftlichen Vereinen, bei Produzentenverbänden und beim Maschinenring sowie Mitarbeiter in der Regionalentwicklung und in Umweltorganisationen.

Die Interviews dauerten zwischen 40 und 90 Minuten. Sie wurden digital aufgenommen und vollständig transkribiert. Eine qualitative Inhaltsanalyse wurde mittels Atlas.ti durchgeführt, um die Statements einzugrenzen, zu codieren und zu interpretieren. Deduktives und induktives Kodieren wurde angewendet. Zuerst wurden – basierend auf der Literatur und dem Interviewleitfaden – Codes definiert, die dann den relevanten Textpassagen zugeordnet wurden. Während dieses Prozesses wurden zusätzliche Codes für neu aufkommende Themen generiert (siehe Friese, 2012).

Ergebnisse und Diskussion

Die Interviews zeigen, dass die wahrgenommenen regionalen Klimaveränderungen in den beiden Fallstudienregionen ähnlich sind. Die AgrarexpertInnen berichteten, dass das Temperaturniveau und die Variabilität der Temperatur gestiegen ist, dass sich die Niederschlagsverteilung verändert hat und dass die Häufigkeit und Intensität von Dürren, Hitzewellen und Starkniederschlagsereignissen gestiegen ist. Für die Zukunft erwarten AgrarexpertInnen weitere Steigerungen der mittleren Temperatur und Temperaturschwankungen, weitere zeitliche Veränderungen des Auftretens von Niederschlägen sowie häufigere und heftigere Extremwetterereignisse.

Wahrgenommene Auswirkungen des Klimawandels beziehen sich vorwiegend auf die Pflanzenproduktion, sind aber nicht darauf beschränkt. Dieser Schwerpunkt kann einerseits durch den direkten Zusammenhang zwischen regionalen Klimaveränderungen und Pflanzenwachstum erklärt werden. Andererseits konzentrieren sich Beratungsleistungen traditionell auf produktionsbezogene Aspekte, was ihre Dominanz in den Interviews verstärken kann. Die AgrarexpertInnen thematisierten negative Auswirkungen wie Ernteschäden, Probleme mit der Tiergesundheit, zusätzliche management-bezogene Ausgaben und Bodenverlust am stärksten. Wahrgenommene positive Auswirkungen umfassen gesteigerte Pflanzenerträge und Qualität auf Grund höherer Temperaturen. Erwartete zukünftige Auswirkungen beziehen sich auf Rückgänge bei den Erträgen im Ackerbau, am Grünland und bei der Tierproduktion sowie auf negative Effekte auf natürliche Ressourcen wie Boden und Wasser.

Die AgrarexpertInnen berichteten von privater, öffentlicher und natürlicher Anpassung in Abhängigkeit vom Akteur, der die jeweilige Anpassungsmaßnahme hauptsächlich umsetzt. Private Anpassungsmaßnahmen werden vorwiegend auf Grund des privaten Nutzens implementiert können aber auch positive oder negative Effekte auf öffentliche Güter haben. Inkrementelle, systemische und transformative private Anpassungsmaßnahmen wurden in den Fallstudienregionen wahrgenommen. Inkrementelle Anpassung bezieht sich auf Maßnahmen im Pflanzenbau und der Tierhaltung, die auf einem Teil des Betriebes (Ebene des Sub-Systems) vorgenommen werden, mit dem Ziel den bestehenden Betrieb zu erhalten. Dazu gehören beispielsweise veränderte Anbau- und Erntezeitpunkte, veränderter Viehbesatz und Anpassungen bei den Fütterungsrationen. Systemische Anpassung meint Management-Entscheidungen auf Betriebsebene wie Änderungen der Landnutzung und Landbedeckung und Investitionsentscheidungen. Beispiele sind die Ausdehnung der Ackerbau-, Obst- und Weinbaugebiete sowie die Investition in Wasserspeicher und neue Technologien. Transformative Anpassung thematisiert die strategische Ausrichtung eines Betriebes und inkludiert beispielsweise die Umstellung eines Haupterwerbsbetriebes auf Nebenerwerb, die Veränderung der Betriebsform, Betriebsaufgabe und die Aufnahme von nicht-landwirtschaftlichen Nebentätigkeiten. Mehrere inkrementelle und systemische Anpassungsmaßnahmen werden laut Einschätzung der AgrarexpertInnen in Zukunft an Bedeutung gewinnen. Diese umfassen die Einführung neuer Technologien und komplexer Finanz- und Risikomanagementinstrumente sowie Änderungen der Landnutzung und der Landbedeckung.

Klimawandel, daraus resultierende Auswirkungen oder Anpassungsmaßnahmen werden in allen Institutionen, die von den AgrarexpertInnen repräsentiert wurden, thematisiert. Form bzw. Zweck (z.B. Aus- und Weiterbildung, strategische Ausrichtung der Institution) und Priorität der Themen variieren zwischen den Institutionen. Die Mehrheit der AgrarexpertInnen fühlt sich sehr gut bis gut über Klimaveränderungen und gut bis mittel über aktuelle Entwicklungen von Anpassungsmaßnahmen informiert. Fast alle informieren sich aktiv und bewerten die verfügbare Information als gut. Zudem artikulierten die AgrarexpertInnen einen Informationsbedarf, der sich in zwei Hauptkategorien zusammenfassen lässt, (i) allgemeine Daten und Informationen, die leicht zugänglich und nutzerfreundlich sind und (ii) kontextspezifische Daten und Informationen mit hoher praktischer Relevanz.

Schlussfolgerungen

Die Rückmeldungen der AgrarexpertInnen zeigen, dass höhere Temperaturen und eine Zunahme der Häufigkeit und Dauer von Extremwetterereignissen (i.e. Dürren, Hitzewellen und Starkniederschlagsereignisse) die wesentlichen Klimaparameter sind, die die landwirtschaftliche Produktion gefährden. Obwohl die wahrgenommenen Klimasignale und die dominierenden Chancen und Herausforderungen in den beiden Fallstudienregionen ähnlich sind, werden die beobachteten Auswirkungen von den vorherrschenden Agrarökosystemen und den sozioökonomischen Bedingungen mitbestimmt. Dementsprechend werden regionale Klimaveränderungen als einer von vielen Einflussfaktoren auf die Umsetzung von privaten Anpassungsmaßnahmen wahrgenommen. Mindestens als gleichbedeutend werden von den AgrarexpertInnen die Situation am Markt, Veränderungen in der Agrarpolitik und Veränderungen der gesetzlichen Rahmenbedingungen eingeschätzt. Zudem prägen die verfügbaren Ressourcen (wie Land, Wasser und Infrastruktur) sowie Charakteristika der Betriebe und der LandwirtInnen die Anpassungsentscheidungen. Damit zeigt sich, dass klimabedingte Chancen und Risiken im Kontext des Betriebs, der Region und der gesetzlichen, administrativ-politischen und marktwirtschaftlichen Rahmenbedingungen zu bewerten sind.

Schlagwörter: regionale Klimaveränderungen, private Anpassung, Treiber privater Anpassung, externe Effekte, Wahrnehmungen von AgrarexpertInnen, qualitative Interviews

1 Introduction

Agricultural productivity and land use potential are likely to alter under changing climatic conditions. Results from integrated modeling studies show high regional differences in expected climate change impacts for Austria leading to different agricultural adaptation potentials (Mitter et al., 2015; Schönhart et al., 2014). A timely recognition of chances and risks is essential for developing, facilitating and implementing adaptation strategies. Although agricultural experts play an important role in facilitating and supporting climate change adaptation in Austria, systematic information on their perceptions and expectations of changes in regional climate conditions, climate change impacts and agricultural adaptation is limited. This knowledge gap can constrain the adaption process and may reduce the capacity and willingness to take adaptation decisions (Moser and Ekstrom, 2010). Klein and Juhola (2014) argue that adaptation research focuses on conceptualizing and categorizing adaptation measures and mostly ignores the process of taking adaptation decisions.

Therefore, a focus group discussion and qualitative expert interviews have been carried out in two Austrian production regions, the Mostviertel region and South-East Styria, in order to learn about agricultural experts' perceptions as well as their future expectations. In particular, we were interested in

- perceived and expected changes in regional climate conditions in the two case study regions,
- perceived and expected climate change impacts on the agricultural sector in the case study regions,
- adequate adaptation measures for the case study region, perceived drivers and barriers for their implementation on farms as well as potential positive and negative side-effects,
- the level of information of agricultural experts, their preferred information sources and information needs, and
- how climate change is addressed in agricultural institutions (e.g. agricultural engineering schools, agricultural extension agencies, administration) in Austria.

Based on this qualitative analysis, recommendations for policy makers and public authorities are derived on how private adaptation can be facilitated in Austrian agriculture by agricultural institutions.

The qualitative study has been conducted within the project PATCH:ES – Private Adaptation Threats and Chances: Enhancing Synergies with the Austrian NAS Implementation, funded by the Austrian Climate and Energy Fund within the Austrian Climate Research Program (ACRP). Within PATCH:ES, private adaptation is investigated in four Austrian case study sectors: agriculture, winter tourism as well as flood protection and thermal comfort on private household level. The case study results are used as an empirical basis for investigating maladaptation and the governance of private adaptation (see specific reports).

2 Data and methods

2.1 Case study regions

Two agricultural production regions, the **Mostviertel** region and **South-East Styria,** have been selected as case study regions (Figure 1). The selection was based on the pedo-climatic conditions in the regions as well as on results from integrated modeling studies on the regional vulnerability of the agricultural sector (see Table 1 Table 1and Mitter et al., 2015, 2014; Schönhart et al., 2014).

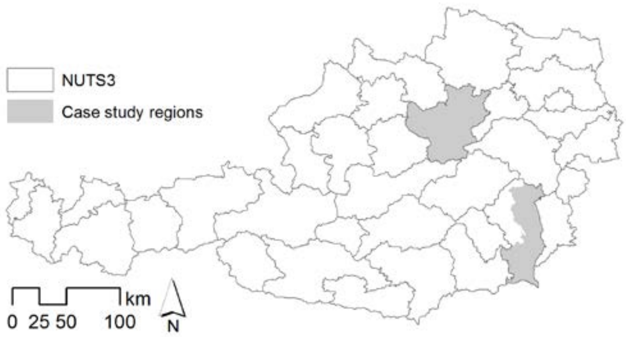

Figure 1. Location of the case study regions in Austria.

The **Mostviertel** region (NUTS3 region AT121 consisting of the four districts Melk, Scheibbs, Amstetten and Waidhofen an der Ybbs) is located in the Alpine foothills in the province of Lower Austria. Total agricultural land amounts to around 145,200 ha. Thereof, about 74,400 ha are used as cropland and about 69,000 ha are used as grassland. Alpine pastures amount to about 1,800 ha (calculations based on data from the Integrated Administration and Control System, IACS, from 2010). Soil and climate conditions are rather heterogeneous in the Mostviertel region leading to highly variable agricultural production conditions. Most prevalent soil types are brown earth and pseudogley, according to the digital soil map of Austria (www.bfw.ac.at/ebod). Mean annual temperature ranges between 3.5 °C at an altitude of around 1,500 m and 9 °C at an altitude of around 200 m. Mean annual precipitation sums range between 550 mm in the North-Eastern, cropland dominated part of the region and 1,400 mm in the grassland dominated South of the region (Strauss et al., 2013).

Results from integrated modeling studies indicate that grassland productivity may increase under climate change in the Mostviertel region. Grassland may benefit from rising temperatures and the CO_2-fertilization effect as long as water is not limiting and heat stress is absent (Schönhart et al., 2014). Crop yields are simulated to increase or decrease in the Mostviertel region, depending on the considered climate change scenario, thus reflecting high uncertainties in optimizing crop production and management decisions in the Mostviertel region (Mitter et al., 2015, 2014; Schönhart et al., 2014).

In **South-East Styria,** which encompasses the districts Südoststeiermark and Hartberg-Fürstenfeld, about three quarters of the total agricultural land of around 89,500 ha are used as cropland (around 68,000 ha). Grassland is found on around 21,000 ha and alpine pastures on around 500 ha (calculations based on IACS data from 2010). Similar to the Mostviertel region, soil conditions vary considerably within South-East Styria. Dominant soil types are brown earth, pseudogley and gley, as recorded in the digital soil map of Austria. South-East Styria has a moderate continental climate with rather mild winters and low annual precipitation. Mean annual temperature ranges between 8 and 10 °C and mean annual precipitation sums are between 700 and 900 mm (Prettenthaler et al., 2010).

Model results reveal that South-East Styria may have to accept grassland forage and crop yield losses under changing climatic conditions. While grassland forage yields could increase in selected climate change scenarios, crop yields are projected to suffer from water shortages and heat stress in the majority of the investigated climate change scenarios which emphasizes the high vulnerability of the agricultural sector in South-East Styria (Mitter et al., 2015; Schönhart et al., 2014).

Table 1. Characteristics of the case study regions.

Characteristics	Mostviertel	South-East Styria
Total agricultural land (ha)[1]	145,200	89,500
Cropland (ha)[1]	74,400	68,000
Grassland (ha)[1]	69,000	21,000
Alpine pasture (ha)[1]	1,800	500
Mean annual temperature (°C)[2]	3.5-9	8-10
Mean annual precipitation (mm)[2]	550-1,400	700-900
Main soil types[3]	brown earth, pseudogley	brown earth, pseudogley, gley

Sources: [1]Own calculations based on data from the Integrated Administration and Control System (IACS) from 2010. [2]Prettenthaler et al. (2010) and Strauss et al. (2013) [3]Digital soil map of Austria (www.bfw.ac.at/ebod)

2.2 Qualitative analysis

Our analysis is based on **qualitative, semi-structured face-to-face-interviews** with agricultural experts from the two case study regions. The interviews were preceded by a **focus group discussion** in the Mostviertel region. This discussion aimed at developing the research questions and the research design together with farmers and extension experts. Twelve participants from the region with heterogeneous experience reported on changes in regional climate conditions, provided insights into adequate climate change adaptation measures for the region, and pointed out barriers for their implementation. The results of the focus group discussion served as a starting point for designing the qualitative interview guide.

The qualitative interviews were conducted with agricultural experts in the Mostviertel region and South-East Styria. The interview partners were selected in three steps combining direct (scientists identify potential interview partners by themselves) and indirect approaches (scientists approach experts, e.g. from the region, who may suggest potential interview partners). First, a list of relevant agricultural institutions and potential interview partners in the case study regions has been compiled based on an online search (direct approach). Furthermore, key persons in climate change administration and coordination have served as 'gatekeepers' (Helfferich, 2005) in order to identify relevant interview partners (indirect approach). Second, the identified, potential regional interview partners have been prioritized by the BOKU-project team. Third, the sample of interview partners was complemented through the snowball approach (see Biernacki and Waldorf, 1981; Reed et al., 2009) which has been applied during the interview request by phone and after the face-to-face interviews (indirect approach).

In total, 21 qualitative interviews (following 27 inquiries) have been conducted between August and October 2015. Thereof, ten interviews were carried out in the Mostviertel region and eleven in South-East Styria. In the following, we refer to the interview partners in the Mostviertel region as M1, M2, …, M10 and to the interview partners in South-East Styria as S1, S2, …, S11 (see Figure 2).

The interview partners represent the bandwidth of agricultural institutions in the case study regions and include agricultural extension specialists, people from administration, teachers and heads of farming engineering schools, scientists and engineers of regional research institutes, people from agricultural cooperatives, producer groups and machinery co-operations as well as people working for regional development agencies and environmental organizations. Regional experts from the Austrian Hail Insurance Company were not available for an interview due to a high workload induced by unfavorable weather conditions in some parts of Austria in summer 2015. Two female and 19 male agricultural experts were interviewed.

The majority of the interviews was carried out in the case study regions at the respective workplace of the interview partners. Two interview partners combined the interview with other meetings in Vienna and were thus interviewed at BOKU University. One representative of a farm engineering school preferred to be interviewed at home.

The interview guide (see sub-section 7.1) contained five parts and touched upon the following issues

i. Agricultural experts' perceived and expected changes in regional climate conditions

ii. Agricultural experts' perceived and expected impacts of changes in regional climate conditions on regional agriculture
iii. Climate change adaptation measures already applied in or at least relevant for the farmers in the case study region
iv. Level of information and information needs of agricultural experts
v. Addressing changes in regional climate conditions within the agricultural institution

The face-to-face interviews lasted between 40 and 90 minutes each (in total about 1,300 minutes). They were digitally recorded and have been transcribed word-for-word using the easytranscript-software (in total about 255 pages, i.e. about 166,000 words).

Qualitative content analysis, facilitated by Atlas.ti, has served as a means for condensing and coding collected data, and for interpreting the interview partners' statements. Deductive (top-down) and inductive (bottom-up) coding has been used (see Kuckartz, 2007). In a first step, theme codes were defined deductively, i.e. based on concepts and theories presented in the climate change adaptation literature (see e.g. sub-section 3.1.1). These theme codes were then assigned to relevant text passages of the transcribed interviews. In this work step, additional codes were created inductively, i.e. for emerging topics, and theme codes were separated from those adding further description such as an evaluation or temporal scope (see Friese, 2012). Combining deductive and inductive coding allowed us to develop and refine the concepts and theories presented in the climate change adaptation literature and resulted in a new analytical framework for investigating private adaptation in the agricultural sector. In a next step, the derived analytical framework, which is presented in sub-section 3.1.1, has been applied to the data collected in the case study regions. Figure 2 points to the spatial scales relevant for investigating the qualitative interviews. Single cases may be analyzed in order to identify local characteristics of climate change adaptation in agriculture. The interviews from the case study regions may be used for examining the bandwidth of perceptions in the regions, to analyze differences between the case study regions and to perform an inter-regional analysis. We aim at revealing the spectrum of perceptions on changes in climate conditions, regional impacts and adequate adaptation measures and therefore focus on the regional level.

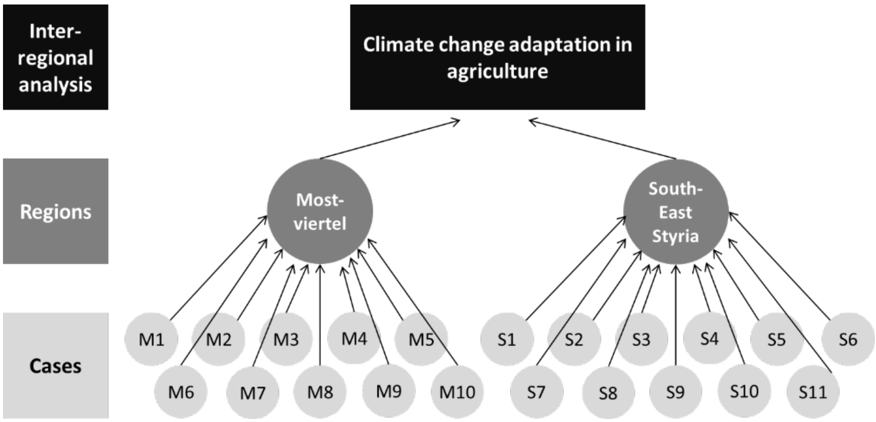

Figure 2. Spatial scales for analyzing the qualitative interviews.

3 Results

3.1 Climate change adaptation in agriculture

3.1.1 Analytical framework

Based on the collected qualitative data, we have developed and refined the concepts and theories presented in the climate change adaptation literature. The derived analytical framework, which is presented in Figure 3 and Figure 4, allowed us (i) to investigate perceived drivers of private adaptation measures on farms, (ii) to analyze climate change adaptation in agriculture, and (iii) to examine perceived and potential positive and negative on-farm and off-farm effects of private adaptation.

