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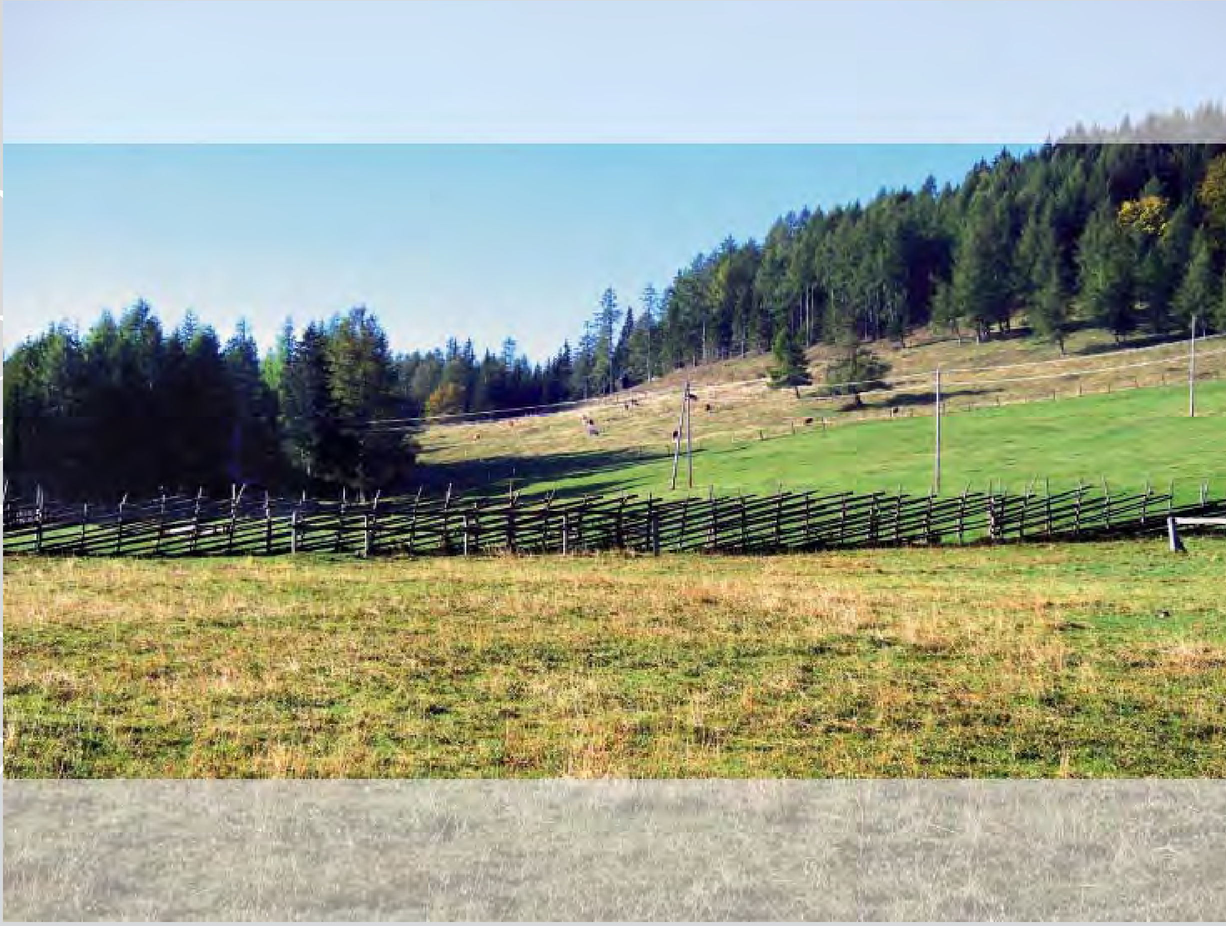
Klaus Wagner, Julia Neuwirth, Hubert Janetschek

Agriculture and the Threat of Water Scarce in Alpine Regions

Final report of the research project AWI/165/09 EU,
a sub-project of the EU Alpine Space project "Alp Water Scarce", 5-1-3-F
Abschlussbericht zum Forschungsprojekt AWI/165/09 EU,
Teilprojekt des EU Alpine Space Projektes "Alp Water Scarce", 5-1-3-F



BUNDESANSTALT für Agrarwirtschaft

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Klaus Wagner
Julia Neuwirth
Hubert Janetschek

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Wien, 2012

Content

Tables

Figures

Preface

This study was conducted within the EU Alpine Space Project "Alp Water Scarce" under the coordination of the Mountain Institute, University Savoy. The project "Alp Water Scarce" investigated into water supply and water demand of alpine regions regarding the expected changing climatic conditions. In a sub-study, the Federal Institute of Agricultural Economics assessed the vulnerability of agricultural systems within alpine pilot-sites via a set of developed indicators. Furthermore, agricultural-political measures were analysed regarding their effects on the water consumption of agriculture. Based on these assessments region-specific recommendations for the adaption of agricultural systems towards a possible threatening water scarce due to climatic changes were developed. The realisation of this study within the broader context of the EU Alpine Space Project enabled an interdisciplinary perspective which could take into account the extensive area of water management and could stress the major influences of agriculture on regional water management. A recent study by the Commission on Sustainable Agriculture and Climate Change stated that regarding the effects of climatic changes and the increasing food demand it is of extreme importance to think about long-term adaptation of agriculture in order to secure food supply. Special thanks go to the project coordinators from Savoy University for the considerate and successful conduction of the project and all the other project partners for fruitful discussions.

Vorwort

Die vorliegende Studie wurde im Rahmen des EU Alpine Space Projektes Alp Water Scarce unter Koordination des Mountain Institutes der Universität Savoyen durchgeführt. Das Gesamtprojekt untersucht das Wasserangebot und den Wasserverbrauch in alpinen Regionen unter den zu erwartenden Klimabedingungen. Im Teilprojekt der Bundesanstalt für Agrarwirtschaft wurden Empfindlichkeitsabschätzungen für das Agrarsystem in alpinen Pilotregionen anhand eines entwickelten Indikatorsets durchgeführt und agrarpolitische Maßnahmen auf ihre Wirkung hinsichtlich des Wasserverbrauches in der Landwirtschaft analysiert. Auf dieser Basis wurden regionsspezifische Empfehlungen zur Anpassung des Agrarsystems an eine mögliche drohende Wasserverknappung infolge des Klimawandels erarbeitet. Die Einbettung in das EU Projekt mit dem breiten Bearbeitungsrahmen des gesamten Wassermanagements ermöglichte einen interdisziplinären Ansatz, bei dem die wichtige Rolle der Landwirtschaft im regionalen Wassermanagement verdeutlicht werden konnte. Wie auch jüngst in einer Analyse der Kommission für Nachhaltige Landwirtschaft und Klimawandel festgestellt wurde, sind langfristige Anpassungen der Landwirtschaft wichtig, um die Versorgungssicherheit mit Nahrungsmitteln bei steigendem Bedarf und unter Klimawandelbedingungen zu gewährleisten. Besonders zu danken ist den Projektkoordinatoren der Universität Savoyen für die umsichtige und erfolgreiche Abwicklung des Gesamtprojektes sowie allen anderen Projektpartnern für wertvolle Diskussionen.

Dr. Hubert Pfingstner, Direktor

Conclusions and recommendations

The report of the Intergovernmental Panel on Climate Change (IPCC 2007), which serves as the underlying framework of the Alp-Water-Scarce project, stresses the important role of research and development policies, institutional reforms, land tenure and reform, training and capacity building, and financial incentives, e.g. insurance systems, in coping with climate change.