The core theme of the project PATCH:ES are climate change adaptation measures that are already applied or have the potential to be applied on farms. Therefore, climate change adaptation has been placed in the center of the analytical framework which also captures the causal links between private adaptation measures as well as the drivers for and the perceived effects of their implementation. Mainly public adaptation is referred to as well. Depending on the viewpoint, public adaptation can also be interpreted as external drivers of private adaptation, as shown in Figure 4. In the analysis they are treated differently. Changes in regional climate conditions as well as their impacts are presented in sub-sections 3.1.2 and 3.1.3. Availability and provision of information, technical and financial infrastructure is further described in sub-section 3.2.2 as part of the agricultural institutional setting. Despite of the focus of the interviews on private adaptation, natural adaptation was also addressed in the interviews and is therefore mentioned in the analytical framework but not further analyzed. The analytical framework is explained in some more detail in the following sub-sections.

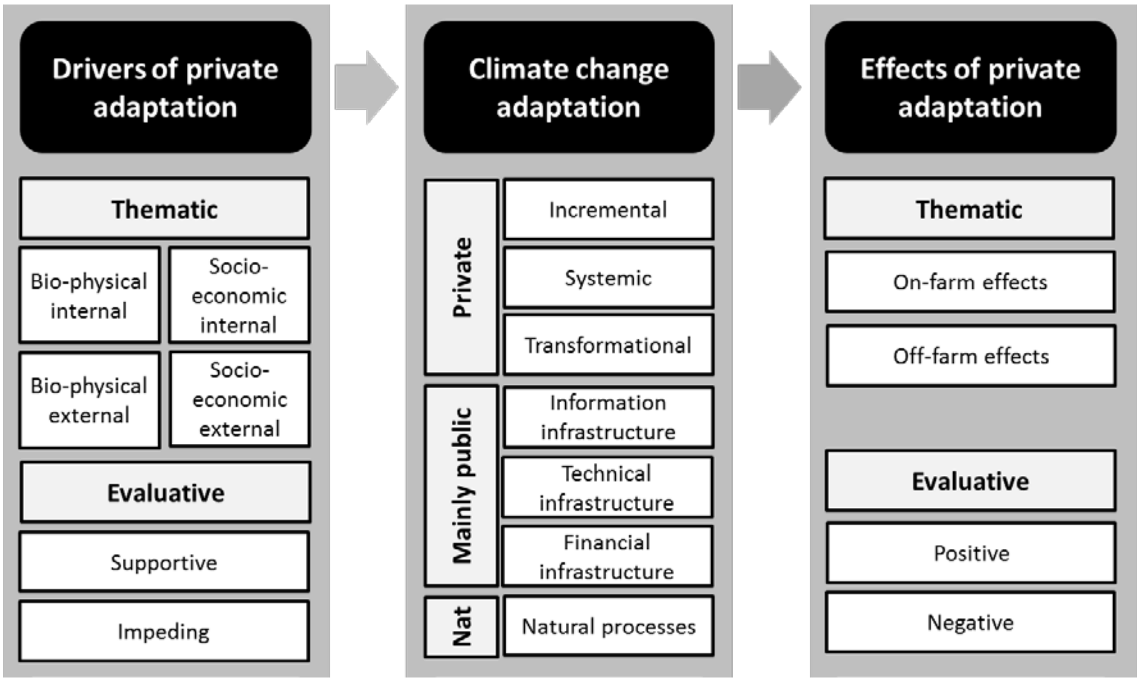

Figure 3. Illustration of the analytical framework [Note: Nat = Natural].

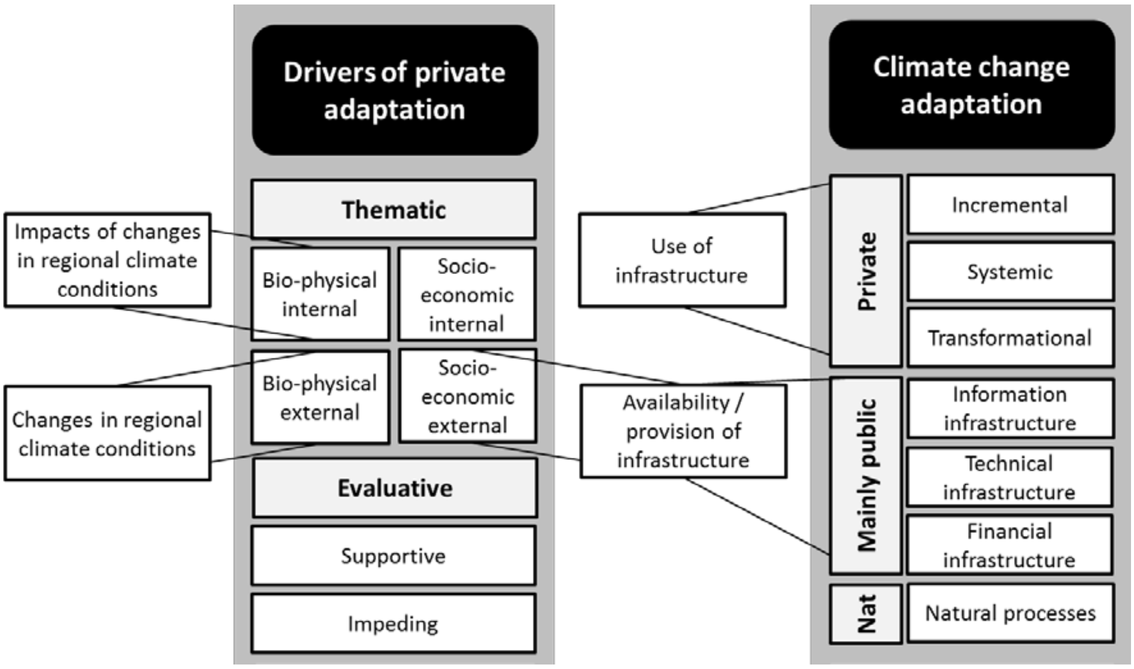

Figure 4. Illustration of the interrelations between drivers of private adaptation and mainly public adaptation [Note: Nat = Natural]

3.1.1.1 Drivers of private climate change adaptation measures

The procedure for identifying the drivers of private climate change adaptation is based on the classification of vulnerability drivers identified by Füssel (2007). He groups vulnerability drivers according to their respective domain, i.e. bio-physical and socio-economic, and their sphere, i.e. internal and external. The bio-physical domain relates to the system properties of the natural or built environment. The socio-economic domain refers to the legal and institutional frameworks, policy and market conditions, power relations, and characteristics of social groups and actors. Depending on the scale and scope of the investigation, i.e. the defined system boundary, internal drivers refer to the characteristics of a system whereas external drivers apply to factors outside a system. Following this suggestion, we categorize the drivers for private climate change adaptation into internal and external bio-physical, and internal and external socio-economic drivers, whereby the farm is chosen as the system boundary. Internal bio-physical drivers are further clustered in local climate conditions, local natural resources (e.g. soil, water) and farm management-related aspects (e.g. crops, livestock). Similarly, external bio-physical drivers refer to regional climate conditions and regional natural resources. Internal socio-economic drivers are divided into two sub-categories. The first relates to the characteristics of the individual farmer and includes 'individual-subjective' (e.g. mindset, values) and 'individual-objective' factors (e.g. level of education, skills), as discussed in (Ballard et al., 2013). The second sub-category encompasses the social (e.g. family structure) and economic characteristics of the farm (e.g. farm type). External socio-economic drivers are differentiated into political, economic, social, technological, and legal dimensions – similar to the factors relevant for a PESTLE analysis[1] (see e.g. Srdjevic et al., 2012; Zalengera et al., 2014). In a next step, the supportive and impeding qualities of the adaptation drivers are evaluated.

We investigate the drivers of private climate change adaptation in greater detail by examining one sub-category for internal (see sub-section 3.1.3) and external bio-physical (see sub-section 3.1.2) and external socio-economic drivers (see sub-section 3.2.2), respectively. The choice of the sub-categories is driven by the thematic and regional focus of the analysis which become apparent by the

[1] The environmental dimension of the PESTLE analysis is covered in the bio-physical domain.

close link between adaptation drivers and the perceived private climate change adaptation measures. Two major components of adaptation are actual and expected climate conditions and its impacts on the agricultural sector (IPCC, 2014a). Accordingly, we explore perceived and expected changes in regional climate conditions (external bio-physical drivers) and perceived and expected impacts of changes in regional climate conditions (internal bio-physical drivers) in more detail.

Public provision of information, technical and financial infrastructure needs to be considered from two sides. From the viewpoint of adaptation drivers, it is referred to as *'institutional incentive'* that influences adaptive capacity and enhances the chances of effective climate change adaptation (Gupta et al., 2010; Mandryk et al., 2015). From the viewpoint of agricultural adaptation, establishing infrastructure is classified as mainly public adaptation (see e.g. Howden et al., 2007; Smit and Skinner, 2002), though making use of the infrastructure falls within the category of private adaptation. In our analysis, we refer to the provision of infrastructure in sub-section 3.2.2 and illustrate the two explained approaches in Figure 3 and Figure 4.

3.1.1.2 Climate change adaptation measures

Adaptation, as defined in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014a), is *"the process of adjustment to actual or expected climate and its effects"* in order to alleviate or avoid negative developments and take advantage of emerging opportunities due to changes in climate. For the purpose of this investigation, we focus on adaptation in the agricultural sector in the case study regions. In the following, we refer to climate change adaptation measures', or simply 'adaptation measures' when addressing agricultural adaptation. We would like to stress that adaptation in agriculture is rarely driven by changing climatic conditions and its effects alone but is typically influenced by a mix of climatic and non-climatic conditions and stresses (Howden et al., 2007; McLeman et al., 2008; Smit and Skinner, 2002). Accordingly, and similar to Moser and Ekstrom, (2010), we deviate from the IPCC definition by acknowledging that adaptation has to consider changing climatic conditions though this may not be the sole reason for action.

We differentiate between **mainly private, mainly public and natural adaptation,** depending on the main actor involved in the implementation process of agricultural adaptation. **Private** adaptation refers to on-farm management and investment decisions in the various sub-sectors in regional agriculture and are mostly implemented for private benefit but may also exert positive or adverse effects on public goods (see Tompkins and Eakin, 2012). For private adaptation, we further distinguish **incremental, systemic and transformational adaptation measures,** as suggested in the literature (see e.g. (Dowd et al., 2014; IPCC, 2014a, 2014b; Park et al., 2012; Rickards and Howden, 2012; Vermeulen et al., 2013). Incremental adaptation relates to moderate changes within a system, systemic adaptation takes place at system level but still aims to maintain the essence of the system, and transformational adaptation changes the systems' characteristics. We assume that the system boundary relates to the farm level. Accordingly, incremental adaptation refers to land and livestock management decisions, which are taken at sub-system level in order to 'preserve' the existing farm (How to produce?). Systemic adaptation is linked to investment decisions and to management decisions at farm level such as land use and land cover decisions (What to produce?). Transformational adaptation relates to changes in the systems' characteristics and thus the strategic orientation of the farm.

Infrastructure provision for the agricultural sector is – for the most part – in **public** responsibility and comprises information, technical and financial aspects (see sub-section 3.2.2). Public infrastructure provision is motivated by retaining agricultural land use in less favored areas and aims at *"supporting agricultural practices beneficial for the climate and the environment"* (European Parliament and European Council, 2013). Both, individual farmers and the public should benefit of such adaptation measures, though to different extents (see Tompkins and Eakin, 2012). Private infrastructure providers usually focus on prosperous production areas and are mostly found in the technical and financial sectors.

Natural adaptation refers to natural selection and evolutionary processes that allow for autonomous adaptation of natural systems. Humans may intervene in order to facilitate such natural processes

(IPCC, 2014a, 2014b). Although the interviews focused on private adaptation measures, some of the respondents enriched the discussion by talking about the adaptability of nature.

3.1.1.3 Effects of private climate change adaptation measures

In general, adaptation in agriculture is expected to moderate or avoid harm and seize favorable opportunities that arise from changes in climate conditions (see definition above and IPCC, 2014a). Farmers, in particular, are likely to engage in activities which are most profitable under the new conditions. Apart from the (at least partly) intended on-farm effects, farmers' adaptation activities may affect related sectors and alter local, regional and global ecosystems (see e.g. Fezzi et al., 2015).

Therefore, we differentiate between on-farm and off-farm effects in our analysis. On-farm effects refer to both, deliberate and accidental effects of private climate change adaptation measures that are directly related to the respective farm. Off-farm effects also emerge from agricultural adaptation. They concern other economic sectors, adjacent or remote areas further or far away and may contribute to the provision of private, common pool or public goods (Tompkins and Eakin, 2012)[2]. We recognize that the boundary between on-farm and off-farm effects may be blurred and provide additional explanations for two-sided cases.

The effects of private adaptation differ in level and sometimes even in direction, depending on the actual changes in regional climate conditions. Accordingly, actual effectiveness of agricultural adaptation can only be assessed after the period of interest due to the inherent uncertainties in climate projections. However, the thematic categorization is complemented by perceived evaluations in order to identify potential synergies and trade-offs of agricultural adaptation.

3.1.2 Perceived and expected changes in regional climate conditions

3.1.2.1 Perceived changes in regional climate conditions

By analyzing the interviews, we find that perceived changes in regional climate conditions are similar in the two case study regions (see Table 2). The respondents agreed on increasing temperature levels and variability, changes in precipitation distributions and the increasing number and intensity of droughts, heat waves and heavy precipitation events. Different opinions were expressed with respect to changes in annual precipitation volumes and the occurrence of hail events, storms and thunderstorms. Interestingly, the perceptions varied not only between but also within the regions. Such differences may arise because hail and storm events are perceived as local events, in contrast to heat waves and droughts which typically affect larger areas. An interview partner used the following words: *"Hail events vary from area to area, they occur very locally. It hailed heavily in [regional toponym]. I saw it looking out of my window. At home, the sun was shining and then it rained a little bit. And the hail damaged the roofs in [regional toponym]. You never know, where it will be hailing."*[3] *(M6)* Furthermore, extreme events are mostly perceived through their impacts on agricultural productivity and environmental resources. Perceived impacts of storms are limited to forests, and hail impacts are considered low because technical adaptation measures including hail nets and cloud seeders are well-established in both case study regions and hail insurance is very common (see sub-section 3.1.3).

We clustered agricultural experts' perceptions of changes in regional climate conditions into four groups:

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[2] A similar categorization is used by the World Conservation Approaches and Technologies (WOCAT) programme in order to record and assess the effects of sustainable land management technologies (Liniger et al., 2008; WOCAT, 2015).

[3] Note: We use the following abbreviations in direct quotes:
[…] is used if one or several words are not shown for reasons of clarity.
[Note: xxx] is used when the authors added an explanation in order to increase the compressibility of the quote.
[regional toponym] is used after removing a name of a municipality, region etc. for reasons of privacy.
… is used if the interview partner made a pause.

(i) Changes in level and variability of temperature

The interview partners of both regions perceived an increase in temperature over the last years to decades as indicated by the following statement *"The temperature has risen enormously" (S2).* The respondents refer to milder winters or temperature-related impacts on plant or animal growth when talking about higher temperatures. For instance, one of them claimed *"It has become warmer, definitely. What occurs to me most is that winters are not so rich in snow and there are no long lasting cold spells." (M2)* Another agricultural expert added that *"late frosts do not happen any more" (S11).* Additionally, a person perceived *"a high frequency of high sugar contents [Note: in grapes] because of warmer climatic conditions." (S1)*

Higher inter-annual temperature variabilities and more rapid short-term temperature fluctuations (between several days or within a day) are perceived as well. One of the interview partners summarized this aspect as follows *"we have very, very high weather variabilities." (M7)* Other respondents referred to the related challenges *"such high temperature variabilities are, of course, not ideal for the plants currently grown in the region. They are used to different conditions." (M1)* and *„if temperature variations between day and night or from one day to another are too rapid, livestock often fall sick." (S10)*

(ii) Changes in precipitation sum and distribution

Annual precipitation sums have been perceived to remain almost constant *"precipitation sums during a year are, I think, relatively constant in our region" (M2)* or to decrease *"I think that precipitation decreased in total." (S3).* Small-scale variability in precipitation volumes were addressed by the interview partners as well, *e.g. "rainfall is often very local. … It rains 30 mm within a 5 km distance and it is dry at our place" (S2),* and may have contributed to the diverging perceptions in South-East Styria.

Changes in seasonal and intra-seasonal precipitation distributions are perceived as highly challenging for agricultural production. One of the interview partners stated *"In total, rainfall amounts have not fallen but precipitation distribution has changed. And if we do not get the precipitation amounts in the main growing season, we face serious maize yield reductions." (S10)* Similarly, another respondent mentioned *"Observations over the last years show that precipitation sums are not lower but the distribution did not match the plants' needs." (S5)* As such, perceived changes in precipitation distributions are related to perceived changes in extreme events, i.e. droughts, dry spells and heavy precipitation events. These results suggest that changes in precipitation distribution are of greater concern than changes in annual precipitation amounts in both case study regions.

(iii) Changes in seasons

The respondents perceive that the 'classical' seasons have changed over the years they have been working in the agricultural sector in the respective region. Thereby, they refer to changes in the characteristics and the duration of different seasons. For instance, an agricultural expert explained that *„The transition periods between the seasons have changed significantly. In spring, it is extremely cold and after a short time it is almost summer. Spring and autumn, they are not the same than 20 to 30 years ago." (M2)* Similarly, another expert mentioned that *„the classical transition seasons like spring and autumn disappear more and more." (M1)* Another agricultural expert remarked that "*The winter lasts longer meaning that the winter is extended to the spring seasons." (M6)* Such seasonal irregularities are easily identified by changes in the regional cropping calendar, in particular for sowing and harvesting. For instance, one interview partner noticed that *"the rainy autumns, when soils are easily compacted during harvesting, do no longer occur very often" (S3)*

(iv) Changes in extreme events

Interview partners in both case study regions talked about perceived increases in frequency and intensity of heat waves, droughts and heavy precipitation events and the related challenges and concerns in agriculture. One of the respondents referred to the heat waves in summer and explained that *"summer temperature affects production because the livestock fertility can suffer. And we see that the animals react with a decrease in performance because of the duration and frequency of tropical nights." (S10)* Another one talked about changes in droughts over the last two decades *"the topics we are concerned about were also relevant in earlier days. In other words, phases of water scarcity were* *not unusual. … But the intensity changes according to one's subjective impression. That is, if it is hot, temperatures are even a bit higher today. If it is dry, one has the subjective feeling that the drought lasts longer. And this feeling is confirmed by data." (M5)* The interplay between a lack or a surplus in precipitation with agricultural production was articulated as follows *"Precipitation … the events are more severe. That is either drought or a lot of precipitation which often cannot be used by agriculture because of high runoffs." (M1)* High inter-annual variabilities in extreme events were summarized by another respondent as follows *"currently we have high variabilities from year to year […] and range from extreme precipitation amounts to extreme dry spells, from very hot to very rainy summers and to totally cold winters which are rich in snow. We experienced everything during the last years" (S10)*.

Table 2. Perceived changes in regional climate conditions in the two case study regions.

Perceived changes in regional climate conditions	**Mostviertel**	**SE-Styria**
Changes in level and variability of temperature		
Mean temperature	↑	↑
Temperature variability	↑	↑
Changes in precipitation sum and distribution		
Annual precipitation sum	±	± / ↓
Inter-annual and regional precipitation distribution	✓	✓
Changes in seasons	✓	✓
Changes in number and severity of extreme events		
Droughts, dry spells	↑	↑
Heat waves	↑	↑
Heavy precipitation events	↑	↑
Hail events	↑ / ±	↑ / ± / ↓
Storms and thunderstorms	↑ / ± / ↓	↑ / ±
Cold and wet spells	↓	n.m.

Legend:
✓ ... perceived change (without identifying a trend or direction of change)
↑ ... perceived increase
↓ ... perceived decrease
± ... perceived to be similar, i.e. no change perceived
n.m. ... *not* mentioned in the interviews

3.1.2.2 Expected changes in regional climate conditions

In general, expected changes in regional climate conditions are similar in the two case study regions (see Table 3). Interview partners expect further increases in temperature level and variability, changes in precipitation variability and distribution as well as more frequent and more severe extreme events. The expectations are dominated by high inter- and intra-annual variabilities in future climate conditions as summarized by an agricultural expert as follows *"We do not really know about climate, if it will get more extreme … Certainty is gone. Do I have four good cuts a year or not?" (M6)*

However, the interview partners are critical in discussing potential future climate conditions. Some of them refer to climate models but face difficulties in interpreting their outputs for the region. Thus, they do not totally trust the models as indicated by the following statement *"I do not think that somebody is capable of telling us with guarantee how it will be in the next 5 or 10 years. […] There are tendencies but nobody knows about the rate of change." (S5)* Others do not want to express their expectations or only express their hopes and wishes about further changes in climate. And a third group of people thinks that changes in *global* climate conditions may have very *local* characteristics and could therefore be influenced locally, for instance by governing the microclimate. *"I claim that we can create our own microclimate. And this message is not at all circulated by science." (S4)*

Table 3. Expected changes in regional climate conditions in the two case study regions.

Expected changes in regional climate conditions	Mostviertel	SE-Styria
Mean temperature	↑	↑
Temperature variability	↑	↑
Precipitation variability	↑	↑
Precipitation distribution	✓	✓
Number and severity of extreme events	↑	↑

Legend:
✓ ... expected change (without identifying a trend or direction of change)
↑ ... expected increase

3.1.3 Perceived and expected impacts of changes in regional climate conditions on agriculture

3.1.3.1 Perceived climate change impacts

We identified four main climate change impact categories related to the interview partner's perceptions. They comprise of (i) **impacts on yields** referring to changes in plant and livestock yields, (ii) **impacts on expenses** with the two sub-categories expenses for plant production and expenses for salaries (i.e. workload), (iii) **impacts on natural resources** such as land, water, and biodiversity (iv) **impacts on physical capital** including forests, real estate and infrastructure. The interview results show that the perceived climate signals are linked to the perceived climate change impacts (see Figure 5).

(i) Perceived impacts on yields

Impacts on yields have been mentioned in connection with all identified main categories of perceived changes in regional climate conditions. **Higher growth rates and improved yield qualities** of field crops, permanent crops, grassland and forestry are attributed to temperature increases and associated changes in the vegetation period. One of the interview partners described this as follows for field crop production*: "above all, higher temperatures which basically prolong the vegetation period and stimulate growth. These are the positive effects." (M9)* Another one referred to viniculture and the improved quality in grapes. The person explained *"if it is warmer, we simply have more sugar." (S1)* With respect to benefits on grassland an agricultural expert told *"One has to say that grassland yields have also increased considerably over the last 30 years. Grassland used to be cut three times. And nowadays, the majority of the grassland is cut five times." (S3).* Though forestry was not the focus of the interviews, another expert referred to forest growth rates *"What I also observe a little – but this is forestry – is the growth rate of trees and young trees, I have the feeling that it is large." (M9).*

Negative impacts on yields are perceived because of higher temperature and precipitation variabilities and extreme events such as droughts, heat waves, heavy precipitation, hail and storms. One of the interview partners referred to the high variabilities with the following words *"That's for sure. One never knows what the year will be like. It was probably not so bad in earlier days." (M6).* Droughts and heat waves during the growing season cause water and heat stress and thus affect plant growth. For instance, one respondent mentioned *"Maize, of course, and also, for instance, sugar beet definitely suffer during a dry spell." (M2).* And another one added *"With respect to maize for seed production we have another problem. We cannot ensure pollination in these really hot years, when we have a high number of extreme heat days. This is because we do not have enough humidity and the maize pollen goes dry on the way from the flower to the corn cob. And if we have temperatures above 34 degrees we have a serious problem. Then, we do not have a drought problem but a heat problem." (S11).* Other extreme events such as hail are also damaging field crops as well as permanent crops as indicated by the following statement *"Hailstorms in orchards transform fruits from high quality to low quality fruits such that the harvest cannot be paid any more. … Hail renders the most beautiful crops* *useless. Lettuce is 100% damaged by hail, pumpkin has high damages with hail, maize and cereals withstand a little bit." (S5).* Changes in seasons are perceived to be ***beneficial or adverse*** for plant growth and yield quality. For instance, autumns with long warm and dry periods positively influence fruit and grape qualities whereas mild winters influence development cycles of e.g. pests and indirectly contribute to yield reductions (see also perceived impacts on natural resources).

Livestock production is perceived to be sensitive to higher temperature levels and higher temperature variabilities in general, and to heat waves in particular. Agricultural experts are mostly concerned about animal health, animal growth rates and the quality of livestock products. For instance, one of the interview partners told *"We had 38° in the open stable in summer. It is obvious, if we have 38° outdoors and the stable is totally open, it cannot be cooler. But if air circulates – one knows about problems with claws, high number of cells; everything turns up under such circumstances with a short time lag. It is, of course, a damage because it is reflected in the milk income. And it is stressful that all animals recover." (M6)*

(ii) Perceived impacts on expenses

Changes in **expenses for plant production** are perceived to be influenced by temperature increases and seasonal shifts. For instance, **higher variable costs** for soil management and pest control are perceived, especially after mild winters "*The mild winters show that the winter furrow is not broken by frost as it used to be in earlier days. And more pests can overwinter, for example snails. In the past, I did not experience that maize fields are infested by snails. But nowadays, the infestation leads to severe damages. Mild winters simply allow all snail eggs to survive. Anyway, the production costs increase because of such seasonal changes." (S7)* **Lower production costs** due to higher temperatures are mentioned as well. One of the respondents told *"Maize is not storable in our region, meaning that it is always too humid for storage. But in the last years, we have observed years in which maize is harvested with a water content of 20 to 22%. And the standard is probably around 30% in this region. That means costs for drying are reduced." (M7)* And another one added *"There are years where we do not have to dry the maize any more, may be a bit. In earlier days, costs for drying were the main cost factor, with variabilities over the years. But the dry matter content after harvesting has certainly increased …" (S3)*

Increasing temperatures, changes in seasons and heavy precipitation events are perceived to have an impact on **work flows and work loads**. Work flows are perceived to be affected **negatively or positively**. Additional work is, for example, required for maintaining animal health because of higher temperatures (see also perceived impacts on livestock production) and for cleaning-up-activities after a flooding or an erosion event as told by an agricultural expert *"There was so much sand, so much sand. The forestry terrain is higher now because you cannot dig mechanically. I think they digged the sand of the cropland and they cleaned the streets." (M6).* In contrast, farmers can benefit from warm and dry autumns because it prolongs the vegetation period and relaxes autumn fieldwork such as articulated by an agricultural expert: *"If you sow earlier, usually you can harvest earlier. This is an advantage in autumn. […] Soil cultivation and re-sowing is less stressful in autumn." (S8).*

(iii) Perceived impacts on natural resources

Changes in **natural resources** including land, water, and wild plants and animals are attributed to temperature increases and droughts, seasonal changes and heavy precipitation events. **Soil degradation** is perceived to be amplified by more frequent and intense rainfall events. For instance, one of the interview partners remarked *"Erosion leads to humus loss and changes agricultural land. And we experience erosion not only on steep slopes but also on almost flat areas. Valuable nutrients are lost" (S4).* Another expert added *"If you can see erosion with the naked eye, only few decades are left until the soil is totally degraded. I think we are currently in this phase." (S7).* Agricultural experts also mentioned that soil conditions are affected by higher winter temperatures because the winter furrow is not broken by frost. The sensitivity of the grassland is touched in the interviews as well, especially because of the increased sensitivity of the greensward under very dry or very wet conditions as indicated by an interview partner *"The greensward suffers considerably under dry conditions. Then, one has to think about re-sowing." (M4).*

Sufficient **water supply** is a big concern of agricultural experts and even aggravated under dry climate conditions. Furthermore, nutrient inputs to groundwater reservoirs and surface water are perceived to be higher during extreme droughts or heavy rainfall events. For instance, an agricultural expert told *"The availability of water is key. It [Note: Plant growth] is not a question of nutrients. This is another problem we face. If nutrients are not taken up under dry weather conditions, nutrient inputs to the groundwater are considerable." (S4.)*

Temperature-triggered **changes in development cycles of pests, diseases and weeds** are perceived as challenging in field crop and permanent crop production as well as in forestry and perceived to be affected by temperature increases and seasonal changes. One of the interview partners reported on perceived changes as follows *"We have to deal with pests that we did not face in such an intensity in earlier times. For instance, pest control for potato beetles took place once a year in earlier times. Nowadays, the problem occurs very early and pest control is carried out two to three times a year. It may be partly because fungicides with adverse side effects on insects were previously applied. […] But I think it is also because of higher temperatures that, in earlier times one generation matured per year whereas nowadays two to three generations mature per year. We have cicada which spread viruses and which were not known formerly. We have aphids, which are new, and pass on the barley yellow dwarf. We also have changes in weeds. For instance, locoweed and ragweed were not known previously." (M5)* Another one addressed new diseases in viniculture *"We have two diseases. One of them is Stolbur, a phytoplasma infection, and the second one is Flavescence dorée, also a phytoplasma infection and both are passed on by the American grapevine leafhopper – a thermophilic animal that has been observed in the region in the last years. The American grapevine leafhopper has successively come from the south and meanwhile, it is domestic. Nowadays, the whole development cycle takes place in the region and this development took place in the last 10 to 15 years." (S1).* Changes in occurrence of predators for natural pest control is mentioned as well but not discussed in detail.

(iv) Perceived impacts on physical capital

Forest, real estate and infrastructure are treated as physical capital. Forests are perceived to suffer from droughts and storms. They are more sensitive to bark beetle infestations under dry conditions and wind throw is often perceived after storms. Farm buildings and roads are perceived to be affected by extreme events including hail, storms and heavy precipitation. One of the interview partners explained it as follows *"Hail damages, of course, different cultivates and also buildings. I don't remember the exact time, but there was a big event in the region where the roofs in several villages were destroyed by hail. And storm damages typically occur in forests or buildings." (M2).*

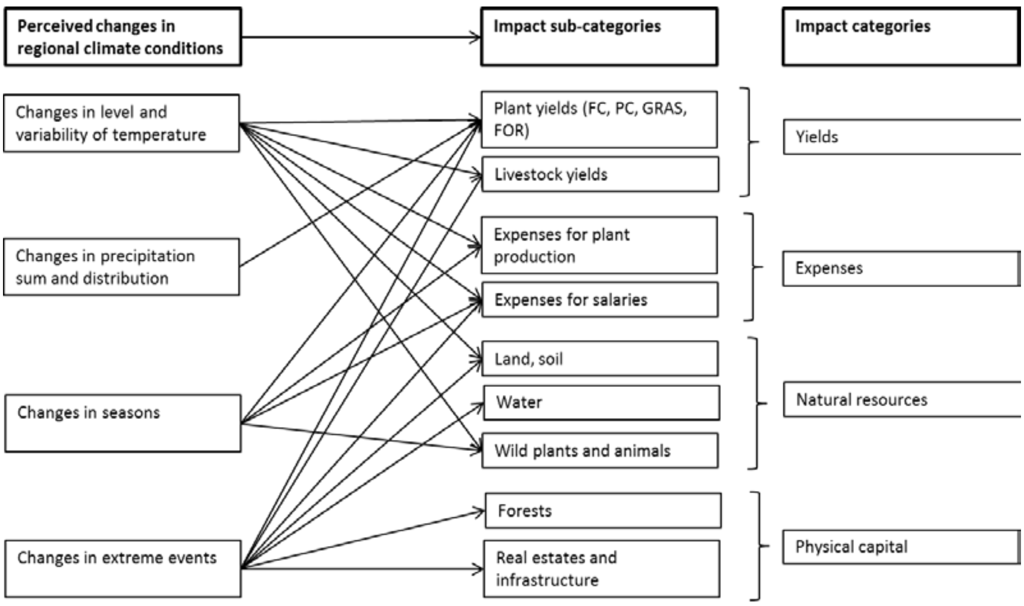

Figure 5. Interlinkages between perceived changes in regional climate conditions and impacts [Note: FC = field crops, PC = permanent crops, GRAS = grassland, FOR = forestry].

Perceived climate change impacts are focused but not limited to crop production. This focus can be explained by the direct link between changes in regional climate conditions and crop growth rates. Furthermore, extension activities traditionally concentrate on production-related aspects as addressed by one of the interview partners *"We are mostly targeting crop production in the personalized expert services." (S11).* This may amplify their dominance in the interviews. The interview partners mostly addressed negative climate change impacts such as crop damages or soil loss triggered by a broad variety of climate signals, i.e. temperature levels and variabilities, changes in precipitation and seasons, and increasing frequency and severity of extreme events (see Figure 5 and Table 4). Climate conditions leading to perceived positive impacts are limited to temperature increases and changes in seasons. Perceived benefits encompass higher crop and grassland forage yields and improved yield qualities.

Most of the climate change impacts were addressed in the context of additional drivers, meaning that climate change is one of several drivers for the named impacts. The agricultural experts also referred to local soil attributes and topography, structural changes, and technological progress in breeding and crop management as additional drivers.

Perceived impacts are similar in the two case study regions and complement each other for the production types which are relevant in both regions, i.e. field crops, grassland, forestry, livestock, and natural resources. The perceptions are limited to the crops typically cultivated in the respective region and differ in the level of detail. For instance, management related aspects for silage production were only mentioned in the Mostviertel region whereas specific factors in vegetable production were only remarked by experts in South-East Styria. Permanent crops are of higher relevance for agricultural production in South-East Styria, compared to the Mostviertel region. Accordingly, they are playing a more important role in the interviews with agricultural experts from South-East Styria. Impacts on viniculture are only addressed in South-East Styria, which is a traditional wine growing region. In contrast, wine growing is not yet practiced in the Mostviertel region and is only addressed as future potential for farmers. Impacts on fruit production were mentioned in both case study regions. The perceived impacts on fruit production was more diverse in South-East Styria, compared to the Mostviertel region, which can be partly explained by the high relevance of commercial fruit plantations in South-East Styria. However, orchard meadows are important landscape elements and extensive fruit production is a local tradition in the Mostviertel region (see e.g. Schönhart et al., 2016, 2011).

Table 4. Perceived climate change impacts and their evaluation in the two case study regions.

		Evaluation	
Impact categories	**Impact sub-categories**	**Mostviertel**	**SE-Styria**
Yields	Plant yields	+ / -	+ / -
	Livestock yields	-	-
Expenses	Plant production	+ / -	+ / -
	Salaries	+ / -	+ / -
Natural resources	Land	-	-
	Water	-	-
	Wild plants and animals	-	-
Physical capital	Forests	-	-
	Real estates	-	-
	Roads	-	-

Legend:

- … negative evaluation of climate change impacts

+ / - … positive and negative evaluation of climate change impacts

n.m. … *not* mentioned in the interviews

3.1.3.2 Expected climate change impacts

Expected climate change impacts are mostly negative and refer to plant and livestock yields, natural resources and physical capital (see Table 5).

(i) Expected impacts on yields

Increases in inter-annual crop and grassland forage yields as well as a higher probability of crop failure are expected in both case study regions as supported by the following statement *"The probability of crop failure is increasing steadily meaning that the whole harvest fails more often" (S7).* This may lead to higher pressure on livestock production because of limited fodder availability as addressed by another agricultural expert *"It will become more and more difficult. If climate change follows the predictions, we will have big troubles. The green fodder – we are in a livestock intensive region – the on-farm green fodder supply is very, very important." (M2).* Higher potentials for wine growing are addressed in South-East Styria and the Mostviertel region. This is interesting because wine is currently only grown in South-East Styria but is expected to be relevant in the Mostviertel region in the future.

(ii) Expected impacts on natural resources

Soil degradation, limited water availability and new pests, diseases and weeds are expected to be challenging in both regions in the future period. For instance, one of the interview partners reflected on soil erosion *"I would say that an increase in soil erosion with all induced problems is a big danger in the future." (M7).* Another one referred to potential water scarcities for crop production *"I think that maize production will be more difficult because maize relies on a particular water regime. And if dry summers like this years' are becoming the rule, maize will suffer most." (S11).*

Landscape diversity may be negatively affected in the future as well. This was addressed in South-East Styria *"if it is not green in summer, this is bad for landscape perception. We are well-known for a soft, female landscape which is well-maintained and beautiful. If this landscape is dry and not maintained any more because it is inefficient […] than it will affect tourism and other sectors as well." (S4).*

(iii) Expected impacts on physical capital

Potential future impacts on physical capital were only mentioned in South-East Styria. One interview partner referred to expected damages of trellis in fruit production *"Commercial plantations of fruit … if we have a heavy rainfall event and high wind speeds, our trellis are highly demanded and might burst. Water saturated soils combined with strong winds, that will be very interesting." (M2).*

Table 5. Expected climate change impacts and their evaluation in the case study regions.

Impact categories	Impact sub-categories	Evaluation Mostviertel	SE- Styria
Yields	Plant yields	+ / -	+ / -
	Livestock yields	-	-
Expenses	Plant production	n.m.	n.m.
	Salaries	n.m.	n.m.
Natural resources	Land	-	-
	Water	-	-
	Wild plants and animals	-	-
Physical capital	Forests	n.m.	n.m.
	Real estates	n.m.	n.m.
	Infrastructure	n.m.	-

Legend:

- … negative evaluation of climate change impacts

+ / - … positive and negative evaluation of climate change impacts

n.m. … *not* mentioned in the interviews (i.e. not expected in the respective region)

3.1.4 Climate change adaptation measures

3.1.4.1 Perceived drivers of private climate change adaptation measures

Agricultural experts perceive that incremental, systemic and transformational adaptation is driven by a broad variety of factors which are categorized in bio-physical and socio-economic internal and external drivers, whereby the farm is defined as the system boundary (see Table 6).

Perceived internal bio-physical drivers comprise local climate conditions, the availability and quality of abiotic resources at farm level including soil, water and topographic conditions as well as farm management related aspects such as yield stability of certain crops and animal welfare. For instance, one of the interview partners told that the implementation of irrigation facilities depends on the soil quality and the cultivated crops: "*Farmers who irrigate, mostly have gravel soils. They often needed it in the past. But I don't see that irrigation is gaining much. […] And we do not have special crops such as vegetables or sugar beet. They are of minor importance here. Cereals and maize play a rather important role on cropland in our region. And there are very, very few farmers who irrigate these crops. Cereals are practically not irrigated and maize is irrigated by a small number of individual farmers." (M4)*

Internal socio-economic drivers can be attributed to characteristics of the farmers (demographic data and personality characteristics) and the farm. Farmers' decision-making is perceived to be influenced by farmers' personality, age, education, knowledge, experience and awareness as well as by the family structure, farm traditions, farm size and farm type. For instance, one of the agricultural experts stated *"[Note: Influencing factors are] farm size, farm structure, age of the actors, education, personal character or better, personality structure – if he is an introverted or extroverted type. I think it makes a big difference on how he decides on certain things or how sensible he is for certain things." (M8)* And another one emphasized the role of education *"Education is, in my opinion, the most important factor. The more farmers know about it [Note: climate change adaptation measures], the better it is. I think great progress has already been achieved. The education system with the agricultural engineering schools and the adult education programs provides a much more comprehensible education than in earlier times and pupils and students are sensitized to the topic and beyond." (M3)*

Perceived external bio-physical drivers refer to regional climate conditions and its changes as well as to the availability and quality of regional biotic and abiotic resources such as changes in development cycles of pests and weeds, landscape diversity, and the regional water balance. For instance, one of the agricultural experts remarked the importance of perceived extreme events "*I think the most important influencing factor is own perception. They say: 'There is no choice and we have to move. We can't operate in the way we have up to now because we have experienced more frequent dry periods, e.g. at a time when we don't need it.'" (S9)* Another one added that future changes in regional climate and induced impacts are relevant drivers. *"It depends on the next years. If, e.g. 2016 and 2017 are dry, will we see rapid changes but if it is moderate, the pressure is lower. So, it always depends on the history of suffering. If the level of suffering is high, changes occur faster, because one is more dedicated." (S1)* Other interview partners are more skeptical and scrutinize if climate change matters a lot in decision-making. *"It is still the money which is decisive whether a crop changes or not. We have been 'taught' by the subsidies. There are some co-benefits with respect to climate but I think that the awareness for climate change is not very strong." (S4)* Others even think that some farmers do not belief in climate change *"It strikes me that the majority of the farmers are skeptical about climate change in agriculture. They rather discount it as an exaggeration. Not so much the catastrophes, the catastrophes are seen, also because of the media's attention. I have the feeling that particularly older farmers believe that it is an exaggeration that agriculture changes completely and that one has to be worried about climate change. And I think they do not place a value on information." (S3)*

External socio-economic drivers are perceived to have a strong influence on farmers' decision-making and the implementation of climate change adaptation measures. They comprise **legal guidelines** and regulations, the **market situation** and its development, changes in **agricultural policies** and payments, **social changes** as well as the availability of **information and technical infrastructure**.