For the agricultural sector, the Commission of the European Communities in 2009 provided the orientation for an adaptation strategy:

- More sustainable use of resources to build up resilience towards climate change;
- strengthening the role of agriculture as a provider of ecosystem services;
- enhancing the resilience of agricultural infrastructure;
- improving the adaptive capacity of farmers;
- facilitating co-operation between EU member states;
- enhancing research on climate and agriculture;
- developing vulnerability indicators

(Commission of the European Community 2009).

The difficult situation of addressing sustainability and environmental concerns in times of economic crisis is made evident in the recommendations of the Austrian Ministry of Agriculture, Forestry, Environment and Water Management for the Initiative Agriculture 2020 (BMLFUW 2010c), where the focus is placed on economic issues (market regulations, income and competitiveness). But there is also a strategy for adaptation to climate change (Lebensministerium 2011a, 2011b) which gives recommendations for various sectors including agriculture.

When regarding effects of climatic changes on water Scarce, it is important to consider the various cross-effects, not only on local or regional scale but also on a global scale. Developments related to demographics, the changing climate and the supply of food and energy to the global market increase conflicts in reaching predefined goals and in the use of natural resources. As a result, the stress on resources in regions that are not directly affected by such conflicts increases likewise (Balas 2010). Due to regional differences climate change preventive measures against water scarce are not universally applicable. General measures concern soil stability, its structure and its water-saving potential. In order to avoid erosion and land degradation and to maintain the potential for production, a stable and adapted land cover and adequate land use is necessary. With respect to the increasing food demand the Commission on Sustainable Agriculture and Climate Change (2011) affirmed the importance of adapting agriculture to changing climatic conditions.

General recommendations of the Alp Water Scarce project

Common to all recommendations elaborated within the general Alp-Water-Scarce project is the need to preserve the water resources of the Alps for future generations, to meet the increasing water demand and to cope with the climate change-induced stress on resources. An institutional willingness for regional, national and transalpine cooperation, as well as a common understanding of the terms “water scarce” and “drought,” are the preconditions for implementing long-term measures to tackle water scarce. Viviroli et al. (2010) conclude that there is a strong need for promoting research and the exchange of knowledge with practitioners. This is why in the Alp-Water-Scarce project the resulting recommendations have been worked out in cooperation between the Federal Institute of Agricultural Economics and experts for water management in the Alps, using a transdisciplinary and participatory approach (Alp-Water-Scarce 2011).

The measures elaborated in the general and transdisciplinary Alp-Water-Scarce project comprise early warning systems for water scarce, which have been developed as a framework for a set of specifically focused measures in four pilot sites (Arly, Carinthia, Piave and Slovenia). A short term crisis management is recommended, one that builds on forecasts and the quick and efficient implementation of measures to prevent scarcity. It includes adaptation in the face of longer and more frequent periods of water shortage. The approach for meeting future water demands is based on precise investigation of the development of future water resources and future water demand using data sharing methods, the development of scenarios and the integration of all sectorial and regional stakeholders in order to avoid conflicts between agriculture, tourism, industry, energy production, drinking water supply and ecological requirements. To raise consciousness for possible water scarce, such integration requires profound information of the various different stakeholders. Interregional and transboundary co-operation may lead to further potential for conflicts, which can only be overcome by more intensive co-operation and joint agreements. In addition to the existing agreements for major river basins like the Danube, Elbe, Rhine and others, agreements for smaller catchments should also be concluded. These efforts on a political level must be complemented by technical solutions, for example:

- The increase of storage capacities of dams and drinking water reservoirs in a manner compatible with ecological considerations;
- increase of the efficiency of existing infrastructure;
- establishment of water-saving technologies;
- optimisation of water re-use opportunities

(Alp Water Scarce 2011).

Agricultural recommendations of the Alp Water Scarce project

Agricultural adaptation strategies to climate change and water scarce must take into account socio-economic constraints that vary widely depending on production systems, types of cultivation and the competitive situation with other sectors regarding water consumption. With respect to those varying regional and structural conditions the mapping of vulnerable areas, hazard assessments, forecasting and appropriate spatial planning should serve as a basis to develop strategies. Especially in the case of agriculture, implementing measures is easier if adaptation goals are already integrated on a high level directly within the Common Agricultural Policy (CAP). The EU Commission’s proposal for the CAP until 2020 provides a topic of risk management in pillar I. The greening component which might become connected to the direct payments could also have indirect effects on water consumption. As in the previous period, pillar II includes more water relevant measures. In the new proposal for the rural development regulation, knowledge transfer and advisory services play an important role, and improving water management and increasing efficiency in water use by agriculture are explicit priorities (European Commission 2011b, article 5) . The former agri-environment payments now are called agri-environment-climate payments, which may offer new possibilities to react to climate change, but measures against water scarce are not mentioned directly. Water saving only becomes a topic, if new investments for irrigation are made. (European Commission 2011b, article 46).

The developed indicator set which estimates water scarce vulnerability of the agricultural system has been analysed for selected Alp Water Scarce pilot sites in order to represent a broad range of present and future water-scarcity vulnerability patterns for agriculture. The present situation shows a relatively higher vulnerability of water scarce due to land use and livestock in the eastern sites of Austria and Slovenia, for example within Steirisches Randgebirge, Koralpe and Dravsko-Ptujsko. The western and southern sites of France, Slovenia and Italy, e.g. Tarentaise, Scrivia, Noce, Julian Alps, are characterised by relatively worse soil and climate conditions. Especially the Italian regions even now greatly rely on irrigation.

Especially **agricultural short-term measures**, designed to mitigate future water scarcity - like those related to land-, livestock-, farm management, or technical facilities - may be strengthened by including them in regional-specific rules of good agricultural practice or agri-environmental programmes. Short term measures may serve various objectives. They save water, reduce the contamination with pesticides, reduce leaking of nutrients, decrease erosion, and contribute to biodiversity, amenity and structures of landscapes.

Agricultural long-term measures – such as improving land-use and livestock structures towards more efficient and water saving systems – can only be implemented by including them in long-term strategies, objectives and programmes. In order to achieve this, they need to be positioned at the highest level of EU CAP strategies, as already proposed for the CAP until 2020, within pillar 2 and objective 2 (European Commission 2010) but must also extend down to the regional and local level.

Nevertheless, changes in crop rotation systems, as well as other developments leading towards less intensive and less water-consuming land use and livestock, affect the economic output of agriculture significantly. In addition, the effects on water consumption always need to be weighed up against the effects on other sectors of the regional economy, and on the environment and landscape. The present trends of lower economic growth and higher stress on public budgets, and on the energy and food markets, necessitate a thorough and regional-specific analysis in order to find the best balance between long-term water consumption and sustainable, efficient agricultural production. The estimation of the recent G20 agricultural ministers' declaration (G20 2011), that food production needs to increase by 70 % by 2050 should also be taken into account.

Our economic analyses of selected water-saving measures demonstrate the significant influence of the market situation. Thus, changing crop rotations to water-saving variants often has the consequence of considerable economic disadvantages for farmers. Land management measures are easier to achieve and their implementation is not always clearly negative from an economic point of view – for example, alternative soil treatment techniques. Irrigation is an option only for regions with sufficient ground water supplies, and for crops with high gross margins and a beneficial market situation. When facing long periods of water scarce, the sustainability of artificial irrigation is questionable. Weather risk-management measures (i.e. insurance systems) help to reduce the economic risk for farmers, but it is not sure that they can operate without public assistance and support; therefore they do not seem to be a sustainable long-term option within a climate change scenario.