Legal guidelines affect, for instance, crop rotations as stated by an interview partner *“We grow more sorghum now because we have a legal crop rotation restriction. Currently, we are allowed to cultivate maize three times within four years.” (S11)* Another one refers to legal guidelines and the society’s requirements when constructing a stable *“I think everybody constructs the stable such that it meets the legal requirements. For ventilation, the requirements of the society and the legal guidelines are comprehensive and cover a lot.” (M2)* The importance of the status and expected development of supply and demand is summarized by one interview partner *“The market trends are an important factor for us. And the consumers’ behavior plays a crucial role. And climate is an important aspect and acceptance and environmental friendliness are crucial as well. […] The population’s acceptance, consumers’ behavior, the price situation and marketing are very important, and of course, everything that refers to environmental protection, and also new breeds which can deal with certain changes.” (S1)* Agricultural premiums are perceived very important for creating awareness and changes in farmers’ behavior. For instance, an agricultural expert noticed the effectiveness of agri-environmental payments *“A change in awareness, a clear change in awareness in agriculture. The stimulus for this change in awareness was certainly the agri-environmental premium for cover cropping in ÖPUL.” (M9)*

We have found that a broad variety of drivers is perceived important in the adaptation process. Typically, a combination of bio-physical and socio-economic internal and external factors drive farmers’ decision on the selection and implementation of adaptation measures. However, in general, the interview partners agreed that socio-economic interests are more relevant in decision-making than purely climate-related factors as summarized by the following statement *“The rationale is not: climate changes; the farmer’s rationale is: how can I maintain the income.” (M1)*

Table 6. Perceived drivers of private climate change adaptation measures.

	Bio-physical	Socio-economic
Internal	**Local climate conditions** Microclimate	**Farmer's characteristics** Age Education Personality, e.g. values, motivation, interest Knowledge, experience and awareness Risk perception
	Availability and quality of local natural resources Soil conditions, e.g. texture, depth Topography Water balance, water availability and limitations	**Household characteristics** Family structure Family tradition Family members working on the farm
	Production process and management related aspects Yield stability and yield quality Crop choice, e.g. driver for irrigation Experienced negative impacts of changes in regional climate conditions Animal health, animal welfare Emissions	**Farm characteristics** Farm tradition Farm type, e.g. cash crops, livestock production Farm size, field size Part-time vs. full-time farm Available machinery, mechanization Farm transition Economic efficiency and farm income Work organization, work load, available workforce
External	**Changes in regional climate conditions (Climate change)** Level and variability of temperature Precipitation sum and distribution Seasons Extreme events Uncertainties	**Legal guidelines and regulations** EU-level, e.g. Protein Strategy National level, e.g. Animal Welfare Act, Water Law Regional level, e.g. Spatial Planning Law Municipal level, e.g. Soil erosion control
	Availability and quality of regional natural resources Regional land cover and land use Landscape diversity and scenery Ecological value of landscape Regional water balance Distribution of wild plants and animals	**Market situation and market development** Output prices Variable costs Investment costs Regional, national and international demand Location of customers Quality requirements of potential customers Import dependency **Agricultural policies and payments** Decoupled payments Greening requirement Agri-environmental payments End of milk quota Investment subsidies, subsidized credits Subsidized insurance products Disaster fund **Characteristics of the society** Social pressure, e.g. from public authorities **Availability of infrastructure** Information infrastructure, e.g. warning services Technical infrastructure, e.g. breeding

We have shown that a broad variety of factors is perceived important in the on-farm adaptation process.

A particular incremental, systemic or transformational adaptation measure is typically not taken because of one single driver. In most of the cases, a combination of various bio-physical or socio-economic internal or external factors drive farmers' decisions. By analyzing the interviews, we could identify factors that are perceived to promote or support the implementation of adaptation measures as well as factors that may exacerbate or impede or limit the implementation of adaptation measures. These supporting and impeding factors may inform agricultural and climate policies.

The interview partners rated the following factors **supportive** for implementing private adaptation measures:

- Farmers' experience of extreme events and induced negative impacts are expected to push the implementation of (mostly reactive) adaptation measures.
- High agricultural commodity prices and high demand for specific outputs (e.g. 'new' crops) are likely to encourage farmers to change management practices or to invest in e.g. 'new' technologies.
- Reliable information (e.g. field trial results, localized results) and discussion with peers may stimulate short-term and long-term changes.
- Financial incentives for particular management options or particular target groups may spur agricultural adaptation. For instance, awarding measures to improve carbon capture in soils or 'no-regret strategies' that derive (public or private) benefits even in the absence of climate change (see (Hallegatte, 2009) are mentioned as positive examples. Additionally, the interview partners ask for financial incentives for young entrepreneurs dealing with climate change mitigation or adaptation measures.
- Legal guidelines (e.g. crop rotation requirements, animal welfare act) may accelerate the implementation of adaptation measures.
- Legal certainty is considered a *prerequisite* for long-term investments in agriculture.

The agricultural experts identified the following factors to **impede** the adaptation process:

- The farm type and the strategic orientation of the farm may limit the adoption of certain management options. For instance, a livestock farm depends on the on-farm production of forage which reduces the farmer's flexibility in crop choice.
- Habits and traditions are deemed to hinder or delay innovation. For instance, 'traditional' crop rotations are perceived in the case study regions which could hamper the introduction of 'new' crops.
- Work force is typically limited on farms and employing (seasonal) workers increases variable costs. Limited time resources may thus exacerbate the implementation of labor-intensive adaptation measures.
- Low levels and high volatilities of agricultural commodity prices as well as high investment costs are perceived to narrow farmers' flexibility and alternatives for action.
- The agri-environmental program is criticized for its high administrative burden and the frequent alterations in supported management measures.
- Legal obligations may slow down innovation processes. For instance, the approval of innovative technology may be hampered because of insufficient or outdated legal regulations.
- Payments from the disaster fund aim at maintaining the current system and are likely to impede systemic and transformational adaptation.

3.1.4.2 Perceived climate change adaptation measures

The interview partners reported on private, mainly public, and natural adaptation whereby private adaptation is further categorized in incremental, systemic, and transformational adaptation (Table 7). We focus on private climate change adaptation measures perceived in the case study regions.

Private, **incremental adaptation** in field crop production refers to, for example, changes in timing of planting and harvesting, tillage, fertilizer and pesticide management. In livestock production, it is, for instance, related to changes in stocking densities and adjustments in feeding ratios. Incremental adaptation is largely based on farmers' knowledge and experience and has a **short-term, mostly responsive** focus on keeping the current system. Management decisions are taken on a daily, weekly or seasonal basis and often follow adverse impacts. For instance, one of the interview partners told

*"The farmers **react** by adopting erosion control measures such as mulching, and some of them are experimenting with direct seed. (M7)".* Changing climatic conditions are articulated as **'unconscious'** drivers of incremental adaptation measures as summarized by the following statement of an agricultural expert *"I think that the changes in regional climate conditions play a more important role than the farmers perceive themselves. I think they take decisions and the driver for their decisions is climate change but they are not aware of it. For instance, I am sowing two weeks earlier. This is a classical decision where he does not realize. He says, the temperature is appropriate, I am sowing now. But that this is a continuous development and he is probably not aware of it that sowing is earlier every year – or one week earlier every ten years." (M8).* One incremental adaptation measure, which is perceived to be taken because of changes in regional climate conditions only, i.e. **'intentionally',** is the purchase of insurance products against extreme events such as droughts or storms. However, insurances are perceived to impede systemic or transformational change, also because of publicly supported insurance premiums. One of the interview partners expressed *"I have been trying to encourage farmers to deal with water supply for quite some time. But it is not concrete yet, they do not really think about it. […] I think it is at little bit overlaid. […] Economically, it is overlaid by the hail insurance and the drought insurance. I think this is a wrong approach to overlay the things. The effects are compensated financially, though it could be corrected in the nature." (S6).*

Systemic adaptation is, for instance, linked to the expansion of cropland, fruit and wine growing areas, and the investment in water reservoirs and new technologies, whereas **transformational adaptation** includes converting from full-time to part-time farming, changing the farm type, farm withdrawal and engaging in non-agricultural secondary activities such as tourism or care of elderly. Systemic investment decisions and transformational adaptation have a **long-term** focus. They are typically related with higher costs and potential benefits compared to incremental adaptation, and changes in regional **climate** conditions are perceived as management challenge. However, a number of additional drivers such as legal, policy or market conditions are understood as highly relevant, too. In comparison to these factors, the climate-related pressure for change is considered moderate though all of the interview partners believe in anthropogenic climate change. In particular, climate change is addressed in investment decisions (e.g. constructing stables, constructing water reservoirs and establishing irrigation facilities), in land use decisions and land cover change, and play a role when farmers decide on the strategic orientation of their farm.

The relevance of specific adaptation measures is perceived differently in the two case study regions. For instance, wine growing and fruit production are of high relevance in South-East Styria but play a limited role in the Mostviertel region. Accordingly, adopted adaptation measures as well as perceived future challenges are more diverse in South-East Styria in viniculture and fruit growing. Field crops and grassland are important in both case study regions and similar adaptation measures are proposed. However, the implementation status of adaptation measures depends on the 'initial' situation that agricultural experts refer to. For example, more diversity in crop rotations has already been perceived in South-East Styria whereas experts in the Mostviertel region identified this as a crucial adaptation measure in the future. While the experts in both regions agree on the effectiveness of changes in crop rotations, legal crop rotation restrictions have been mentioned as a driver for the perceived changes in South-East Styria. Interestingly, the legal restrictions were similar in both case study regions at the time of the interview (see NÖ Pflanzenschutzverordnung, 2015; Stmk. Maiswurzelbohrerverordnung 2015) indicating that the interview partners in South-East Styria referred to '(maize) monocultures' as the initial situation which was not true for the Mostviertel region. Irrigation is already implemented for special crops (e.g. maize for seed production, wine) in both case study regions. However, the interview partners do not agree on the relevance of irrigation systems for main crops. Opponents of irrigation over a wide area doubt its sustainability because of limited water availability in the case study regions. Others argue that irrigation is too expensive under current market conditions (see sub-section 0). Proponents of irrigation suggest to collect water in reservoirs during the more humid winter season in order to allow for irrigation on cropland during the vegetation period, regardless of the cultivated crop.

Several incremental and systemic adaptation measures are perceived to gain in importance in the future. They comprise of the implementation of new technologies (e.g. fertigation, precision farming), changes in land use (e.g. changes in cultivars and crops) and land cover (e.g. expansion of wine growing areas), and more sophisticated financial and risk management strategies.

Table 7. Climate change adaptation measures perceived in the case study regions.[4]

Actor	Intent	Perceived climate change adaptation
Private	Incremental	Changes in timing of planting and harvesting
		Changes in tillage, fertilizer and pesticide management
		Changes in varieties
		Humus management
		Applying new machinery
		Changes in stocking density (livestock)
		Adjusting feeding ratios
		Changes in ventilation systems in stables
		Investing in hail protection nets
		Purchasing an insurance product
		Using information infrastructure
		Using technical infrastructure
		Financial management and using financial infrastructure
	Systemic	Changes in land cover and land use
		Constructing water reservoirs
		Investing in new technologies
		Investing in new buildings
		Collective action (e.g. with neighbors)
		Leasing farmland from e.g. neighbors
		Using information infrastructure
		Using technical infrastructure
		Financial and risk management and using financial infrastructure
	Transformational	Farm withdrawal
		Leasing farmland to e.g. neighbors
		Change in farm type
		Converting to organic farming
		Converting from full-time to part-time farming
		Direct marketing
		Diversification
		Engaging in non-agricultural secondary activities
		Using technical infrastructure
		Using financial infrastructure
Mainly public	Provision of information infrastructure	Seminars, excursions, advanced trainings
		Magazines, brochures, newsletters
		Personalized expert service
		Warning services
	Provision of technical infrastructure	Breeding activities
		Running a feed laboratory
		Constructing water retention basins and flood protection measures
	Provision of financial infrastructure	Decoupled payments
		Agri-environmental payments
		Subsidized insurance products
		Investment subsidies, subsidized credits
		Disaster fund
Nature		Evolutionary process

[4] A more detailed list on climate change adaptation measures is presented in Appendix 8.2, Table 9.

3.1.4.3 *Perceived effects of private climate change adaptation measures*

The implementation of private climate change adaptation measures may produce beneficial and harmful on-farm and off-farm effects. Negative off-farm effects may involve the risk of maladaptation. The agricultural experts perceive that positive and negative effects differ by adaptation measure and production region and may vary inter-annually. Accordingly, actual effectiveness of adaptation measures can only be assessed after the period of interest. One of the interview partners referred to the effectiveness of adaptation and explained *"It's not always the same technology which is the right one. Well, there is the question: What is better, with or without ploughing? In particular, with respect to water conservation. There are years, where non-plough tillage is definitely better, in particular if costs are considered. And there are others, where ploughing is better. You have to consider local data, the own soil conditions, without any ideological blinders." (M5).*

Effects were reported on production quantity and quality, farm income, the production chain, and on natural, human and social resources. While production and income are directly related to the respective farm and effects on other economic sectors can be classified as off-farm, effects on natural, human and social resources can be relevant for both, the farm itself and the surroundings. This points to the interlinkage between on-farm and off-farm effects that are intentionally or incidentally brought about.

(i) Effects on quantity and quality of agricultural products

Quantity and quality of agricultural products are perceived to be influenced by incremental and systemic adaptation. In particular, changes in management practices (e.g. timing of cultivation, crop and cultivar choice, irrigation and pesticide management) and investment decisions (e.g. ventilation in stables) are taken in order to generate positive on-farm effects. However, adverse effects may occur, depending on the weather conditions. One of the interview partners referred to the choice of varieties and its positive effects on crop yields: *"Variety choice is easy to conceive. I mean, we have … I don't know the percentage change of yields since the 70ies, for instance. When I studied, the average winter wheat yields were about, I think, 45 deci-tons, and currently, yields are in the magnitude of 70. But this is not because of fertilization. This is simply because of varieties. There is so much potential in variety choice. I think it is totally underestimated." (M8).* Another one explained that earlier sowing is beneficial for crop yields because of higher soil water contents and reduced risk of pest damage. However, the interview partner also warned of potential late frost damages: *"Sowing is about 14 days earlier, compared to 20 years ago. […] Well, it is markedly earlier because there are no late frosts. And there was only one year during the last 20 years where we experienced late frost. […] We need this earlier sowing in order to make better use of winter precipitation […] And the earlier sown crops make better use of winter precipitation. And there is another aspect. We have different pests. […] And we need earlier sowing in order limit root damages." (S11).* Investment in stable ventilation is perceived as profitable because of its positive effects on animal welfare and livestock products as expressed by one of the agricultural experts. *"Ventilation and byre climate are very important, too. And it is good to invest, because the money comes back via the milk and that the cows are healthier etc. Very reasonable." (M6).*

(ii) Effects on variable and fixed costs

Variable and fixed costs are directly affected by management practices and investment decisions for incremental, systemic and transformational adaptation. Both, management and investment decisions are planned to be profitable in the short- or in the long-run but high uncertainties in future climate and market development may lead to inefficient on-farm adaptation activities as summarized by an agricultural expert: *"The yield is the element of uncertainty. Let's say, it's not a problem of business administration, but of which numbers I use in business administration. This is the actual challenge. And the effect of climate change on the yield of a permanent crop is difficult to predict." (M9).*

Changes in **variable costs** have been attributed to altering costs for fertilizers, tillage operations, pesticides, power, fuel, insurance, labor, and consulting. In several cases, variable costs are directly related to regional climate conditions and increase or decrease with incremental adaptation. One example is reduced costs for drying maize because of higher temperatures on the one hand (see sub-section 3.1.3), and later harvesting dates on the other hand, as indicated by the following statement:

"With respect to maize, we can harvest it relatively late; decreases drying costs." (S2). Higher variable costs are perceived to be accepted if adaptation leads to positive long-term effects such as for green manuring. *"Especially with green manuring, for example, it is expensive. There are sowing costs etc. I say, the benefit is not immediately visible, but it is there." (M6).* Additional transportation costs may occur due to changes in land use as indicated by one of the interview partners: *"Location issues are influenced by climatic changes. That is, the starch factory in [regional toponym1]; one has tried to develop the more favorable cultivation areas in [regional toponym2], too. But then, a commodity with a value of 70 €/t is transported 200 km to [regional toponym1]. And this is a matter of costs. They appear because cultivated potatoes in [regional toponym3] are not enough to ensure to use the factory to capacity." (M5).* Engaging in non-agricultural secondary activities such as tourism, care of elderly and direct marketing is perceived as highly work intensive and thus increases labor costs as expressed by an agricultural expert: *"Food and direct marketing are also important. I mean, direct marketing is very important but everybody who has experienced direct marketing knows what lies behind. And the generation who has established direct marketing, they have worked, worked and worked. And then the question comes up: Do you pay for an employee or not." (M6).*

Investments in buildings, machinery or technology because of systemic or transformational change have been mentioned to co-determine **fixed costs**. The efficiency of investments in e.g. stables, water retention basins and irrigation equipment is perceived to depend on current and future weather, climate, market and legal conditions, natural resource endowment, and farm characteristics such as farm size and farm type. One of the interview partners explained *"Currently, producer prices are very low. Of course, the more I have to invest in a building today or the more I have to invest in order to comply with regulations, the more difficult it is, the longer it lasts until a stable pays off." (M2).* And another one added *"In dairy farming, if you decide to take a milking robot […]. You need twice the number of cows, twice as much land, you get twice the number of calves, twice the number of fertilizations, twice the number of opportunities that there are problems with the calves. Well, I think stress does not decrease. […] Dependency increases, also on weather." (M6).* Furthermore, the high degree of uncertainties about investment decisions was stressed by the interview partners. One of them remembered *"extremely dry years, 92, 93, I think. Very many [Note: farmers] invested in irrigation. They were not used. The investment did not pay back in the last 20 years. Higher yield qualities were achieved only in a few years but it did not pay off." (S5).* Machinery co-operations have been promoted in the agricultural sector because of their potential to reduce or avoid on-farm mis-investments. These advantages were acknowledged by the interview partners who evaluated the efforts and the widespread network of machinery co-operations positively, as indicated by the following statement *"The machinery co-operations are organizers of new technologies, simply to allow for testing without the necessity to invest in technology." (M7).* Another interview partner summarized the achievements of the machinery co-operations with the simple words *"Machinery co-operation is great." (M6).* However, it was also critically remarked that farmers *„are not willing to participate in machinery co-operations, in order to, for instance, better use the capacity of the machinery." (S7).*

(iii) Effects on other economic sectors

Changes in management practices and investments due to incremental, systemic or transformational adaptation are mentioned to have effects on other **economic sectors.** With respect to other economic sectors, demand for agricultural inputs, machinery and services is influenced by the implemented adaptation measures. For instance, an interview partner referred to reduced herbicide inputs in orchards and vineyards due to changes in tillage *"It's soil cultivation in fruit and wine growing where herbicides are substituted." (S5).* Another one added that *"Sugar purchases in the wine industry are much lower than in earlier times. Sugar industry has a slight disadvantage." (S3).* This is mainly because grapes have a higher sugar content at harvesting compared to several decades ago. Construction companies as well as producers and traders of agricultural machinery and irrigation equipment are perceived to either benefit from investments or to suffer from structural change and farm withdrawal. An agricultural expert talked about achievable off-farm profits: *"You can do business in the upstream sectors because now I have to invest in irrigation. […] With respect to stables, there is certainly something to do, and farmers have to pay for it." (S2).* On the contrary, another one reported on potential losses by referring to the detrimental results of a vicious cycle: *"The lower the number in small-scaled farms, the lower the need for agricultural machinery mechanics. The lower the number of* *agricultural machinery mechanics, the lower the need for shop." (M1).* Another expert also addressed negative effects of restructuring *"Smaller farms are withdrawn. It means that small machinery is not demanded any more. The trend is towards less but larger machinery. That is, if I a run a farm with 40 ha of cropland and expand cropland to 60 ha, I do not need an additional tractor." (S6).*

New chances and challenges may arise in regional markets due to climate-induced changes in agricultural commodity supply. Agricultural experts perceive trends in regional creation of value and induced job retention or creation differently. While agricultural institutions promote regional production and processing of agricultural commodities as a meaningful adaptation strategy, consumers' willingness to pay higher prices for regional products is perceived to be limited as described by an interview partner: *"We tried to push organic pig husbandry in the last year. Currently, the share is very, very low. And we do not manage to increase the share. I have to say, we failed in convincing the traders because all of them said that they do not need this pig, they cannot sell it." (S10).* A more optimistic perception was "*One feels that consumer's willingness to pay higher prices for some regionally produced things increases gradually." (M1)*. This comment was complemented by another interview partner *"People do not only want organic, they also want regional production. They want to know, see, this was produced in the region and they even know they farmer who raised the animal. This is important for them." (M10).*

(iv) Effects on natural resources

Adaptation management-related effects on **natural resources** comprise effects on **soil properties, surface water and groundwater, climate conditions, air quality, landscape diversity and esthetics, and biodiversity.** Perceived effects on ***soil*** include changes in soil erosion, soil water holding capacity, humus formation, and soil carbon sequestration. Positive on-farm and off-farm effects are achieved with erosion control measures including conservation tillage (e.g. mulch tillage, no tillage, contour farming), more diversity in crop choices, and small field sizes, i.e. incremental adaptation, as explained by one of the interview partners *"Concretely, that is chisel plow instead of plow. That is soil cultivation in fruit and wine growing where we use herbicides. That is, specific machinery for strip seeding in order to minimize run-off. Many things are tried." (S5).* And another one added *"Erosion control has a positive effect on the neighbors, on the people living downstream. If water flows to their land is reduced or avoided or if mud is reduced." (M7).* Negative effects on sediment loss are also perceived and expected because of enlarged field sizes and cropland expansion to steep areas or areas with currently high precipitation sums, i.e. incremental and systemic adaptation, which was pointed out by an agricultural expert: *"Assuming that temperature increases and precipitation decreases, intensive agriculture will expand to the south. This is a little bit of a problem because we have flysch there, which is very prone to sliding. […] slopes are steeper […] and still I have some cropland […] what means that I increase erosion risk." (M8).* Soil humus and soil water holding capacity are strongly interrelated such that an increase in soil humus results in an increase in stored soil water (Morris, 2004). On the one hand, the interview partners acknowledged the positive effect of low input farming, reduced tillage, and cultivating cover crops (i.e. incremental and systemic adaptation) on humus formation and attributed beneficial on-farm and off-farm effects to improved humus management. These effects include a reduced risk of flooding, likely reduced nitrogen inputs, higher carbon storage capacities, and improved soil biology, as pointed out by an interview partner *"We could probably easily apply management options, for instance winter cover crops or […] mulch-till […]; carbon changes – will enormously, well, if I do not plow anymore and use the chisel plow instead, for instance, I will get a different carbon content." (M8).* On the other hand, intensive farming in terms of tillage, fertilizer and pest management (i.e. incremental adaptation) was criticized for its adverse effects on humus, as summarized by this statement *"Today we know that the combination of the measures intensive tillage and chemical inputs have clearly led to loss in humus. And therefore, the problem that arises with climate change, is even exacerbated." (S7).*

Perceived effects on ***water*** are changes in runoff and thus erosion (see paragraph above), nutrient immissions in surface and groundwater water as well as changes in the regional water balance. Surface and groundwater contamination are perceived either if adaptation is not considered (see sub-section 3.1.3) or with poor management decisions (i.e. incremental adaptation), sometimes even induced by public incentives. An example was reported by one of the interview partners: *"I must not subsidize a green cover that is plowed in autumn. This is a completely wrong signal. It is ineffective,* *there are only costs. There are public expenses. It is costly for the farmer because he has to buy the seeds first, then he has to sow and he has not achieved anything in the soil, nothing at all. Even worse. If legumes are part of the green cover and he plows in autumn, he has a severe nitrogen-bomb which mineralizes in winter; the mild winter. And then, I have all nitrogen which was fixed in the groundwater, with 100% certainty" (S7).*

Positive effects on the regional water balance are attributed to improved humus management, reduced tillage, and cultivation of cover crops (i.e. incremental adaptation). It was described in the following words by one of the interview partners *"long-term oriented farmers pay attention to stabilization […] And, for instance follow the direction of maintaining humus, maintaining soil, covering soil in order to reduce risk factors, like water scarcity with a good humus structure, for instance, or temperature extremes or also excess water." (M3).* Interestingly, only positive effects of new water reservoirs and irrigation facilities (i.e. systemic adaptation) on the regional water balance (e.g. decreased severity of floods) were addressed by the interview partners. Competition in water usage, for instance with drinking water, is not perceived as a problem. This is because abstraction of water for irrigation is strictly regulated. One of the interview partners told *"Water abstraction from groundwater for irrigation is […], I think, not very easily proved. And if, it will be rather limited because of the groundwater level which is important for drinking water supply. One is very cautious." (S1).* Another one added *"I think the authority even regulates that we are only allowed to irrigated at night. On the one hand to minimize transpiration losses and there is a psychological effect, too. If water is already scarce and then – I think on the [regional toponym]-cycling path, there are many cyclers. They have to have the feeling that agriculture wastes the water if we irrigate during the heat of the day." (S9).*

Climate mitigation was not explicitly addressed in the interviews, but the interview partners referred to it in the context of humus formation and soil carbon sequestration activities (see above), animal husbandry, and extensification (i.e. incremental and systemic adaptation). Smaller structures in combination with regional markets as well as low input farming are perceived beneficial in terms of climate protection because of improved logistics and reduced inputs. For instance, an agricultural expert explained *"one really pays attention to regionality and sustainability. Basically, we try to react partly to these questions and in particular to climate protection. And I think, that one was not bad positioned in the past […] because we have really short transport routes, for instance in terms of fodder." (S10).* However, though the interview partners are aware of synergies between climate change adaptation and mitigation measures, potential synergies are not always utilized by farmers because of external constraints. For instance, demand for organic livestock products is limited and thus extensification strategies had to be postponed (see quotation, four paragraphs above).

Positive effects on the ***microclimate*** may be achieved by maintaining or establishing landscape elements as well as by increasing soil fertility and soil water holding capacity (i.e. incremental adaptation). Both, the farmers and the society may benefit of changes in microclimate as told by an interview partner *"The services we provide for the public for free need to be promoted much more. I am glad about every farmer who works in smaller structures and keeps his forest edge and his hedges and his tree because everybody benefits of that, I say, even climate, microclimate. One can see that microclimate – he says, wow, everything grows very well on my field. […] If a farmer can manage to have his own microclimate, this is a big advantage because he not so dependent." (M6)*

Air quality may be negatively affected by dust formation (e.g. ploughing dry soils) or odor development (e.g. livestock production, slurry application on farmland). Such effects are ascribed to poor on-farm management decisions *"Slurry application at 34, 35, 38 degrees with a distributor in the back […] 90% of it is probably gone at these temperatures. […] And it smells in the whole area." (S2).*

Landscape and biodiversity are strongly related and perceived to be affected by incremental, systemic and transformational adaptation, especially by construction projects (e.g. water retention basis, hail nets), changes in land cover and land use (e.g. afforestation, reduction in monocultures and diversification in crop choices, ground cover in winter), and intensification or extensification. Even though effects on landscape structure and biodiversity are important for farmers and the society, positive as well as negative developments are perceived. One of the interview partners reported *"One notices now that open and clear landscapes are not much to look at. Something is planted in between or field edges are established in order to enhance biodiversity." (M10).* Another one explained *"The* *hail nets would be more beautiful in green colors. But green hail nets are not so resistant to UV radiation because of some substances. And only the black ones work. Additionally, it's a matter of price. In summer, it is not so visible but in winter the hail nets shine." (S1).* However, the interview partners added that information, communication, and consultation are critical in order to reduce opposition against new projects *"It is always the same, if you find a reasonable way, there will be less difficulties. If you do it egoistically, sooner or later you will have difficulties." (S1).*

(v) Effects on human resources

Systemic and transformational adaptation are perceived to affect **human resources** relevant for both, the farmers and the society, because of gain or loss in local knowledge. Organic farming is seen as a nucleus of growth in local knowledge, as pointed out by one of the interview partners *"I think that knowledge on humus formation increases slowly. Certainly because of organic farming, it radiates a bit." (M3).* Additionally, developing new or rediscovering 'old' branches of production amplifies the increase in local knowledge, as perceived by another interview partner: *"Well, we try to cultivate wheat. We find that it works. and we relearn to grow wheat in the region, both, quality wheat and mill wheat." (S4).* Farm withdrawal or changing farm types are likely to contribute to the loss of local knowledge as one of the interview partners pointed out *"If the farmers cease their activities, it's not only the farms that are gone, it's also about knowledge, loss of knowledge. Very few people are aware of this." (S4).*

(vi) Effects on social resources

Social resources are perceived to gain in importance in the future because collaborative efforts of farmers are needed for erosion and pest control, liquid manure management, long-term investment projects and long-term development of markets for 'new' agricultural commodities. Collaborative activities are relevant for generating both, on-farm and off-farm benefits. However, farmers' actual willingness to engage in collaborations and co-operations is perceived to be rather low despite the guidance by regional agricultural institutions, as described by an interview partner: *"I think, if something is going on nicely, the agricultural chamber is involved. That they [Note: the farmers] really get together and say, we organize a crop rotation system, I think it does not occur. Cooperation ends at the boundary of the field." (S6)* On the contrary, positive examples of successful cooperation were reported as well: *"Well, not the single farmer but the community applied and built, after an authority procedure, ten [Note: irrigation] fountains or so. This was an initiative." (S9).*

(vii) Indications of maladaptation

The interview partners reported mostly on potential positive and negative on-farm and off-farm effects. The actual effectiveness of private adaptation can, however, only be evaluated after the period of interest. This is mainly because of high uncertainties in future climate and market conditions which need to be considered in adaptation processes. Some authors suggest to focus on robust adaptation measures which are typically low-regret, i.e. beneficial even without significant changes in climate conditions and reversible by having low costs of maladaptation (Hallegatte, 2009). The interview partners reported on potentially maladaptive private adaptation measures. They refer to:

- Winter cover crops that do not freeze are often treated with pesticides. This may contribute to pesticide immissions to surface and groundwater.
- Changes in land cover and land use affect landscape structure and scenery and may have adverse effects on tourism.
- Additional purchase of forage and fodder for livestock production extends transport routes leading to additional greenhouse gas emissions.
- Ventilation and air-conditioning in stables may increase energy demand. If energy is not provided by renewables, livestock production could produce additional greenhouse gas emissions.
- Tillage on very dry soils contributes to dust formation.
- Irrigation of farmland may lead to conflicts of interest between water users, overuse of the water supply network, additional energy demand and additional workload.
- Changes in feeding ratios (for instance because of changes in cultivated forage crops) are likely to change emissions from livestock production.

- Long investment periods, e.g. in viniculture or fruit production, may lead to path dependencies.
- Hail nets which are typically applied in viniculture and fruit production affect landscape esthetics.
- Purchase of agricultural insurance products, in particular if farmers' premiums are publicly subsidized, may impede systemic and transformational adaptation.

3.2 Agricultural institutional setting in the context of climate change

3.2.1 Climate change discourse in regional agricultural institutions

Based on the interview results, we found that changes in climate conditions, related impacts or adaptation strategies are directly or indirectly addressed in all institutions represented by the interview partners, though for different **purposes** and with different **priorities.** We identified **four main purposes** of dealing with climate change, i.e. education and training, research and development, strategic orientation and development of the institution, and managing mitigation and adaptation processes.

Education and training programs are initiated by each institution (see sub-section 3.2.2). The programs focus on different target groups and touch on various topics. Target groups include, for instance, farmers-in-training, professional farmers, extension agents, and the wider public. Discussed topics are directly or indirectly related to climate change and cover, for instance, humus management, water management, erosion control and animal feeding.

Research and development activities deal with understanding the agricultural system, defining regional challenges, and developing and assessing options to deal with the identified challenges. Academic or non-academic research institutes typically initiate such regional research projects and collaborate (inter alia) with the agricultural institutions represented by the interview partners and with farmers.

In some of the institutions, climate change plays a role in their *strategic orientation*. For instance, a cross-departmental project involving representatives of different sectors has been initiated in the office of the provincial government in Lower Austria to work on climate change-related topics. In the chambers of agriculture, climate change is particularly addressed by the plant production experts. Some educational institutions have chosen to offer specific courses on climate change in order to attract students. Representatives of farm machinery co-operations and agricultural cooperatives mentioned to consider changing climatic conditions especially in long-term investment decisions.

Specific institutions or groups of institutions have developed and carried out regional projects in order to *encourage mitigation and adaptation processes*. The institutions (e.g. office of the provincial government, chamber of agriculture, educational institution, regional management, environmental organization, producer group) provide professional guidance, financial incentives or organizational infrastructure to successfully implement, monitor and evaluate mitigation and adaptation activities.

Prioritization of climate change in the institutions has been identified to depend on (i) the institution's focus or strategic orientation, (ii) the personal commitment and interest of the head of the institution and collaborators, and (iii) the funding opportunities for climate-related activities.

Agricultural institutions that aim at advancing the agricultural sector concentrate their work on several topics including medium- to long-term changes in climate conditions, the development of the Common Agricultural Policy (CAP) as well as the handling of the currently unstable agricultural market conditions. Some respondents perceive that climate change is only discussed in case of extreme events in such institutions. Specialized institutions or divisions working on the interface between agricultural production and environmental resources are found to dedicate more resources to climate change-related activities and most of their projects are – in some way or the other – connected to climate change mitigation or adaptation.

Deep commitment of the head of the institution or division on climate change stimulates projects linked to the topic in hierarchically structured institutions such as the office of the provincial government or the chamber of agriculture. Institutions organized in the form of cooperatives (e.g. producer groups, environmental organizations and agricultural cooperatives) spend time and resources on climate change mitigation and adaptation measures if collaborators or members are highly interested. Financial incentives and public funding is of particular relevance for research projects and for facilitating mitigation and adaptation processes on the ground.

3.2.2 Provision of infrastructure by regional agricultural institutions

The representatives of the regional agricultural institutions reported on their engagement in providing information, technical and financial infrastructure (see Table 8). Depending on the **strategic focus** of the respective institutions, they provide solely information (i.e. schools and research institutes), information and technical infrastructure (i.e. chambers of agriculture and machinery co-operations), information and financial infrastructure (i.e. regional management and environmental organization) or information, technical and financial infrastructure (i.e. provincial government, agricultural cooperative and producer group). The infrastructure provision by a broad variety of regional institutions increases the likelihood that farmers can be reached and supported in their climate change adaptation activities. This diversity is considered positive.

The analyzed regional agricultural institutions provide a broad variety of information. They organize expert talks, seminars, excursions and advanced trainings; publish magazines, brochures and (fee-based) newsletters; conduct or contribute to research projects and field trials; and offer warning services and personalized expert service. However, agricultural experts perceive several major challenges in brokering information and knowledge to farmers with limited time resources. They experience difficulties in reaching most of the farmers in the region (i.e. addressing the heterogeneity of farms and farmers), in providing objective and user-friendly information and in facilitating the interpretation of the information for the individual farmer *("the proper interpretation of the information sources, this is somehow missing", M9*), and in supporting short-, medium- and long-term management decisions. Accordingly, the professionalization of communication and consulting strategies with respect to climate change and climate change adaptation is important and should follow "good communication" standards. Integrating potential user groups in the information development process is likely to increase the confidence in the data, methods and results as expressed by one of the interview partners *"[We are] very satisfied, because we have been partly involved in data collection; and we are always able to access these data." (S8).*

The institutions facilitate farmers' access to technical infrastructure by breeding activities, running a feed laboratory, planning and constructing water retention basins and flood protection measures, and by providing weather stations and (special) agricultural machinery for lease. Financial support and infrastructure provided by the studied regional agricultural institutes includes, for instance, subsidies for particular management measures (e.g. for planting fruit trees or hedges), joint purchasing of agricultural inputs, and joint marketing, distribution and sales activities.

The interview partners highlighted the benefit of field trial results and excursions to farmers who are already experiencing higher variabilities in temperature and precipitation for intensifying farmers' adaptation efforts. Furthermore, they emphasized the steadily rising quality and usefulness of weather and warning services and pointed to the high number of subscribers for newsletters providing latest weather and market information as well as recommendations for near-term management decisions (e.g. pesticide and fertilization management). Assuming that extreme events such as droughts and floods may increase in frequency and duration – as expected by the agricultural experts and suggested by global (Dai, 2011a, 2011b; IPCC, 2013) and Central European studies (Trnka et al., 2015) as well – such short- and medium-term weather and warning services may increase in importance for farm management decisions.

Administrative bodies, public and private organizations and institutions represented by the interviews also devote attention and effort to providing information, technical and financial infrastructure. The interview partners mentioned the importance of technological progress in crop and livestock breeding and agricultural machinery initiated by private companies. For instance, improving drought tolerance in crops, reducing fodder input in livestock production without reducing the output quantity and quality as well as the development of precision farming are considered of high relevance. Incentivizing crop and livestock breeding seems to be of high relevance not only because of the need expressed by the interviewees but also because of the long lead time. While major crops and livestock breeds are likely to be propagated by private companies, breeding of minor crops and rare animal breeds which are valuable to preserve or increase diversity may need to be facilitated by public stimulus.

Agricultural investment subsidies and subsidized credits initiated at European and national level were positively evaluated. Publicly subsidized crop insurance products (co-financed by the national and provincial governments) are perceived controversially. While proponents argue for improving and expanding the crop insurance system, the opponents think that it may hamper systemic and transformational change. Different strategies to change existing or implement additional crop insurance products were suggested by the interview partners. One group of agricultural experts advocates for simplifying the insurance products such that climate-related parameters trigger insurance payments and suggest strengthening public support at national and provincial level for insurance products. Such an approach could facilitate management-related adaptation efforts (e.g. investing in irrigation facilities) because currently farmers only receive money if they experience high crop or grassland losses and are thus not willing to apply anticipatory adaptation. Another group of agricultural experts opts for withdrawing subsidies for crop insurance. They argue that insurance partly impedes systemic and transformational adaptation because of publicly supported insurance premiums. Extending the portfolio of risk management instruments is, in general, deemed important under changing climate conditions though reservations are expressed as well. Insurances may be part of a risk management portfolio, although their effectiveness depends on the farm's risk exposure and the farmer's risk attitude (Gröbmaier, 2012).