Project web page: www.alpwaterscarce.eu

Ergebnisse und Empfehlungen

Der Bericht des Zwischenstaatlichen Ausschusses für Klimaänderungen (IPCC 2007), der den Rahmen zum Alp-Water-Scarce Projekt bildet, betont im Umgang mit dem Klimawandel und dessen Folgen die wichtige Rolle der Forschung, der Entwicklungspolitik, institutioneller Reformen und von Reformen der Grundbesitzstrukturen. Des Weiteren empfiehlt er verstärkte Bemühungen im Bereich der Weiterbildung institutioneller Kapazitäten sowie verstärkte finanzielle Anreize, unter anderem auch bei Versicherungssystemen.

Im Jahr 2009 gab die Europäische Kommission einen Leitfaden für eine Anpassungsstrategie des Agrarsektors heraus, der folgende Punkte betonte:

- nachhaltige Nutzung von Ressourcen, um durch Resilienz dem Klimawandel vorzubeugen;
- Stärkung der Agrarwirtschaft als Lieferant von Ökosystemleistungen;
- Verbesserung der Stabilität von Agrar-Infrastrukturen;
- Verbesserung der Anpassungsfähigkeit von Landwirtinnen und Landwirten;
- Förderung der Kooperation zwischen den EU Mitgliedsstaaten;
- Förderung der Klima- und Agrarforschung;
- Entwicklung von Vulnerabilitätsindikatoren.

(Europäische Kommission 2009)

Wie schwierig es ist, in Zeiten der Wirtschaftskrise Nachhaltigkeits- und Naturschutzthemen in den Mittelpunkt zu stellen, wird in den Empfehlungen des österreichischen Lebensministeriums zum Unternehmen Landwirtschaft 2020 (BMLFUW 2010c) offensichtlich, in welchen ökonomische Themen wie Marktregulierung, Einkommen und Wettbewerbsfähigkeit dominieren. Kürzlich wurde jedoch auch eine österreichische Strategie zur Anpassung an den Klimawandel veröffentlicht (Lebensministerium 2011a, 2011b), die Empfehlungen für verschiedenste Sektoren, darunter auch die Landwirtschaft, ausspricht.

Betrachtet man die Auswirkungen des Klimawandels auf eine eventuell drohende Wasserknappheit, muss man die unterschiedlichen grenzübergreifenden Wirkungen nicht nur auf lokaler oder regionaler Stufe, sondern auch auf globaler Ebene berücksichtigen. Demografische Entwicklungen, der Klimawandel und die Globalisierung in der Nutzung von Nahrungsmittel- und Energieressourcen erzeugen Ziel- und Nutzungskonflikte. In Folge dessen steigt auch der Druck auf die natürlichen Ressourcen solcher Regionen, welche nicht direkt von diesen Konflikten betroffen sind (Balas 2010). Aufgrund der regional unterschiedlichen Auswirkungen des Klimawandels sind präventive Maßnahmen gegen Wasserknappheit nicht universell einsetzbar. Generelle Maßnahmen betreffen die Struktur und die Stabilität des Bodens und seines Wasserrückhaltevermögens. Des Weiteren ist in jedem Fall eine stabile und angepasste Landbedeckung und Landnutzung notwendig, um Erosion und Bodendegradation zu vermeiden und das Potential für die landwirtschaftliche Produktion zu erhalten. Die Kommission für Nachhaltige Landwirtschaft und Klimawandel (2011) hat auf die besondere Wichtigkeit hingewiesen, die Landwirtschaft an den steigenden Nahrungsmittelbedarf unter schwierigen Klimawandelbedingungen anzupassen.

Generelle Empfehlungen des Alp Water Scarce Projektes

Alle durch das Alp-Water-Scarce Projekt ausgearbeiteten Empfehlungen betonen, dass die Wasserressourcen der Alpen für zukünftige Generationen erhalten bleiben müssen, dass der wachsende Wasserbedarf gedeckt werden muss und dass der richtige Umgang mit einem durch den Klimawandel bedingten erhöhten Druck auf die natürlichen Ressourcen gefunden werden muss. Der institutionelle Wille für regionale, nationale und transalpine Kooperation und das gemeinsame Verständnis der Begriffe „Wasserknappheit“ und „Trockenheit“ sind Voraussetzungen, um langfristige Maßnahmen gegen eine drohende Wasserknappheit zu implementieren.

Die im transdisziplinären Alp-Water-Scarce Projekt ausgearbeiteten Maßnahmen beinhalten unter anderen auch Frühwarnsysteme für Wasserknappheit. Sie wurden in Form von Rahmenvorgaben für eine Reihe von speziellen Maßnahmen in vier verschiedenen Pilot-Regionen (Arly, Piave, Kärnten, Slowenien) entwickelt. Ein vorausschauendes und schnell agierendes Krisen Management System, welches die effiziente Implementierung von Maßnahmen gegen Wasserknappheit möglich macht, wird empfohlen. Dies beinhaltet eine flexible Anpassung des Systems an die drohenden häufigeren und längeren Perioden der Wasserknappheit. Es beruht auf detaillierten Untersuchungen der Entwicklung der zukünftigen Wasserressourcen und des zukünftigen Wasserbedarfes. Die Recherchen wurden auf der Basis von Datenverbünden, der Entwicklung von Szenarien und der Integration aller sektoralen und regionalen Akteure durchgeführt, um Konflikte zwischen der Landwirtschaft, dem Tourismus, der Industrie, der Energieproduktion, der Trinkwasserversorgung und des Naturschutzes zu vermeiden. Auch das Bewusstsein der Akteure und Entscheidungsträger um diese potenziellen Konflikte muss gestärkt werden. Notwendige interregionale und grenzübergreifende Kooperationen beinhalten möglicherweise weiteres Konfliktpotenzial, welches jedoch nur mit Hilfe von intensiveren Kooperationen und weiteren Vereinbarungen lösbar ist. Zusätzlich zu den bereits bestehenden Abkommen für große Einzugsgebiete wie z.B. jene der Donau, der Elbe, des Rhein, sollten auch Vereinbarungen für kleinere Einzugsgebiete getroffen werden. Technische Lösungen, wie z.B. die Erhöhung von Speicherkapazitäten von Dämmen und Trinkwasserreservoirs, sind zu überdenken, wenn dies mit ökologischen Aspekten zu vereinbaren ist. Eine verbesserte Effizienz von bereits bestehender Infrastruktur, wassersparende Technologien und Optimierung der Wasserwiederverwertung, sollten die Bemühungen auf Organisations- und Managementebenen begleiten (Alp Water Scarce 2011).