The national disaster fund was considered important in years of heavy losses. However, the interview partners discerned that transfers from the disaster fund are likely to impede farmers' private adaptation efforts. Farmers tend to count on the money from the disaster fund and are thus not always well prepared for extreme events (see sub-section 3.1.4.1). Payments from the national disaster fund have decreased in the agricultural sector over the last decades due to rising claims from various sectors and limited resources. A transparent and easily comprehensible regulation on when agricultural producers can expect transfers from the disaster fund could help to sharpen farmers' sense of security and may foster alternative private adaptation measures.

Table 8. Information, technical and financial infrastructure provided by the regional agricultural institutions.

	Regional research institutes	Office of the provincial government	Chambers of agriculture	Farming engineering schools	Farm machinery co-operations	Regional management	Environmental organization	Producer group	Agricultural cooperative
Information infrastructure	✓	✓	✓	✓	✓	✓	✓	✓	✓
Technical infrastructure	--	✓	✓	--	✓	--	--	✓	✓
Financial infrastructure	--	✓	--	--	--	✓	✓	✓	✓

Legend:
✓ … mentioned in the interview
-- … not mentioned in the interview

3.2.3 Agricultural experts' level of information about climate change

One group of agricultural experts feels very well or well informed about changes in climate conditions and well or moderately informed about latest developments in climate change adaptation measures. These interview partners specified that they are actively seeking for information related to changing climate conditions and they rated the available information generally as good. The availability of adequate information was summarized by an interview partner with the following words: *"If somebody wants to catch up on the topic, he can obtain the information at any time" (S7).* Another interviewee stated that he is not well informed about climate change and climate change adaptation. Though being aware of the availability of knowledge and expertise, this person stated that he is not actively seeking for or reading information related to the topic.

Efforts in effective research communication in general and in communication of adaptation measures in particular could be intensified in order to increase agricultural experts' and farmers' awareness and understanding of potential benefits and drawbacks of climate change adaptation measures. Such communication activities can be stimulated by research, boundary organizations or extension services. Special focus should be put on the spatio-temporal context of the research results in order to allow for their reasonable interpretation by experts and practitioners. The farmers' request for 'localized' results was summarized by one of the interview partners with the following words: *"You reach the farmers only if their farm is considered. Yes, my farm is considered in this study. … They have studied the neighboring district. The conditions are similar. But farmers do not look at studies which are undertaken in other provinces." (S11).*

3.2.4 Agricultural experts' preferred information sources and media on climate change related topics

The interview partners in the case study regions mentioned a broad variety of **information sources and media,** which are relevant for their daily business (see Figure 6 and Figure 7). Information is provided by (i) agricultural institutions, (ii) agricultural companies, (iii) educational institutions, (iv) research institutes, and (v) peers and experts. Additionally, personal experience and observations are important information sources.

Used information media encompass (i) print media such as agricultural magazines and books, (ii) visual media such as television, (iii) digital media such as e-mail newsletters and online services as well as (iv) education media such as seminars and excursions. Information is also gathered (v) within the personal social network, e.g. in informal discussion with peers or experts, and (vi) by own experience or observation.

Personal experience and observations as well as information provided by established agricultural institutions, educational institutions, peers and experts are perceived as particularly reliable and are used on a regular basis in both case study regions. These findings are in line with previous investigations (see e.g. Tribbia and Moser, 2008) and suggest that the traditional institutional structure in the Austrian agricultural sector can effectively support climate change adaptation.

Depending on the required information, agricultural experts are actively searching for information in print media and in digital media. They refer to print media such as agricultural specialist magazines or books to guide farmers' medium- and long-term decisions. Digital media are mostly consulted to inform everyday and short-term decisions but advance medium- and long-term decisions as well. For instance, online weather and pest warning services are regularly used to inform crop and grassland management decisions. Online data portals, product catalogs and reports provide information to support e.g. investment decisions.

Interestingly, social media such as blogs, Twitter feeds, RSS feeds and podcasts have not been mentioned in the interviews indicating that agricultural experts in the case study regions are predominantly informed by traditional information sources and media. Social media allow users to rapidly create, share or exchange information in virtual communities and social networks. Globally, digital technologies are gaining in importance for delivering timely information and for coordinating and optimizing farming activities at comparably low cost (Herrick et al., 2013; The World Bank, 2016). This suggests that there is no single optimum approach for distributing information and future information campaigns may benefit from including both traditional and new media even if their utilization is limited at the moment. New media is not expected to replace but to complement traditional information material and may enhance its use.

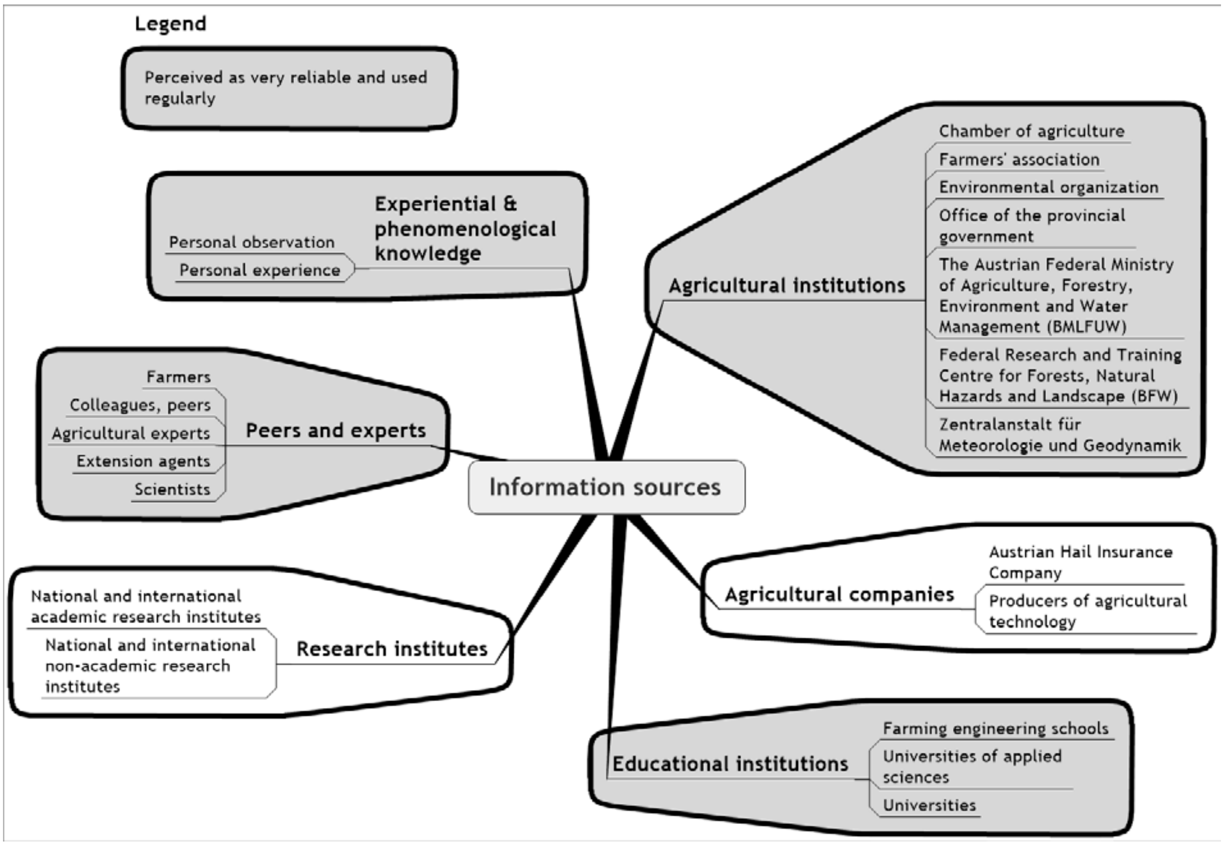

Figure 6. Agricultural experts' preferred information sources on climate change related topics.

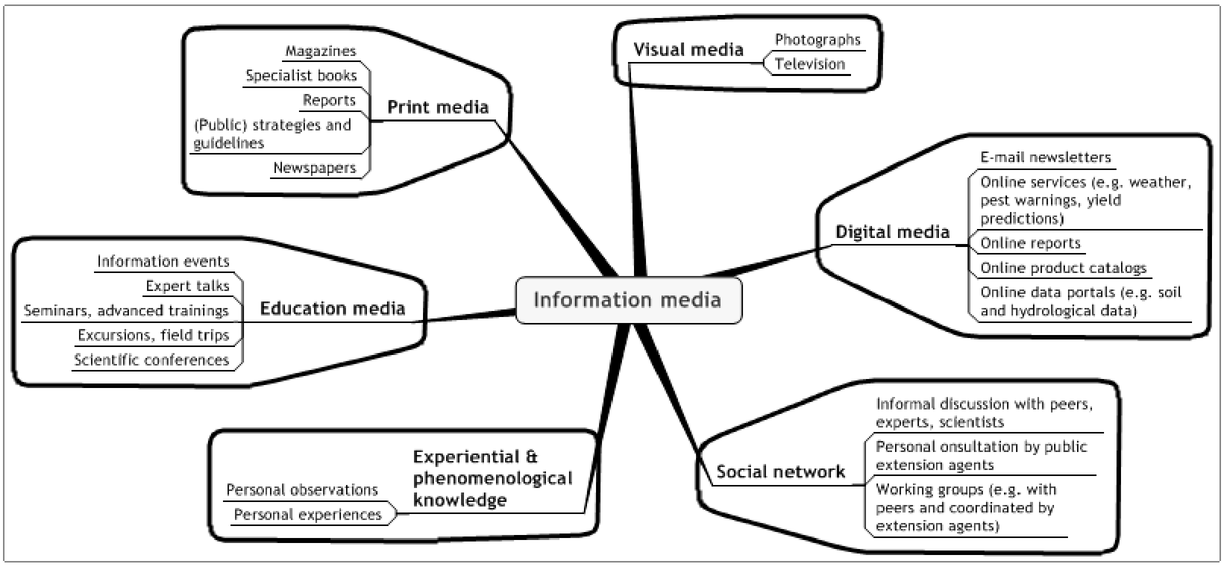

Figure 7. Agricultural experts' preferred information media on climate change related topics.

3.2.5 Agricultural experts' information needs in the context of climate change

We asked about the information agricultural experts in the Mostviertel region and in South-East Styria lack in order to understand, plan and manage climate change adaptation. The general availability of information was appreciated (see sub-section 3.2.3), but the interview partners asked for better accessible data and regionally explicit information. In the climate change adaptation literature, similar findings are reported by Hanger et al. (2013) and Tribbia and Moser (2008). The results suggest that further efforts should be rather devoted to improving the quality of existing information sources and – to a lesser extent – to establishing additional ones.

Most interview partners expressed their current information needs rather vaguely. Though climate change is addressed in all investigated agricultural institutions (see sub-section 3.2.1), strategic adaptation planning is at an early stage. Combined with the inherent uncertainties in climate change adaptation, this may have contributed to the respondents' low sensitivity to information and research needs. Stimulating systematic development of private adaptation pathways is likely to contribute to an increase in the quality of defining specific information needs (see Hanger et al., 2013).

The **information needs** expressed by the respondents can be summarized in two major categories. **First,** the agricultural experts asked for *generalized data and information,* which are *easily accessible and user-friendly. Generalized data and information* focus on understanding the system without referring to context-specific conditions and constraints (see Enengel et al., 2012). *Data* of peculiar interest include climate data with high temporal resolution as well as data on changes in average climate parameters (trends) and in extreme events. Preferred *information* topics are

- causal links between CO_2-emissions in agriculture and climate change,
- potential changes in the probability of occurrence of extreme events,
- potential climate change impacts in agriculture triggered by average changes and by changes in frequency and duration of extreme events,
- expected future development of environmental resources, i.e. soil conditions, water supply and air quality, and
- required adaptation processes in the agricultural sector.

Establishing a central contact point was suggested to facilitate *accessibility* to latest data and research results. The Climate Change Center Austria (CCCA) was launched in 2011 to meet (inter alia) this requirement (Loibl et al., 2012). Lack of public awareness of the CCCA and its services call for additional efforts in public relations activities focusing on specific target groups such as agricultural experts.

User-friendliness of data and information is a key criterion for their public use. In this context, the interview partners highlighted the need for well-structured and synthesized research results with informative conclusions. A meta-study on latest, national research results was demanded in order to reveal the bandwidth of potential futures in agriculture. The Austrian Assessment Report 2014 (AAR14; Kromp-Kolb et al., 2014), which follows the example of the IPCC-reports, aims at reviewing and assessing latest scientific, technical, and socio-economic information relevant to the understanding of climate change. Again, its distribution among relevant actors in the agricultural sector should be ensured.

Second, the respondents asked for *context-specific data and information* with high *practical relevance.* Context-specific data and information is typically linked to the region or the individual case (Enengel et al., 2012). *Data* requested by the respondents are regionally explicit 14-days weather forecasts. *Information* of interest refers to mitigation and adaptation measures. The interview partners asked for information about carbon sequestration in terrestrial ecosystems, the effectiveness of management practices under changing climatic conditions, strategies to improve humus formation and water supply, and income alternatives for the agricultural sector.

According to the interview partners, *practical relevance* of data and information can be improved by adjusting investigation periods to decision-making periods in agriculture, coming up with regionally explicit results that are easy to understand, and by providing information that can support decisions on managing, i.e. implementing, monitoring, and evaluating, mitigation and adaption measures (see Moser and Ekstrom, 2010).

Based on the information and research needs mentioned by the interview partners, we have derived thematic and methodological **research needs.** *Thematically,* investigations on (i) carbon sequestration potentials of terrestrial ecosystems, (ii) potential climate change impacts on environmental resources, (iii) the effects of extreme events and CO_2 fertilization on agricultural production, and (iv) the effectiveness of climate change adaptation measures with limited negative environmental effects have priority. The analyses should focus on homogeneous production regions and the next decades.

Methodological developments should include (i) field trials on implementing, monitoring, and evaluating mitigation and adaptation measures, (ii) breeding of new cultivars and testing of alternative feeding ratios, (iii) model development and improvement in order to better understand biases and uncertainties, (iv) inter-sectoral and interdisciplinary studies in order to get a more holistic view on the complex topic of climate change, and (v) participatory approaches in order to integrate the knowledge of farmers and local actors in research projects and develop climate change/climate change adaptation communication.

4 Discussion and conclusions

Based on qualitative, semi-structured interviews with agricultural experts from a broad variety of agricultural institutions relevant to the two case study regions in Austria (Mostviertel and South-East Styria) we have investigated perceptions and expectations on regional climate change, climate change impacts on and private adaptation in the agricultural sector. In addition, we have analyzed how climate related topics are addressed, and how regional agricultural institutions facilitate private adaptation measures. Agricultural experts' level of information, their favored information sources and media, and their information needs are examined as well.

We find that an increase in temperature levels and variability, more severe extreme events and high uncertainties in future climate conditions are perceived as challenging for the agricultural sector in both case study regions. Beneficial and adverse climate change impacts were reported, though the latter prevailed. While positive impacts were only attributed to higher mean temperatures, negative impacts were perceived as a result of changes in temperature, precipitation, seasons, and extreme events.

Private climate change adaptation in agriculture

Private adaptation in agriculture is perceived to be important in both case study regions. Regional and local climate conditions are perceived to push private adaptation. However, legal, market and policy conditions are at least of equal importance. Additional drivers relate to the characteristics of the farmer, the farm and the society as well as to the availability of information and technological infrastructure. The interview results show that mostly combinations of bio-physical and socio-economic internal and external stimuli influence private adaptation. Accordingly, different public incentives need to be offered in order to reach the majority of the farmers in the regions and to facilitate private adaptation. The development of external framework conditions should, in general, amplify positively evaluated and reduce impeding drivers. In particular, changes in legal guidelines and regulations, changes in the design of financial incentives, and provision of relevant information is demanded. The legal guidelines are asked to limit negative external effects, support innovative ideas, and ensure legal certainty for long-term investments. Contradictory regulations as well as complicated administrative processes should be avoided in order to reduce transaction cost. Furthermore, the legal and institutional frameworks should be coordinated. Publicly provided (financial) resources can increase farmers' adaptive capacity and incentivize private adaptation. Public payments should be adopted to the regional conditions and the farmers' individual requirements. They should support efforts that are robust, innovative, have high investment costs or require collaborative efforts to ensure long-term effectiveness. Again, administrative burden needs to be kept low in order to minimize transaction costs. Information and communication strategies should be adapted to the state of the agricultural system in the region and should deal with both, direct and indirect climate change impacts. Direct impacts can be addressed during and right after the occurrence of an extreme event. Such 'windows of opportunity' should be used in order to inform farmers' adaptation decision making – even if investments have to be postponed because financial resources may be limited in particularly bad years. Including indirect impacts in a regular communication strategy is key because farmers tend to assess indirect effects (via the market) stronger than direct climate-induced impacts.

Subject to the dominant agricultural production systems, a broad spectrum of incremental, systemic and transformational adaptation measures was discussed. Though the national adaptation strategy (NAS), which was adopted by the Austrian government in 2012 (BMLFUW, 2012), was not touched upon in the interviews, only two (out of 14) recommendations for action were not mentioned in the interviews because of their lack in applicability, i.e. maintaining alpine pastures and optimizing crop cultivation in greenhouses. Adaptation measures that were added to those summarized in the NAS are of transformational nature. While the NAS focuses on actions to maintain or enhance agricultural activities, the interview partners also addressed changes in the strategic focus of the farms, engagement in non-agricultural secondary activities, leasing farmland to colleagues and even farm withdrawal. Controversial opinions were related to crop insurance and the relevance of irrigation systems for main crops. Both adaptation measures were perceived promising by one group of respondents, whereas another group stressed the potential delay of systemic and transformational change, also because of publicly supported insurance premiums. Such contradictions were only found for crop insurances and investments in irrigation, which calls for additional investigations on these specific topics. With respect to crop insurance products, previous studies find that their effectiveness depends on the farm's risk exposure and the farmer's risk attitude (Gröbmaier, 2012). With respect to irrigation, integrated modeling studies suggest that economic benefits are sensitive to the cultivated crops (Lehmann et al., 2013; Mitter et al., 2015) and to changes in price levels and variabilities (Finger, 2012; Finger et al., 2011).

Adopting climate change adaptation measures leads to positive and negative on-farm and off-farm effects. The effects differ in level and sometimes even in direction, depending on the actual changes in regional climate conditions. Due to the high uncertainties in future changes and in order to increase local knowledge, structured monitoring and evaluation processes at farm and regional level are crucial. Monitoring and periodic evaluation of the changing environment and the outcome of the realized adaptation measure can and should inform future (private and public) adaptation decision-making processes in order to reduce potential maladaptation in agriculture. Such monitoring and evaluation activities can be supported by (i) preparing monitoring and evaluation plans with (jointly) developed goals and targets, (ii) establishing methods and indicators for monitoring and evaluation activities which consider private and public benefits and drawbacks, (iii) collecting and analyzing data from different farm types and regions in order to monitor long-term effects and to allow for intra- and inter-regional comparisons and evaluations, and (iv) providing knowledge for monitoring and evaluation activities by other economic sectors (see Moser and Ekstrom, 2010).