Landwirtschaftliche Empfehlungen des Alp Water Scarce Projektes

Die Anpassung der Landwirtschaft an den Klimawandel und an die drohende Wasserknappheit sollte sozio-ökonomische Bedingungen miteinbeziehen, welche je nach Produktionssystem, Art der Bewirtschaftung und der Konkurrenz um Wasser mit anderen Sektoren stark variieren. Zur Erreichung dieses Ziels sollten die Kartierung sensibler Gebiete, die Entwicklung von Frühwarnsystemen und eine angepasste Raumplanung beitragen. Es ist leichter, Maßnahmen umzusetzen, wenn die entsprechenden Ziele bereits auf einer hohen Ebene wie z.B. der Gemeinsamen Agrarpolitik (GAP) der EU integriert und formuliert sind. Die Vorschläge der Europäischen Kommission für die GAP bis 2020 enthalten Themen des Risikomanagements in Säule

1, ebenso könnte die Ökologisierungskomponente positive Auswirkungen auf eine Senkung des Wasserverbrauches bringen. Wie auch schon in der vorherigen Periode, beinhaltet Säule 2 der GAP mehr Maßnahmen mit Bezug auf den Wasserschutz. Im neuen Vorschlag haben die Verbesserungen des Wassermanagements und die effizientere Wassernutzung durch die Landwirtschaft explizite Priorität (Europäische Kommission 2011b, Artikel 5). Ebenso wird den Beratungseinrichtungen und dem Transfer von Wissen im Programm der ländlichen Entwicklung eine wichtige Rolle zugeordnet. Die einstigen Agrar-Umweltmaßnahmen werden in Agrar-Umwelt-Klima-Maßnahmen umbenannt, wobei eventuell neue Möglichkeiten entstehen, um auf den Klimawandel zu reagieren. Konkrete Maßnahmen gegen Wasserknappheit finden jedoch nur im Fall neuer Investitionen für die Bewässerung Erwähnung (Europäische Kommission 2011b, Artikel 46).

Mit Hilfe der in dieser Studie entwickelten Indikatoren wird die Sensibilität von Agrarproduktionssystemen hinsichtlich einer drohenden Wasserknappheit bewertet. In einem weiteren Schritt werden ausgewählte Pilotgebiete, welche ein breites Spektrum gegenwärtiger und zukünftiger gefährdeter landwirtschaftlicher Gebiete im alpinen Raum repräsentieren, analysiert. Die gegenwärtige Situation zeigt eine relativ höhere Empfindlichkeit gegenüber Wasserknappheit, vor allem auf Grund der bestehenden Landnutzung und Viehwirtschaft in den östlichen Teilen Österreichs und Sloweniens (z.B. Steirisches Randgebirge, Koralpe und Dravsko-Ptujsko). Die westlichen und südlichen Pilotregionen in Frankreich, Slowenien und Italien (z.B. Tarentaise, Scrivia, Noce, Julische Alpen) hingegen sind besonders wegen geringer Wasserspeicherfähigkeit der Böden und der Klimaindikatoren als empfindlich zu bezeichnen. Vor allem die italienischen Regionen müssen sich schon heute größtenteils auf die Bewässerung stützen und sind daher als sehr empfindlich gegenüber einer zukünftig verstärkten Wasserknappheit einzustufen.

Kurzfristige landwirtschaftliche Maßnahmen mit Potenzial, eine zukünftige Wasserknappheit zu mindern - z.B. Betriebsorganisation, Management in der Landnutzung und Viehhaltung, gezielter Pflanzenbau oder Einsatz von technischen Hilfsmitteln - könnten durch Festlegung in regionsspezifischen Vorgaben wie der Guten Landwirtschaftlichen Praxis oder den Agrar-Umweltmaßnahmen, verstärkt werden. Sie sparen nicht nur Wasser, sondern tragen zur Erreichung mehrerer Ziele bei; sie vermindern auch den Eintrag von Pestiziden, das Auswaschen von Nährstoffen, das Erosionsgeschehen und tragen zum Erhalt der Biodiversität und von ansprechenden Landschaftsstrukturen bei.

Langfristige landwirtschaftliche Maßnahmen – wie z.B. die Anpassung der Landnutzungssysteme und der Strukturen der Viehhaltung an wassersparende Alternativen – können nur eingeführt werden, wenn sie in langfristigen Strategien, Zielen und Programmen festgelegt werden. Dies sollte z.B. auf der Ebene der EU-GAP Strategie verankert werden, wie es auch bereits für die GAP bis 2020 in Säule 2, Achse 2 (Europäische Kommission 2010) vorgeschlagen wurde. Nach unten hin sollten diese Maßnahmen auf regionaler und lokaler Stufe umgesetzt werden. Wassersparende Bewirtschaftungsweisen beeinflussen jedoch die ökonomischen Ergebnisse in der Landwirtschaft signifikant. Zusätzlich sollten Maßnahmen für Einsparungen im Wasserbereich auch immer die Effekte auf die gesamte regionale Ökonomie, die Landschaft und den Naturschutz berücksichtigen. Der gegenwärtige Trend des reduzierten Wirtschaftswachstums, des höheren Druckes auf Energie- und Nahrungsmärkte und auf das öffentliche Budget, veranschaulicht die Notwendigkeit gründlicher und regionsspezifischer Argumentation, um die beste Balance zwischen langfristigem Wasserverbrauch und nachhaltiger, effizienter landwirtschaftlicher Produktion zu finden. Die aktuelle G20 Landwirtschaftsminister Deklaration (G20 2011), die eine Steigerung der Nahrungsmittelproduktion bis 2050 um 70 % notwendig erscheinen lässt, muss mitberücksichtigt werden.

Im Laufe des Alp Water Scarce Projektes wurden ausgewählte Wassersparmaßnahmen auch ökonomisch analysiert. Dabei macht sich der signifikante Einfluss der Marktsituation bemerkbar. Veränderte Fruchtfolgesysteme hin zu weniger Wasserbedarf haben zumeist ökonomische Einbußen der Landwirte zur Folge. Andere Landbewirtschaftungsmaßnahmen hingegen sind leichter umzusetzen und haben nicht immer negative ökonomische Konsequenzen - z.B. Maßnahmen alternativer Bodenbearbeitung. Die Bewässerung hingegen kann nur eine Option für Regionen mit langfristig ausreichendem Grundwasserangebot sein und nur für Pflanzen mit hohen Deckungsbeiträgen und guten Marktprognosen in Frage kommen. Die Nachhaltigkeit bei einer langfristig drohenden Wasserknappheit ist zu hinterfragen. Risikomanagementsysteme bei meteorologischen Extremereignissen (z.B. Versicherungen) reduzieren das ökonomische Risiko der Landwirte, jedoch ist umstritten, ob sie ohne öffentliche Unterstützung auskommen können. Daher können sie nur begrenzt als eine langfristige Option im Angesicht des Klimawandels betrachtet werden.

Internetseite des Projektes: www.alpwaterscarce.eu

1 General information and objectives of the Alp Water Scarce project

The Federal Institute of Agricultural Economics participated in the EU Alpine Space project "Alp Water Scarce", Nr. 5-1-3-F under coordination of the Mountain Institute, University of Savoy (FR). Other project partners were:

- Society of Alpine Economics of Upper Savoy (FR),
- Local Government of Savoy (FR),
- Government of Carinthia (AT),
- Government of Styria (AT),
- University of Salzburg (AT),
- Federal Office for the Environment FOEN (CH)
- Swiss Federal Institute of Aquatic Science and Technology (CH)
- LAG Appennino Genovese (IT),
- Province of Alessandria (IT),
- Province of Trento (IT),
- UNCEM Piemont Delegation (IT),
- Regional Agency for Prevention and Protection of the Environment of Veneto (IT),
- Geological survey of Slovenia (SL),
- National Institute of Biology (SL) and
- Slovene Chamber of Agriculture and Forestry (SL).

The project ran from 2008 to 2011 with the full title: "Water Management Strategies against Water Scarce in the Alps". The overall objective was to reinforce authorities and stakeholders to develop an integrated and sustainable water management system and to suggest socio-economic adaptation and mitigation strategies against water scarce. An early warning system against water shortage in the Alps should be based on an operational methodology with strong stakeholder participation. The main anthropogenic and naturally defined surface and ground-water systems have been characterised and their vulnerability towards water scarce has been assessed.

"Water scarce describes a situation of long term water imbalance, where water demand exceeds the level of water resources available" (Alpine Convention, 2008). The results of a conference in Bolzano, Oct 2008 (Umweltbundesamt 2008) stated that there are future risks of changing water regimes in the Alps. In the last 150 years the alpine region experienced an increase in temperature of +2°C. In the southern alpine regions a decline of precipitation of 10-20 % could be observed - mostly in summer - while at the same time water demand has increased further as there are rising water usages for drinking water, hydropower, agriculture, tourism and artificial snow. Hiller and Probst (2008) and Tamme (2008) quote similar results.

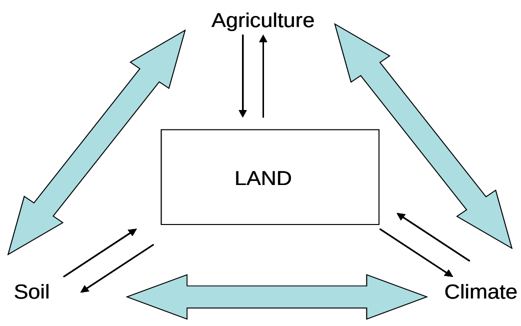
1.1 Tasking of the subproject Agriculture and the Threat of Water Scarce in Alpine Regions

The subproject of the Federal Institute of Agricultural Economics tackled the role of agriculture in an integrated water management system to strengthen the awareness of water consumption in agriculture. It shows the vulnerability and risks for agriculture and water systems in changing climate scenarios. Long term considerations show the possibilities for an adapted land use to increase the efficiency of water usage and to avoid water scarce and its negative consequences for agriculture and regional water systems. The focus of the agricultural sub-project lay at a regional scale. This enabled us to develop an overview of priorities for adaptation strategies and measures in the pilot regions. The developed indicators can contribute to the EU Commission's request for vulnerability indicators for agriculture, stated in the White paper (Commission of the European Communities 2009). They are focussed on water scarce and specific alpine regions. The detailed simulation of the agricultural processes, as elaborated for example in Schaumberger et al. (2006), is not an objective of this subproject.

1.2 Method and project procedure

The sub-project followed the approach to ascertain vulnerabilities of the agricultural land use system concerning water scarce. Vulnerability in the sense of IPCC describes the predisposition of a system to be adversely affected for example by climate change (IPCC 2011). Results of the project MOVE define that vulnerability is related to the exposure, susceptibility, and fragility of a system and its components as well as its capacity to react to hazardous events (MOVE 2011). Risk is thus the result of a potential hazard and vulnerability conditions. Essential components of the agricultural land use system are areas, soils, the agricultural land use and climate; see Fig. 1 which shows the various interrelations. The soil characteristics, such as depth, water storage capacities, humus concentration, particle size and evaporation influence agricultural land use. Cultivated plants have characteristic demands on soil. The soil also affects the climate by evaporation and transport of water. In turn, the climatic conditions influence the soil characteristics and the whole process of soil development. But climate conditions have effects on agriculture as well, as the selection of appropriate cultivated plants depends on precipitation, radiation and temperature. Agriculture in turn influences the climate by transpiration, interception of water, gutation, respiration and the soil conditions, by its water demand and especially by the way of cultivation (use of fertilizers, pesticides, treatment of soil). All of these processes are interconnected via the surface of the earth - the land.

Figure 1: Interrelations between land areas, agriculture, soil and climate



2 Identification of vulnerability

Agriculture is one of the climate sensitive sectors of the national economy. It is linked to climate change in three ways: agriculture acts as causer, solver and recipient of climate change. Together with other economic sectors, it has caused climate change to a certain extent as an emitter of greenhouse gases. On the other hand agriculture acts as a solver of problems caused by climate change by fixing carbon dioxide. Renewable resources from agriculture can contribute to a reduction of greenhouse gas emissions, especially when they substitute fossil fuels. Third, agriculture will be affected by climate change strongly and will have to adapt to changing conditions (Chmielewski 2009). Our report concentrates on this third role of agriculture, although we are aware of huge uncertainties concerning the future climate development and its recent and future drivers, as stated for example in Vahrenholt and Lüning, 2012.

2.1 General impacts of climate change on agriculture

Water consumption in agriculture differs a lot, depending on the actual land use type (grassland, arable land, special crops) and animal husbandry (Prettenthaler and Dalla-Via 2007; Kaiser and Mach 2004). Climate Change in general will have effects on the suitability of areas for agricultural use. An increase of potential for adaptation is necessary because of higher risks as a consequence of extreme weather events, higher temperatures and evapotranspiration, decreasing duration of snow covering and changing infestation. Heat stress, higher CO_2 and O_3 concentrations and increasing UV radiation affect growth and plant constitution. Of high importance are the interdependencies between the different effects (Schaller and Weigel 2007) influencing quantity and quality of crops, even though they are difficult to predict. Indirect consequences concern harvesting conditions, transport, storage and processing of products (Kromp-Kolb 2004). A general list of impacts of climate change is given in the Austrian strategy for adaptation to climate change (Lebensministerium 2011a). The following text shows exemplarily possible climate change scenarios and their effects.

An increase in temperature by +2°C in the next 50 years will cause an earlier phenologic development of plants by 15 days, the management zones will move 200 km to the north. Cultivation of thermophile crops (e.g. sunflower, maize) will increase, maturation will happen two weeks earlier and the frost risk will decline. An increase in temperature will have effects on plant infestation as well, e.g. an earlier appearance of downy and powdery mildew during vegetation period will boost infections, and milder and moist winters will abet fungal attacks; some plant pests (e.g. cicada, esca) will move northwards (Hoppmann 2004).

An extension of the vegetation period within the last decades has already been proven (0,29 days per year; Schaumberger and Formeyer 2008). Agriculture may profit from a longer vegetation period and better conditions for cultivation of arable crops. Moreover, the productivity of agriculture depends very much on spatial and temporal distribution of precipitation and evapotranspiration and the availability of freshwater resources for irrigation (Bates et al. 2008). However, the positive effects of an elongated vegetation period can be undone by dryer summers, extreme weather events and increasing animal infestations causing crop shortfalls or decline in yields (Hiller and Probst 2008; Wirsig et al. 2007). Factors like degradation of land resources (soil erosion, over extraction of groundwater and associated salinisation, over grazing of dry grassland) induce vulnerability and risks for agriculture.

The interactions between CO_2 and water are of great importance. An increasing CO_2 content of the air has a fertilizing effect (Eitzinger et al. 2008; Carraro and Sgobbi 2007) but these positive effects are expected to be offset by increased evaporative demand under warmer temperatures (Bates et al. 2008). This fact can have negative effects on the quality of crops too and depends very much on the type of soils being responsible for the varying availability of soil humidity for the plants (Stenitzer and Hösch 2004). In the same region yield losses and yield increase can occur, depending on the different soil properties, as shown on the example of Marchfeld in Austria (Formayer 2007).