Agricultural institutional setting

Longstanding cooperation between agricultural institutions at national, regional and local levels offers a good basis for coordinating activities at the different levels and facilitating private adaptation. Stronger engagement of the institutions in climate change related topics may be achieved by initiating activities for 'internal' and 'external' purposes. Internal activities are beneficial for the institution and its development (e.g. by designing a training program for the employees) whereas external initiatives support extra-institutional climate change adaptation activities (e.g. by providing an information and knowledge infrastructure for guiding farmers' management decisions). Institutional commitment to support adaptation could be further strengthened by including climate goals in its mission statement. Such activities are also influenced by the commitment of the head of a hierarchically organized institution or by the members of direct democratic organizations. Agricultural adaptation can also benefit from developing and adopting an institutional action plan, stipulating the long-term provision of resources for appropriate initiatives, achieving high transparency on dedicated and spent resources, and defining responsibilities for jointly developed activities. Particular private adaptation measures can likely benefit from institutional engagement. They include measures where a number of actors with similar or diverging interests (needs to) work together, measures for which experiences are low but which offer a promising chance, measures with long lead times or high investment costs, and measures with both on-farm and off-farm effects. Perceived barriers for private adaptation should be removed promptly, if they are grounded in the institution's area of competence. Adverse regulations that have a long tradition or are decided at higher levels are likely to require the cooperation of several institutions.

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7 Appendix

7.1 Interview guide

Themenblöcke

I. **Beobachtete und erwartete Klimaveränderungen**
Beobachtete und erwartete Auswirkungen auf die Landwirtschaft in der Region
Informationsstand und -bedarf

II. **Umgesetzte Anpassungsmaßnahmen**
Informationsstand und -bedarf

III. **Extremwetterereignisse**

IV. **Thematisierung von Klimaveränderungen in der Institution**

V. **Abschluss**

#	Leitfrage	Unterfrage	Check/Memo
I.	**Beobachtete und erwartete Klimaveränderungen** **Beobachtete und erwartete Auswirkungen auf die Landwirtschaft in der Region**		
1	*Klimaveränderungen prägen neben Themen wie Lebensmittelsicherheit, globale Ernährungssicherung und Reform der Gemeinsamen Agrarpolitik internationale und nationale Diskussionen.* Rückblickend auf die Zeit seit Sie im Sektor Landwirtschaft tätig sind – inwiefern haben sich Ihrer Meinung nach die klimatischen Bedingungen in der Region [Name] verändert?	Welche Klimaveränderungen beobachten Sie in Ihrer Region? Wie lange sind Sie bereits im Sektor Landwirtschaft tätig? Wie lange sind Sie bereits in der Region [Name] tätig?	Temperatur Niederschlag Extremwetterereignisse
2	Welche Auswirkungen haben die von Ihnen geschilderten Klimaveränderungen der Vergangenheit auf die Landwirtschaft in der Region?	Welche positiven Auswirkungen beobachten Sie? Welche negativen Auswirkungen beobachten Sie? Wie stark ist aus Ihrer Sicht der Veränderungsdruck dieser Auswirkungen auf die LandwirtInnen? Welche anderen, nicht klimatisch bedingten Faktoren haben aus Ihrer Sicht zu den geschilderten Auswirkungen beigetragen?	Wirtschaftlich, finanziell Ökologisch Arbeitswirtschaftlich Organisatorisch Landnutzungsänderungen Politisch, Rechtlich Institutionell Finanziell Marktwirtschaftlich Infrastrukturell (Information und Ausbildung, Technologien, Finanzwirtschaft) Sozio-kulturell Bio-physikalisch, Ökologisch
3	Welche zukünftigen Klimaveränderungen erwarten Sie für die Region [Name]?		Temperatur Niederschlag Extremwetterereignisse

4	Welche Auswirkungen erwarten Sie von den zukünftigen Klimaveränderungen auf die Landwirtschaft in der Region?	Von welchen regionalen Klimaveränderungen könnte die Landwirtschaft in Ihrer Region profitieren/verlieren? Welche Gefahren/Chancen können sich für die Landwirtschaft in der Region durch regionale Klimaveränderungen entwickeln? Welchen Betriebstypen könnten von regionalen Klimaveränderungen profitieren/verlieren?	 Wirtschaftlich, finanziell Ökologisch Arbeitswirtschaftlich Organisatorisch Futterbaubetriebe Marktfruchtbetriebe Dauerkulturbetriebe (Forstbetriebe) Gemischtbetriebe Veredelungsbetriebe Gartenbaubetriebe
5	Wie gut fühlen Sie sich persönlich über Klimaveränderungen in Ihrer Region informiert?	Welche Informationsquellen nutzen Sie, um sich über neue Erkenntnisse und aktuelle Entwicklungen regionaler Klimaveränderungen zu informieren? (aktive Informationssuche) Welche Informationsquellen nutzen Sie, die regionale Klimaveränderungen thematisieren? (passiver Informationserwerb) Wie zufrieden sind Sie mit den Ihnen zur Verfügung stehenden Informationen? Welche weiteren konkreten Informationen im Themenbereich Klimaveränderungen würden Sie für Ihren beruflichen Tätigkeitsbereich brauchen? (Informationsbedarf)	Institutionen (innerhalb der eigenen Institution, in anderen Institutionen), Herausgeber, Veranstalter, Betreiber (zB von Websites, Prognosediensten) Nützlichkeit der Informationen für die tägliche Arbeit Vertrauen in die Informationen (Unsicherheiten) Besser strukturierte und zugängliche Daten Räumlich explizite Informationen Daten zu Vulnerabilität/ Sozio-ökonomische Daten, Kosten (Nutzen) von Anpassungsmaßnahmen Best practice

II.	**Umgesetzte Anpassungsmaßnahmen**		
6	*Generell geht man davon aus, dass sich LandwirtInnen an regionale Klimaveränderungen anpassen können, um Gefahren zu minimieren oder neue Chancen zu nützen.* Welche Rolle spielen Klimaveränderungen für Entscheidungen am Betrieb? *[Einzelne Anpassungsmaßnahmen können beispielhaft auf Nachfrage oder als zusätzliche Hilfestellung genannt werden. Bodenbearbeitung, Ausstattung am Betrieb, Finanzmanagement]*	Wie passen sich LandwirtInnen in der Region Ihrer Erfahrung nach an regionale Klimaveränderungen an? Welche Maßnahmen wurden bereits umgesetzt, die auf Grund eines anderen Faktors gewählt wurden, die aber Klimarelevanz haben? Welche anderen Faktoren hatten Ihrer Einschätzung nach einen wichtigen Einfluss auf die Wahl der von Ihnen genannten Maßnahmen?	inkrementell – transformativ Pflanzenbau Tierhaltung (inkl. Almen) Finanzmanagement Ausstattung am Betrieb Informatorische Infrastruktur Wirtschaftlich, finanziell Bio-physikalisch, Ökologisch Arbeitswirtschaftlich Organisatorisch Politisch, Rechtlich Institutionell Infrastrukturell (Information und Ausbildung, Technologien, Finanzwirtschaft) Sozio-kulturell, Persönlich
7	Wie schätzen Sie das Kosten-Nutzen-Verhältnis der bereits umgesetzten Maßnahmen ein? *[Diese Frage muss maßnahmenspezifisch abgefragt werden. Ev. auf die beiden wesentlichsten Maßnahmen konzentrieren.]*	Wie wirksam sind diese Maßnahmen aus Ihrer Sicht? In welchem Verhältnis stehen aus Ihrer Sicht Investitions- und laufende Kosten dieser Maßnahmen zueinander? Wie lange dauert es, bis diese Maßnahmen wirksam werden (lead time)? Wie lange sind diese Maßnahmen wirksam (consequence time)? Können diese Maßnahmen rückgebaut werden, oder schaffen sie längerfristige Pfadabhängigkeiten? Begünstigen oder behindern sich diese Maßnahmen gegenseitig? Welche Angebote und Leistungen (zB Beratungsleistungen, öffentliche Zahlungen) werden von den LandwirtInnen für die Umsetzung der Maßnahmen in Anspruch genommen? Welche Maßnahmen können aus Ihrer Sicht in Zukunft effizient umgesetzt werden?	Wirksamkeit Effizienz

8	Wie schätzen Sie die Auswirkungen bereits umgesetzter Anpassungsmaßnahmen auf andere Sektoren oder AkteurInnen ein? *[Einzelne Sektoren oder AkteurInnen können auf Nachfrage oder als zusätzliche Hilfestellung genannt werden: Umwelt, Wasser, Gesundheit, Lebensqualität, Tourismus.]*	Welche positiven Auswirkungen nehmen Sie wahr? Welche Schwierigkeiten sind durch die Umsetzung der Anpassungsmaßnahmen außerhalb des Betriebs (mit anderen Sektoren oder AkteurInnen) aufgetreten? Und umgekehrt, wie wirken sich Anpassungsmaßnahmen, die in anderen Sektoren umgesetzt werden, auf die Landwirtschaft in der Region aus?	positive externe Effekte negative externe Effekte
9	Welche Einflussfaktoren kennen Sie, die das Anpassungsbestreben der LandwirtInnen in der Region beeinflussen?	Welche Einflussfaktoren kennen Sie, die LandwirtInnen in der Region bei der Anpassung an regionale Klimaveränderungen unterstützen? Welche hinderlichen Einflussfaktoren (Barrieren) kennen Sie? Was braucht es aus Ihrer Sicht noch (innerhalb der Institution und darüber hinaus), um Anpassungsmaßnahmen im Sektor Landwirtschaft zu forcieren?	Entwicklung, Bewertung, Auswahl von Anpassungsmaßnahmen [Rahmenbedingungen] Politisch, Rechtlich Institutionell Finanziell Marktwirtschaftlich Infrastrukturell (Information und Ausbildung, Technologien, Finanzwirtschaft) Sozio-kulturell (inkl. zwischenmenschlich) Bio-physikalisch, Ökologisch Beispiele: Wasserrechtliche Genehmigung, Sortenzüchtung, -prüfung, Sortenzulassung, Zulassung von Pflanzenschutzmitteln, GVO

10	Wie gut wissen Sie über Anpassungsmaßnahmen für die Landwirtschaft Bescheid?	Welche Informationsquellen nutzen Sie, um sich über Anpassungsmaßnahmen im Sektor Landwirtschaft zu informieren? (aktive Informationssuche) Welche Informationsquellen nutzen Sie, die Anpassungsmaßnahmen im Sektor Landwirtschaft thematisieren? (passiver Informationserwerb) Wie zufrieden sind Sie mit den Ihnen zur Verfügung stehenden Informationen? Welche weiteren konkreten Informationen würden Sie für Ihren beruflichen Tätigkeitsbereich brauchen? (Informationsbedarf)	Institutionen (innerhalb der eigenen Institution, in anderen Institutionen), Herausgeber, Veranstalter, Betreiber (zB von Websites, Prognosediensten) Nützlichkeit der Informationen für die tägliche Arbeit Vertrauen in die Informationen (Unsicherheiten) Besser strukturierte und zugängliche Daten Räumlich explizite Informationen Daten zu Vulnerabilität/ Sozio-ökonomische Daten, Kosten (Nutzen) von Anpassungsmaßnahmen Best practice
III.	**Extremwetterereignisse**		
11	*Extremwetterereignisse können dem Sektor Landwirtschaft erheblichen Schaden zufügen.* Welche Extremwetterereignisse stellen aus Ihrer Sicht die größte Gefahr für die Landwirtschaft in der Region dar?		
12	Wie stark war die Landwirtschaft in Ihrer Region bisher von den genannten Extremwetterereignissen betroffen?	Wie häufig war die Region bisher von den genannten Extremwetterereignissen betroffen? Welche Auswirkungen auf die Landwirtschaft konnten Sie in Zusammenhang mit den genannten Extremwetterereignissen in der Region beobachten?	Auftrittshäufigkeit
13	Wie erwarten Sie, dass sich das Auftreten der genannten Extremwetterereignisse in der Region in Zukunft verändern wird?	Wie häufig könnten Ihrer Einschätzung nach die genannten Extremwetterereignisse in der Region in Zukunft auftreten? Welche Auswirkungen erwarten Sie davon auf die Landwirtschaft in der Region?	

14	Welche Maßnahmen haben LandwirtInnen in der Region bereits umgesetzt, um die Gefahren der genannten Extremwetterereignisse zu verringern?	Welche anderen Faktoren hatten Ihrer Einschätzung nach einen wichtigen Einfluss auf die Wahl der von Ihnen genannten Maßnahmen? Wie schätzen Sie das Kosten-Nutzen-Verhältnis der bereits umgesetzten Maßnahmen ein? Wie schätzen Sie die Auswirkungen bereits umgesetzter Anpassungsmaßnahmen auf andere Sektoren oder AkteurInnen ein?	
IV.	**Thematisierung von Klimaveränderungen in der Institution**		
15	*Ihre Institution unterstützt [zukünftige] LandwirtInnen bei der Entwicklung, Bewertung und Umsetzung von Maßnahmen, auch im Hinblick auf die Anpassungen an regionale Klimaveränderungen und Extremwetterereignisse.* Wie werden Klimaveränderungen innerhalb Ihrer Institution thematisiert?	Welche Themen werden diskutiert/nicht diskutiert? (innerhalb der Institution, mit anderen Institutionen, im Austausch mit der Klientel) Wie wichtig sind Klimaveränderungen und Anpassungsmaßnahmen im Vergleich zu anderen, tagesaktuellen Themen in Ihrer Institution? Inwieweit sind innerhalb Ihrer Institution Verantwortlichkeiten für die Themenbereiche festgelegt? Inwieweit entsprechen die verfügbaren Ressourcen (Arbeitszeit, finanzielle Ausstattung) den Aufgaben, Anforderungen und Zielen der Institution? Mit welchen Institutionen arbeiten Sie bei den Themen Klimaveränderungen und anpassungsrelevante Maßnahmen zusammen/noch nicht zusammen?	Klimaveränderungen Ursachen Auswirkungen Anpassungsmaßnahmen Vulnerabilität Information Konsultation Kooperation Gemeinsame Entscheidungsfindung

16	Welche Angebote und Leistungen stellt Ihre Institution bereit, um [zukünftige] LandwirtInnen bei der Anpassung an regionale Klimaveränderungen zu unterstützen?	Welche Informationen werden von den LandwirtInnen in der Region eingeholt, welche Angebote und Leistungen genutzt, um sich an regionale Klimaveränderungen anzupassen? Wie haben sich die Angebote und Leistungen Ihrer Institution im Hinblick auf regionale Klimaveränderungen entwickelt?	Information und Ausbildung Betriebsberatungen Finanzielle Anreize
V.	**Abschluss**		
17	*Wir haben jetzt ausführlich über die Region [Name] gesprochen. Ich möchte jetzt zum Abschluss kommen und noch drei Fragen stellen:* Wo sehen Sie im Sektor Landwirtschaft den größten Handlungsbedarf im Umgang mit Klimaveränderungen – in der Region [Name] und darüber hinaus?		
18	Welche Bedeutung haben aus Ihrer Sicht regionale Klimaveränderungen im Vergleich zu anderen Aspekten für die zukünftige Entwicklung der Landwirtschaft in der Region?		
19	Möchten Sie noch etwas zu den Themen regionale Klimaveränderungen oder anpassungsrelevanten Maßnahmen ergänzen, das wir bisher nicht angesprochen haben?		
20	Tipps für weitere InterviewpartnerInnen		

7.2 Perceived private climate change adaptation measures

Table 9 lists the private climate change adaptation measures that have been mentioned in the interviews in the case study regions Mostviertel and South-East Styria (SE-Styria). They have been categorized according to the adaptation intent. Furthermore, perceived drivers as well as on-farm and off-farm effects of private adaptation are described. Both, drivers and effects have been categorized (see sub-section 3.1.1 for further details). Please note that the drivers as well as the on-farm and off-farm effects were not systematically collected, i.e. they were not asked for each private climate change adaptation measure, meaning that Table 9 shows perceived drivers and effects that were mentioned in the interviews, though these perceptions are not comprehensive.

Table 9. Private climate change adaptation measures perceived in the case study regions as well as the perceived drivers and the perceived on-farm and off-farm effects.

Sector		Driver		Private climate change adaptation		Case study region		On-farm effect		Off-farm effect	
Main sector	Sub-sector	Main category	Sub-category	Private climate change adaptation measure	Adaptation intent	Most-viertel	SE-Styria	Category	Eval	Category	Eval
PC	Vini-Mana	Bio-physical internal Bio-physical external Socio-economic internal Socio-economic external	Climate change Farm characteristics Legal guidelines and regulations Local natural resources	Expansion of wine growing areas (e.g. to higher altitudes)	systemic	perc	perc				
PC	Vini-Mana			Earlier harvesting of grapes	incremental	perc	perc	Variable and fixed costs	0		
PC	Vini-Mana	Bio-physical internal	Local natural resources	Changes in grape species (red wine instead of white wine)	systemic	not rel	fut				
PC	Vini-Mana			Planting water-resistant vine stocks	systemic	n.m.	fut				
PC	Vini-Mana			Reduced pesticide input in vineyards (e.g. due to fewer fungal diseases)	incremental	n.m.	perc				
PC	Vini-Mana			Reduced tillage in vineyards	incremental	n.m.	perc				
PC	Vini-Wine			Reduced sugar inputs for wine making	incremental	n.m.	perc			Upstream sector	-
PC	Vini-Invest			Using hail protection nets in vineyards	incremental	perc	perc			Natural resources (landscape)	-

PC	Vini-Invest	Bio-physical external Socio-economic external	Climate change Market situtation and development Regional natural resources	Constructing water reservoirs	systemic	n.m.	perc			Natural resources (landscape)	-
PC	Vini-Invest			Investing in irrigation systems for wine production	systemic	n.m.	perc	Quality of agricultural products	+		
PC	Fruit-Mana			Expansion of fruit growing areas	systemic	perc	perc				
PC	Fruit-Mana	Bio-physical internal Bio-physical external	Regional natural resources Production process	Intensification in fruit production, loss of meadows with scattered fruit trees	systemic	perc	n.m.			Natural resources (landscape)	-
PC	Fruit-Mana			New species in fruit production (e.g. Aronia sp.)	systemic	n.m.	perc				
PC	Fruit-Mana			Mechanical weed control in orchards	incremental	n.m.	perc	Natural resources (water, biodiversity) Variable costs	+ +	Natural resources (biodiversity)	+
PC	Fruit-Mana			Reduced tillage in orchards	incremental	n.m.	perc				
PC	Fruit-Invest			Using hail protection nets in orchards	incremental	perc	perc			Natural resources (landscape)	-
PC	Fruit-Invest	Bio-physical external Socio-economic external	Climate change Market situtation and development Regional natural resources	Constructing water reservoirs	systemic	n.m.	perc			Natural resources (landscape)	-
PC	Fruit-Invest	Bio-physical internal Bio-physical external	Local natural resources Regional natural resources	Investing in sprinkling irrigation systems (e.g. for apples, elder): used for applying pesticides, irrigation water, and for protecting plants from frost	systemic	n.m.	perc	Quality of agricultural products	+		
PC	Fruit-Invest	Bio-physical external	Climate change	Investing in more stable trellis	incremental	n.m.	fut				
PC	For-Mana			Row density (wider distance between newly planted trees)	incremental	perc	n.m.				