As stated in Schönberger, 2008, water scarce is not only a problem by itself for plants; an inappropriate water supply - depending on soil conditions - leads to a lack of nutrients available for the plants. For the production of 1 kg organic mass 200 to 500 l water are needed for the biological processes, as a base for proteins and carbohydrate, for keeping the turgor-pressure, for absorbing and transporting nutrients and as protection against overheating. An increase of temperature leads to higher potential evapotranspiration and therefore the amount of necessary precipitation increases, e.g. 300 mm in the South Eastern part of Austria (Bolhar-Nordenkampf and Meister 2004). The Western part of Austria will not suffer from water scarce in future, as De Toffol et al. (2008) show in their conclusion regarding the Ötztal in Tyrol, Austria. They conclude that the future situation of water resources seems to be positive there. More water will be available in the winter season, when the normal watercourses have low flow; less rain is expected in summer when water in the region is still abundant. Although their assumptions about irrigation in agriculture were very high (high water demand and no precipitation in summer) it can be concluded that agriculture in the analysed region should never be an important water consumer on regional scale compared to other sectors.

Climate change will have different effects depending on region and on different crops and plant species. Here are some more detailed examples: mild winters are advantageous for winter cereals, but winter cereals do not like very low temperatures in February and high precipitation in July. Dry weather in spring is disadvantageous for spring cereals, and especially spring barley shows a high sensitivity to droughts, high temperatures throughout all months and high precipitation in July. Nevertheless, dry weather in harvesting times is good for cereals in general (Soja and Soja 2007). Pfundtner et al. (2004) stated that there are no better yield expectations in durum cultivation because higher temperatures also increase the dissimilation losses.

Dry hot summers are unfavourable for corn and sugar beet and to a lesser extent for potatoes. Corn dislikes droughts in summer and wetness in October while potatoes dislike high precipitation sums because of fungal diseases. Sugar beets need sufficient warmth in April but not too dry summers.

Viniculture could be among the winners of a warming climate because mild winters are advantageous for grapevines, they dislike very cold temperatures in February, moist and cool conditions during summer, but heat and drought cannot harm them seriously (Soja and Soja 2007). In case of vineyards changed sea level thresholds can be observed (Gartner 2004) which are already now 100 to 150 meters higher than 100 years before. Blooming sets in 10-11 days earlier which is an advantage for the plant development but certain diseases and infestations have better opportunities (lower water availability, higher UV-B radiation and higher ozone levels). Apples dislike low temperatures in February and wet conditions in April, May and July (Soja and Soja, 2007).

The CERES (=Crop Environment REsource System) wheat growth model has shown that spring crops are more vulnerable and dependent on soil water reserves. The water within higher groundwater tables during the winter period cannot be utilized by spring crops, and evaporation losses during summer could increase significantly. The model SWAP (Soil Water Atmosphere Plant) was used to study the increase of temperature and varying precipitation regime impacts on irrigation demand. It showed that water retention capacities of soils are very important factors. Water shortage in fluvisols was lower compared to that of Cambisol (especially on flysh, which means sandy loam, it showed the strongest irrigation demand). The model showed that an increase of air temperature has a greater impact on yields than a decrease of precipitation (Zupanc et al.2007).

In the case of grassland droughts lead to losses of yields which necessitate re-cultivation measures, a different spectrum of species and external procurement of fodder (Zarzer 2004). Nearly 30 % of Austrian grasslands are located in drought-risk zones. In addition to this, also areas are at risk even when they are located in alpine regions with good precipitation conditions but are provided with soils of low retention capacity (Schaumberger and Buchgraber 2008). Certain grassland species will disappear and others will get rife which weakens the compactness of the sod and makes it more vulnerable. Former advantaged locations (southern exposed) may then become disadvantaged and vice versa. Quantity and quality effects can lead to scarcity of fodder for livestock which has strong economic implications on agriculture, i.e. costs for irrigation or buying fodder (Fuhrer et al. 2006). On the other hand, longer dry periods and higher temperatures increase possibilities of silage and conservation of grass.

Referring to IFPRI (IFPRI 2009) the yields in the year 2050 of developed countries will be affected less compared to developing countries. Actually, climate change increases yields of a few crops in developed countries. For instance, yields of rainfed maize, soybean and wheat in Europe will increase especially when effects of CO_2 fertilisation are considered. It causes a growth of yield by 8 % in 2050 compared to 2000 (IFPRI 2009; Nonhebel 1996 in: IPCC 2003; Harrison and Butterfield 1999 in IPCC 2003).

Climate change will influence livestock husbandry directly by effects on animal health, growth, reproduction, but indirectly by impacts on productivity of pastures and forage crops as well. Heat stress negatively influences animal production in general but reproduction and milk production of dairy cows as well as fertility of pigs in specific (Furquay 1989 in: IPCC 2003). Therefore, livestock production in summer in currently warm regions of Europe will have the highest risks caused by climate change. On the other hand currently cooler regions could profit from a warming during current cold periods by reduction of feed requirements, increasing survival and lower energy costs. Minor impacts will occur for intensive livestock systems with controlled climate, but generally housing expenses will alter due to changed requirements for insulation and air-conditioning (Cooper et al. 1998 in: IPCC 2003).

Furthermore, not only the direct effects have to be taken into account but also manifold interdependencies between economic sectors. Not only the changing water supply for crops and animals but also natural hazards, changing potentials for tourism and regional development as consequences of different climate and weather conditions seem important in their effects on agriculture. Competition for sufficient water supply may raise water prices.

3 Model development for agricultural vulnerability evaluation

3.1 Indicator development

3.1.1 Fundamental Principles

Indicators for water use in agriculture exist already from OECD (2000) which takes into account the change in total agricultural water use and the intensity of agricultural water use relative to other users. EU has two indicators in the IRENA system (Indicator Reporting on the Integration of Environmental Concerns into Agriculture). The IRENA indicator no. 10, water use intensity by agriculture, measures the irrigable area and the type of irrigated crops. The IRENA indicator no. 34.3 measures the share of agriculture in water use (European Environment Agency, 2005). The already existing indicators are related mostly to irrigation but do not take into account the real total water usage of agriculture, which is of interest in the Alp Water Scarce project. To meet the project goals a system of most relevant agricultural indicators has to be developed, including plant cultivation, livestock husbandry, soil and climate conditions.

3.1.2 Plant Cultivation

Within the topic "plant cultivation" the types of land use (e.g. grassland, arable land, fallow land), the way of cultivation (e.g. irrigation system, mulch seed, furrow diking, crop rotation system), the specific cultivated plants and their water consumption seem to be the most important factors of influence. Many indicators for the measurement of water consumption of different cultivated plants or agricultural land use types can be found in the literature, for instance transpiration coefficient, evapotranspiration, amount of irrigation, necessary precipitation per year and efficiency of water utilisation.

Water consumption of plant cultivation is composed of transpiration of plants, evaporation and soil characteristics (Wolff and Stein 1998). Agriculture endeavoures to minimize unproductive water losses by soil evaporation, leaching water and surface water drain. Absolute water consumption increases with more intensive fertilizing. Nevertheless, most important is the availability of water for plants which depends on precipitation (spatial, temporal distribution and intensity), above and under ground draining, evapotranspiration, soil properties (especially water retention capacity) and cultivated plants – and especially their deepness of roots (Kaiser and Mach 2004).

3.1.2.1 Transpiration Coefficient

A promising indicator is the transpiration coefficient, which is available for a big variety of cultivated crops. It is commonly used in the literature. It depends highly on plant breed (ability of water absorption), climate conditions (temperature, precipitation, vapour pressure deficit of air), natural conditions (water storage capacity of soil, rooting depth) and on management (fertilisation, supply of nitrogen and potassium) (Lütke, Entrup and Oehmichen 2000a; Trepte 2001). Variable natural conditions make it difficult to generalise the water demand of a specific crop or to compare different crops with each other. To demonstrate this problem, the transpiration coefficient of potatoes is used as an example: According to literature, the transpiration coefficient ranges between 182 l water/kg dry matter and 636 l water/kg dry matter. Obviously, the transpiration coefficient is not specific to the crop but depends on natural conditions. This fact explains the wide range of possible water use.

The transpiration coefficient depends also on the produced dry matter. Therefore, crops producing a high amount of dry matter can have a quite low transpiration coefficient even though they have a high water demand - but relative to the produced dry matter their water demand seems to be low - which is of minor importance in our project. To illustrate this problem consider the following example (Spengler et al. 1988): Sugar beet on loess-chernozem soil needs 514 l water for a yield of 2.3 kg dry matter/m². Due to the high production of dry matter, the transpiration coefficient 224 l/kg is quite low. On the same soil potatoes need 291 l water to produce 1.2 kg dry matter/m² - the transpiration coefficient is 252 l/kg. Therefore, sugar beets seem to be the best choice as their transpiration coefficient is lower than that of potatoes. However, in absolute terms, from germination to harvest, sugar beets need 223 l more water than potatoes. Maize is the crop with the highest water-use efficiency, but maize is known to need an annual precipitation of 450-650 mm. Especially in the time from mid July to the end of August maize can have a daily water demand of 6 mm/m² (Lütke Entrup and Oehmichen 2000, Aigner and Altenburger 1997). For a region suffering from water scarce the total amount of water demand appears to be more relevant than the water-use efficiency, as measured by the transpiration coefficient.

3.1.2.2 Crop Coefficient

Another suitable indicator would be the necessary amount of annual precipitation. Because information has only been available for some scattered crops and due to the fact that the temporal allocation of precipitation is not considered within this indicator, we have chosen the crop coefficient as an appropriate and applicable indicator for the comparative classification of water demand per specific crop plant. The Crop Coefficient Kc is one of the most established indicators in the literature. Average crop coefficients are used widely for irrigation planning and management purposes and for hydrologic water balance studies. The crop coefficient is part of the estimation of specific crop evapotranspiration rates (ETc) under certain climatic conditions. ETc contains the effect of the various weather conditions (ETo) and the crop characteristics described by Kc crop coefficient. ETo can be estimated/calculated by using the FAO Penman-Montheith method which measures the evapotranspiration from a well-watered hypothetical grass surface assuming fixed crop height, albedo (reflectance) and surface resistance (Allen et al. 1998, see figure 2).

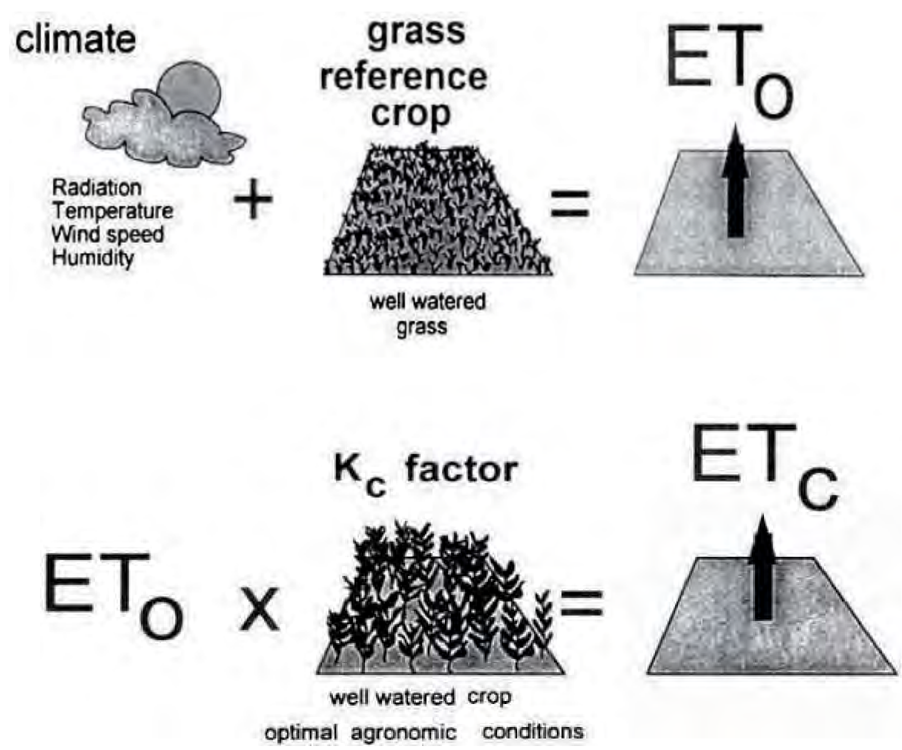


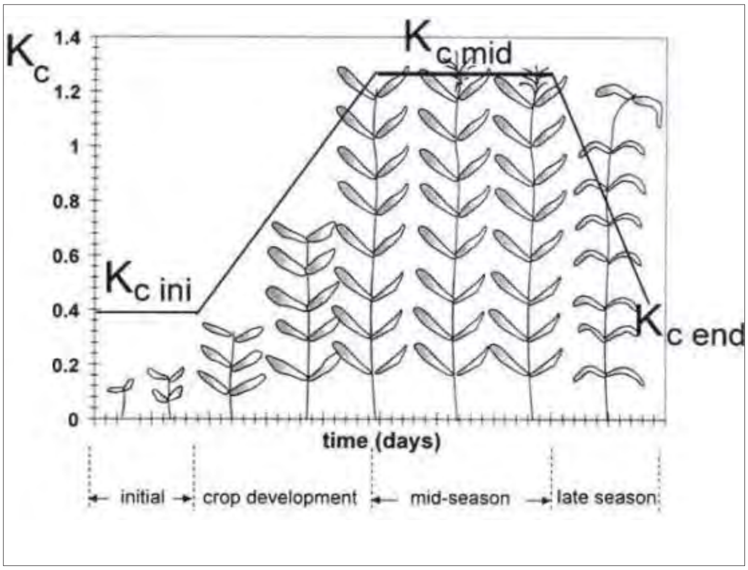
Figure 2: Relevance of the crop coefficient (Kc) for the measurement of evapotranspiration, source: Allen et al. 1998

ET0....Evapotranspiration of well watered grass
ETC... Evapotranspiration of well watered crop
Kc......Crop coefficient

The crop coefficient Kc is a dimensionless number and contains the ratio of the crop evapotranspiration Etc to the reference evapotranspiration ETo. Usually it ranges between 0.1 and 1.2. Kc combines the effect of both specific crop transpiration and soil evaporation. Crop coefficients vary by crop, stage of growth of the crop and cultural practice (Allen et al. 1998). For example, coefficients for annual crops (row crops) vary widely through the season, with a small coefficient in the early stages of the crop, when the crop is just a seedling, to a large coefficient when the crop is at full cover and the soil completely shaded. Another example are orchards with cover crops between tree rows having larger coefficients than orchards without cover crops. As the crop coefficient Kc mirrors the changes in vegetation and ground cover during the growing period, Kc values and the lengths of four crop development stages (initial phase, development stage, mid-season stage and late season stage) are needed (see figure 3).