PC	For-Mana			Controlled deforestation and maintaining protective forest	systemic	fut	n.m.	Quantity and quality of agricultural products Natural resources (soil)	+ +	Natural resources (soil)	+
PC	For-Mana	Socio-economic internal Socio-economic external	Farm characteristics Market situtaion and development	Controlled afforestation and changes in species composition, e.g. more diversified, species choice depending on altitude, natural regeneration, thermophilic tree species	systemic	perc	perc	Quantity and quality of agricultural products	+		
PC	For-Mana	Bio-physical internal Socio-economic internal	Local natural resources Demographic data Farm characteristics	Expansion of areas for Christmas trees and forests, e.g. in marginal areas	systemic	n.m.	perc				
PC	For-Mana	Bio-physical external	Climate change Distribution of wild plants and animals	Using mobile cranes for fighting insects, e.g. bark beetle	incremental	n.m.	fut				
PC	For-Mana			Collective action for fighting diseases	systemic	n.m.	fut				
FC	Mana-Till	Bio-physical internal Bio-physical external Socio-economic internal Socio-economic external	Farmer's characteristics Changes in society Legal guidelines and regulations Climate change Farm characteristics Local natural resources Regional natural resources Market situtaion Agricultural payments Availability of information infrastructure	Reduced tillage on cropland, e.g. mulch-till, no-till	incremental	perc	perc	Natural resources (soil, water, biodiversity) Variable and fixed costs	+ / - + / -	Natural resources (soil, water, air quality, climate)	+ / -

FC	Mana-Till	Bio-physical internal Bio-physical external Socio-economic internal Socio-economic external	Agricultural payments Climate change Local natural resources Changes in society Farmer's characteristics Availability of information infrastructure	Cultivating cover crops	incremental	perc	perc	Natural resources (soil, water) Human resources Variable costs	+ + -	Natural resources (landscape)	+
FC	Mana-Till			Strip tillage on cropland	incremental	perc	perc				
FC	Mana-Till	Bio-physical internal Bio-physical external Socio-economic internal Socio-economic external	Production process and management related aspects Local natural resources Regional natural resources Availability of technical infrastructure Agricultural payments Farmer's characteristics	Manuring	incremental	perc	fut				
FC	Mana-Till			Contour farming	incremental	fut	n.m.	Natural resources (soil)	+		
FC	Mana-Crop	Bio-physical internal Bio-physical externaly Socio-economic internal Socio-economic external	Production process and management related aspects Farm characteristics Lcoal natural resources Climate change Legal guidelines and regulations	Crop rotations, more diversity in crop choices	systemic	fut	perc	Natural resources (soil, climate) Quantity and quality of agricultural products Variable and fixed costs (physical capital)	+ + -	Natural resources (soil, landscape)	+
FC	Mana-Crop			Growing late maturing maize varieties (higher maturity groups)	incremental	perc	perc	Quantity of agricultural products	+		

FC	Mana-Crop	Bio-physical internal Bio-physical external Socio-economic external	Local natural resources Regional natural resources Production process and management related aspects Legal guidelines and regulations	Reduction in maize growing areas	systemic	fut	perc	Natural resources (soil) Variable costs	+ -	Natural resources (soil, landscape)	+
FC	Mana-Crop	Bio-physical internal Bio-physical external Socio-economic internal Socio-economic external	Climate change Farmer's characteristics Local natural resources Availability of technical infrastructure Regional natural resources Market situation and development Legal guidelines and regulations	Expansion of growing areas for winter crops, e.g. winter cereals	systemic	perc	perc	Quantity and quality of agricultural products Natural resources (water)	+ / - +	Natural resources (landscape)	+
FC	Mana-Crop	Bio-physcial external	Climate change	Expansion of growing areas for summer crops, e.g. spring barley	systemic	perc	fut				
FC	Mana-Crop	Bio-physical internal Bio-physical external Socio-economic external	Local climate conditions Climate change Availability of technical infrastructure Market situtaion and development Legal guidelines and regulations	Expansion of growing areas for thermophilic crops, e.g. soybean, millet	systemic	perc	perc	Quantity and quality of agircultural products	+ / -	Natural resources (landscape)	+

FC	Mana-Crop	Bio-physical internal Bio-physical external Socio-economic external	Production prcoess and management related aspects Climate change Market situtation and development	Expansion of growing areas for drought resistant crops	systemic	fut	fut		
FC	Mana-Crop			Expansion of growing areas for crops that can withstand droughts and humidity	systemic	fut	n.m.		
FC	Mana-Crop	Bio-physical external Socio-economic external	Agricultural policies Climate change	Expansion of growing areas for legumes production	systemic	perc	perc		
FC	Mana-Crop	Bio-physical internal	Production process and management related aspects	Exapansion of forage production on cropland, e.g. silage maize, clover	systemic	fut	fut	Quantiy of agricultural production	+
FC	Mana-Crop	Bio-physical internal Bio-physical external Socio-economic internal Socio-economic external	Agricultural payments Farmer's characteristics Production process and management related aspects Market situation and development Regional natural resources Climate change Availablity of technical infrastructure	Increase in crop diversity, cultivating 'new' crops (e.g. flax in Mostviertel; rice, spelt, melon in SE-Styria)	systemic	fut	fut	Variable and fixed costs Natural capital (biodiversity)	+ / - +
FC	Mana-Crop	Bio-physical external Socio-economic external	Market situation and development Climate change	Decrease in sugar beet, decrease in onions	systemic	perc	n.m.		
FC	Mana-Crop			Decrease in crops with high water demand	systemic	n.m.	fut		
FC	Mana-Crop	Bio-physical external	Climate change	Avoiding row crops on steep slopes	incremental	n.m.	fut		

FC	Mana-Crop			Dry areas are not cultivated any more, especially if irrigation water supply cannot be ensured	systemic	n.m.	fut				
FC	Mana-Crop	Socio-economic internal	Famers' characteristics	Double cropping, e.g. cereal and buckwheat	systemic	n.m.	fut				
FC	Mana-Cultiv	Bio-physical external Socio-economic external	Agricultural policies and public payments Regional natural resources Climate change	Changes in timing of cultivation (sowing, harvesting) e.g. sowing and harvesting of maize and pumpkin is about 2-3 weeks earlier, compared to 30 years ago e.g. sowing is about 1-2 weeks earlier in the Mostviertel region, compared to 30 years ago	incremental	perc	perc	Quantity and quality of agricultural products Variable costs Natural resources (water)	+ / - + +		
FC	Mana-Cultiv			Re-seeding after extreme precipitation events	incremental	n.m.	perc				
FC	Mana-Cultiv	Bio-physical external	Climate change	Misting maize in order to improve germination	incremental	n.m.	fut				
FC	Mana-Fertil	Socio-economic internal Socio-economic external	Market situation and development Farm characteristics	Intensification on cropland	incremental	perc	perc				
FC	Mana-Fertil	Bio-physical external	Climate change	Improved fertilizer management (incl. liquid manure), e.g. changes in timing of fertilizer input	incremental	perc	fut			Natural resources (water, climate, air)	+
FC	Mana-Fertil	Bio-physical internal Bio-physical external	Climate change Production process and management related aspects Local natural resources	Extensification, expansion of fallow land	systemic	fut	fut	Variable costs	+ / -		
FC	Mana-Fertil	Socio-economic external	Market situation and development	Organic farming	transformational	perc	perc	Human resources	+		
FC	Mana-Pest	Bio-physical external Socio-economic external	Regional natural resources Social pressure	Changes in pest management on cropland, e.g. more precise (Mostviertel)	incremental	perc	perc	Variable costs Quantity and quality of agricultural products	+ +		

FC	Mana-Gen	Bio-physical internal Bio-physical external	Climate change Local natural resources	Expansion of cropland to areas with currently high precipitation sums	systemic	fut	fut	Natural resources (soil)	-	Natural resources (soil)	-
FC	Mana-Gen	Bio-physical internal Socio-economic internal Socio-economic external	Market situation and devleopment Local natural resources Farm characteristics Farmer's characteristics	Humus management, humus formation	incremental	perc	perc	Natural resources (soil, water) Variable costs	+ +	Natural resources (water, climate)	+
FC	Mana-Gen			Soil tests	incremental	perc	perc	Natural resources (soil)	+		
FC	Mana-Gen			Downsizing fields	incremental	fut	n.m.	Natural resources (soil) Variable costs	+ -	Natural resources (soil)	+
FC	Mana-Gen			Enlarging fields	incremental	perc	n.m.	Natural resources (soil)	-	Natural resources (soil)	-
FC	Mana-Gen	Bio-physical external	Climate change	Ploughing dried crops back instead of cost-intensive harvesting (e.g. maize)	incremental	perc	n.m.				
FC	Mana-Gen	Bio-physical external	Climate change	Cloud seeder	incremental	n.m.	perc	Quantity and quality of agricultural products	+		
FC	Mana-Gen			Using machinery co-operations	incremental	perc	perc	Variable costs	-		
FC	Mana-Gen	Bio-physical external Socio-economic external	Regional natural resources Agricultural payments	Maintaining landscape elements (e.g. hedges)	systemic	perc	n.m.	Natural resources (biodiversity, landscape, climate) Variable costs	+ -	Natural resources (landscape, biodiversity, microclimate)	+
FC	Mana-Gen			Renaturation of rivers, reducing agricultural use in flood plains	systemic	perc	n.m.	Natural resources (soil, water, landscape)	+	Natural resources (water, landscape)	+
FC	Mana-Gen			Drainage systems	systemic	fut	n.m.	Natural resources	-		

FC	Invest	Socio-economic internal Socio-economic external	Legal guidelines and regulations Market situation and development Farm characteristics	Investing in storing capacities (e.g. silo for millet)	systemic	n.m.	perc	Variable costs	-		
FC	Invest	Bio-physical external Socio-economic external	Climate change Market sitution and development Regional natural resources	Constructing water reservoirs, e.g. collecting water from drainage systems, channeling water from rivers at a time with high runoff, channeling water from groundwater at a time with high water reserves	systemic	n.m.	fut	Natural resources (water, landscape) Variable and fixed costs	+ / - -	Natural resources (water, landscape) Upstream sector	+ / - +
FC	Invest	Bio-physical internal Bio-physical external Socio-economic external	Production process and management related aspects Local natural resources Regional natural resources Climate change Legal guidelines and regulations	Investing in irrigation of special crops (main crops, special crops)	systemic	perc / fut / not rel	perc / fut / not rel	Variable and fixed costs	-	Upstream sector Natural resources (water)	+ -
FC	Invest			Investing in water-saving technologies for irrigation	incremental	n.m.	fut				
FC	Invest			Investing in precision farming	systemic	n.m.	fut	Variable costs	+		
FC	Invest			(Joint) investment in 'new' technology	systemic	n.m.	perc	Fixed costs	+		
FC	Invest			Leasing 'new' machinery	incremental	perc	perc				
FC	Invest	Bio-physical internal Socio-economic external	Local natural resources Legal guidelines and regulations	Drying plant	incremental	n.m.	perc				
GRAS	Mana			Reseeding to improve drought resistance	incremental	fut	fut	Natural resources (biodiversity)	+	Natural resources (biodiversity)	+

GRAS	Mana	Bio-physical internal Bio-physical external	Local natural resources Local climate conditions Climate change Production process and management related aspects	Changes in timing of grassland cuts	incremental	not rel	perc				
GRAS	Mana	Socio-economic external	Agricultural payments	Intensification in grassland production	incremental	perc	n.m.	Variable costs	-		
GRAS	Mana	Bio-physical external	Climate change	Increasing number of grassland cuts	incremental	perc	perc	Quantity and quality of agricultural products	-		
GRAS	Mana			Reduced number of grassland cuts	incremental	n.m.	perc				
GRAS	Mana	Bio-physical external	Production process and management related aspects	Decrease in diversity on grassland	incremental	perc	n.m.				
GRAS	Mana	Socio-economic external	Market situation and development	Organic production	transformational	perc	n.m.				
GRAS	Mana	Socio-economic external	Availability of technical infrastructure	Blowers (instead of raking)	incremental	not rel	perc	Natural resources (climate)	-		
GRAS	Mana	Socio-economic external	Agricultural payments	Preserving grassland	systemic	n.m.	fut			Natural resources (biodiversity)	+
GRAS	Mana	Socio-economic external	Market situation and development	Conversion of grassland to cropland	systemic	n.m.	perc			Natural resources (biodiversity)	-
GRAS	Mana			Leasing of grassland areas	systemic	n.m.	perc				
LIVE	Mana	Bio-physical external Socio-economic internal	Farm characteristics Regional natural resources	Purchasing hay, silage or other forage	incremental	perc	perc	Variable costs	-		
LIVE	Mana	Socio-economic internal	Farm characteristics	Using marginal areas for deriving feed (e.g. waysides)	incremental	fut	n.m.				
LIVE	Mana		Farm characteristics	Storage of hay and silage	incremental	perc	n.m.				
LIVE	Mana			Using substitutes for hay and silage	incremental	perc	n.m.				
LIVE	Mana			Reducing the number of livestock	incremental	perc	perc				

LIVE	Mana	Socio-economic external	Market situation and delevoment	Grain maize is silaged (and not sold) in addition to silage maize	incremental	perc	n.m.	Variable costs	+		
LIVE	Mana	Socio-economic external	Agricultural policies and public payments	Using national protein sources	incremental	perc	perc	Variable costs	-	Natural resources (climate)	+
LIVE	Mana			Using protein sources from abroad	incremental	n.m.	perc	Variable costs	+		
LIVE	Mana	Bio-physical internal Socio-economic external	Production process and management related aspects Legal guidelines and regulations	Adjusting feeding ratios	incremental	fut	perc	Fixed costs	-	Natural resources (air quality)	+
LIVE	Mana	Bio-physcial external	Regional natural resources	Intensive livestock production, increase in stocking density	incremental	perc	perc	Variable costs	-	Natural resources (air quality)	-
LIVE	Mana			Quality instead of quantity	systemic	n.m.	fut				
LIVE	Mana	Socio-economic external	Market situation and delevoment	Organic production	transformational	n.m.	not rel				
LIVE	Graz			Providing additional feed for grazing animals	incremental	perc	n.m.				
LIVE	Graz			Herding animals 2-3 weeks earlier to alpine pastures	incremental	n.m.	perc				
LIVE	Graz			Returning animals from the alpine pastures into the valley in later autumn	incremental	fut	n.m.	Quantity and quality of agricultural products	+		
LIVE	Invest	Bio-physical internal Bio-physical external Socio-economic internal Socio-economic external	Local natural resources Climate change Legal guidelines and regulations Availability of technical infrastructure Market situation and development Farmer's characteristics	Stable construction: simple open stables, sheds, pens	systemic	perc	perc	Fixed costs	-		
LIVE	Invest			Stable construction: closed stables	systemic	not rel	perc	Fixed costs	-		

LIVE	Invest			Location of stables, e.g. in areas not prone to floods, mudflows	systemic	fut	n.m.				
LIVE	Invest	Bio-physical internal Bio-physical external Socio-economic internal Socio-economic external	Climate change Legal guidelines and regulations Market situation and development Farm characteristics Production process and management related aspects	Air-cooling in stables, e.g. ventilation, sprinkler	incremental	perc	perc	Quantity and quality of agricultural products Variable and fixed costs	+ -	Natural resources (climate, air quality) Upstream sector	+ +
LIVE	Invest			Solar cooling of stables	incremental	n.m.	fut				
LIVE	Invest	Bio-physcial external	Climate change	Isolation in stables	incremental	n.m.	perc	Variable costs	-		
LIVE	Invest	Bio-physcial external	Climate change	Slatted floor instead of straw	incremental	n.m.	perc			Upstream sector	+
LIVE	Invest	Bio-physical internal Socio-economic external	Local natural resources Public payments	Photovoltaic modules on stables	incremental	n.m.	perc	Natural resources (climate)	+		
NO-AG		Socio-economic internal Socio-economic external	Market situation and development Farmer's characteristics Farm characteristics	Direct marketing, offering niche products	transformational	perc	fut	Human resources Variable costs	+ -		
NO-AG		Socio-economic internal Socio-economic external	Market situation and development Farmer's characteristics Farm characteristics	Tourism	transformational	perc	fut				
NO-AG				Care of elderly	transformational	n.m.	fut				

STRAT	Bio-physical internal Socio-economic internal Socio-economic external	Production process and management related aspects Availability of technical infrastructure Market situation and development Farm characteristics	Structural change (e.g. enlarging farmland area per farm by lease or purchase, flattening and draining farmland, removing landscape elements, mechanization)	transformational	perc	perc	Variable costs Natural resources (landscape, biodiversity)	- 0	Natural resources (biodiversity)	0
STRAT	Socio-economic external	Availability of technical infrastructure	Professionalization (e.g. larger and more professional stables)	systemic	n.m.	perc				
STRAT			Smaller structures (e.g. smaller farmland area per farm, primary production & processing)	transformational	fut	n.m.	Variable and fixed costs Natural resources (soil, landscape, biodiversity, microclimate)	+ / - +	Natural resources (soil, climate, landscape) Upstream sector	+ +
STRAT	Bio-physical internal Bio-physical external Socio-economic external	Climate change Production process and management related aspects Market situation and development	Diversification	transformational	fut	n.m.				

STRAT		Bio-physical internal Bio-physical external Socio-economic internal Socio-economic external	Climate change Legal guidelines and regulations Market situation and development Farm characteristics Famers' characteristics Production process and management related aspects Agricultural payments Local natural resources	Farm withdrawal, leasing farmland	transformational	perc	perc	Natural resources (landscape) Human resources	0 -	Natural resources (landscape) Human resources	0 -
STRAT		Socio-economic internal Socio-economic external	Farm characteristics Market situation and development	Low input farming, organic farming	systemic	perc	perc	Natural resources (soil, biodiversity)	+ / -	Natural resources (climate)	+
STRAT				Intensification	incremental	perc	perc				
STRAT		Socio-economic internal Socio-economic external	Farm characteristics Legal guidelines and regulations Agricultural payments Market situation and development	Change in farm type, e.g. withdrawal of livestock production	transformational	n.m.	perc			Upstream sector	0
STRAT		Bio-physical external Socio-economic external	Market situation and development Climate change Legal guidelines and regulations	Part-time farming instead of full-time farming	transformational	n.m.	perc				
FIN	Mana	Socio-economic external	Market situation and development Legal guidelines and regulations	Delaying investments	incremental	perc	perc				

FIN	Mana	Bio-physical external Socio-economic external	Climate change Market situation and development	Risk management, risk splitting	systemic	fut	n.m.		
INFR	Fin	Socio-economic internal	Farm characteristics	Hail insurance	incremental	perc	perc		
INFR	Fin	Socio-economic internal	Farm characteristics	Crop insurance (e.g. drought, heat)	incremental	fut	perc / fut	Variable costs	-
INFR	Fin			Grassland insurance	incremental	fut	perc		
INFR	Fin	Socio-economic internal	Farm characteristics	Market observation	incremental	fut	perc		
INFR	Fin	Socio-economic internal	Farm characteristics	Futures	incremental	fut	n.m.		
INFR	Fin			Disaster fund	incremental	perc	perc		
INFR	Fin			Investment incentives, subsidized credits (e.g. for stable construction, irrigation systems)	systemic/ transformational	perc			
INFR	Info			Using yield predictions	incremental	fut			

Legend

Sector

PC	Permanant crops
FC	Field crops
GRAS	Grasland
LIVE	Livestock
NO-AG	Non-agricultural secondary activities
STRAT	Strategic orientation of the farm
FIN	Financial management
INFR	Infrastructure use

Sub-sector

Vini-Mana	Viniculture - Management decisions
Vini-Wine	Viniculture - Wine making decisions
Vini-Invest	Viniculture - Investment decisions
Fruit-Mana	Fruit growing - Management decisions
Fruit-Invest	Fruit growing - Investment decisions
For-Mana	Forestry - Management decisions
Mana-Till	Management decisions - Tillage
Mana-Crop	Management decisions - Crop and cultivar choice
Mana-Cultiv	Management decisions - Cultivation and harvesting
Mana-Fertil	Management decisions - Fertilization
Mana-Pest	Management decisions - Pest management
Mana-Gen	Management decisions - General
Invest	Investment decisions
Mana	Management decisions
Graz	Grazing animals
Fin	Financial infrastructure
Info	Information infrastructure

Regional perception

perc	perceived in the case study region
not rel	not relevant in the case study region
fut	relevant in the future
n.m.	not mentioned in the interviews

Evaluation of on-farm and off-farm effects, mentioned in the interviews

+	positive evaluation
-	negative evaluation
+ / -	positive and negative evaluation
0	neutral evaluation