For the project, Kc-values as well as the duration of the growth stages of specific crops by Allen et al. (1998) were used as base. Those data were adapted by applying Middle-European averages to sowing times (Klapp 1967; Aigner & Altenburger 1997; Lütke Entrup and Oehmichen 2000) and Austrian dates of starting duration and ending of the vegetation period (Schaumberger and Formayer 2008). Thereafter we have multiplied the Kc values of the specific stages per specific crop with the lengths of these specific stages. The summarised results were used for a classification into 5 groups (see Table 1)

Figure 3: Different crop coefficients (Kc) according to development stage during vegetation period



Source: Allen et al. 1998

Table 1: Classification of cultivated crops in respect of their water consumption

Plant category	Examples of cultivated crops	Water demand	Classification and weight
Spring Grain, Grapes, Sunflowers	Spring wheat, Spring rye, Spring barley, Spring oats, Millet, Sorghum, Sunflower, Pumpkin, Grapes,	very low	1
Legumes, Maize, Roots, Tubers	Fababean, Soybean, Peas, Maize, Sugar beets, Potatoes	low	2
Winter grain	Wheat, Barley; Oats, Triticale	middle	3
Fruit trees, Berries, Rapeseed	Apples, Cherries, Pears, Apricots, Peaches, Rapeseed, Berries	high	4
Pastures	Rotated pastures, Low input grassland, Meadows	very high	5

Source: own elaboration

Under the assumption that agricultural management practice remains the same and depending on data availability of agricultural land use in the pilot regions an identification of those agricultural areas which are most at risk from water scarce with respect to the different climate scenarios is possible. Either the potential water balance by Penman or the evapotranspiration ETo of Penman together with the amount of precipitation is needed. Attention needs to be paid to the water demand in the course of a year. In detailed investigations it should be compared with the water availability depending on soil and climate conditions, especially throughout the vegetation period. For example winter grain needs more water than spring grain but tolerates dry periods better than spring grain (Oberforster 2009). Because of this the soil properties are explained in more detail in a separate chapter, see 3.1.5, to better relate water availability to water demand.

3.1.2.3 Irrigation

Special attention needs to be placed on the topic of irrigation which is often used as the only reference of water consumption in agriculture. The water balance for Austria says that from the total available amount of water in the year 2004 2 mm/m² water was taken by agriculture for irrigation; this corresponds to 4,5 % of total water usage (Lebensministerium, 2008).

The amount used for irrigation has been estimated only very roughly because of a lack of summarized data and very high dependency on specific weather conditions. Sometimes data of the number of irrigation facilities exist, sometimes even data for the irrigated area and upper limits of irrigation in laws pertaining to water are available, but it is very difficult to find real data on the actual amount of water used for irrigation. The need for irrigation gives hints to plant cultivation in particularly sensitive sites where already a slight change in climate conditions can affect the cultivation. As an example table 2 gives a rough estimate of average irrigation amounts for crops in Austria. The proportion of irrigated area is available for many of the project pilot sites.

Table 2: Plant specific irrigation amounts in Austria

Plants	Average irrigation mm/year
Pumpkin, hop, poppy, clover, field forage	0
Wheat, rye, barley, oats, triticale, rapeseed	30
Peas	35
Spice plants	40
Early potatoes	60
Sunflowers	70
Corn	105
Silage maize, beans, beets, soy, grain legumes	140
Late potatoes, strawberries	180

Source: Umweltbundesamt, 2003

It has to be mentioned that the crop specific water demand for irrigation depends on the climatic conditions of producing areas and especially the market price of the specific crops. Irrigation only takes place if the farmer earns a profit even though the production costs are higher with irrigation. In addition, irrigation areas can be interpreted as an indicator for farming that is not well adapted to regional climate conditions.

Telephone interviews with experts of the agricultural chambers in the involved Austrian districts of Styria and Carinthia stated that irrigation plays only a minor role. Irrigation is necessary only during certain dry years and periods and only in the case of particular crops (Orchards, Vegetables, maize seed). It is implemented for efficient production. Only in the pilot region Steirisches Becken a considerable irrigated area of ~3,000 ha exists, representing a share of 1.9 % of the agricultural area in this region.

A recent study (BUNDESMINITERIUM für LAND- und FORSTWIRTSCHAFT, UMWELT und WASSERWIRTSCHAFT, 2010a) which estimated irrigation in Austria confirms the small amount of irrigated areas and irrigation in the Austrian pilot sites. In most communities of the pilot sites it is below 1 % of the area.

In OECD (2010) is described, that the use of freshwater resources by agriculture (and non-agricultural users) has changed little. Total agricultural land area has decreased and abstractions from groundwater resources have been increasing. The trend differs very much from country to country - as far as data for documentation are available. In France the share of irrigated area increases while in Austria, Switzerland and Italy the share stays constant, but for Italy on a much higher level (17 %) than in Austria and Switzerland.

3.1.3 Livestock

Beside necessary water for regional fodder production which is taken into consideration in the section about plant cultivation (chapter 3.1.2.), livestock needs water for drinking and processing. The amount depends on the type of livestock system and on capacities and strived output. Average values used for animal production, taken from established references, are listed in Table 3. The variance of values offers a classification into three classes. Poultry fattening and piglets are the livestock categories with the highest water demand. These high water demands are caused on the one hand by the fodder (dry feed induces a higher drinking water demand than e.g. grass as succulent feed) and on the other hand by turnover rates. Both poultry and piglets are raised quickly. Water intensive hygienic measures to prevent diseases are indispensable (stabling has to be cleaned quite often before filled newly).

Table 3: Classification of livestock husbandry in respect of their water consumption

Livestock category	Water demand (drinking and processing water per stableplace per year in m³)	Livestock Unit (LU) per animal per year (Lebensministerium 2008b)	Water demand per LU per year in m³	Classification and weight1
Rearing and fattening calf (page 538)	4.4	0.4	11.0	low (1)
Fattening cattle (page 574)	11.5	1	11.5	low (1)
Pigs (20-50kg, Umweltbundesamt 2003)	1.8	0.15	12.0	low (1)
Rearing cattle (page 551)	12.1	1	12.1	low (1)
Fattening pig (page 608)	2.36	0.15	15.7	low (1)
Horses (Umweltbundesamt 2003)	21.6	1	21.6	middle (3)
Laying hen (page 656)	0.09	0.004	22.5	middle (3)
Sheep, goat (Umweltbundesamt 2003)	3.6	0.15	24.0	middle (3)
Breeding sow (page 621)	7.6	0.3	25.3	middle (3)
Suckler cow (page 591)	25.5	1	25.5	middle (3)
Dairy cattle (page 520)	28.5	1	28.5	middle (3)
Fattening chicken (page 671)	0.05	0.0015	33.3	high (5)
Piglet (<20kg, Umweltbundesamt 2003)	0.72	0.02	36.0	high (5)
Fattening turkey (page 686)	0.26	0.007	37.1	high (5)

1 Grouping of indicators: low: <20 m³/LU, middle: 20-30 m³/LU, high: >30 m³/LU
Source: KTBL, 2008, own classification

3.1.4 Indicators for water consumption in agriculture and outlook for agriculture

Derived from the classifications elaborated above the following indicators can be applied as input for water scarce vulnerability assessment of agriculture. The selected indicators are able to describe the regional water consumption in agriculture and are a compromise between data availability, exactness and work load for preparation.

Table 4: Regional agricultural water consumption indicators

Indicator	Definition	Unit of measurement, formula for regional indicators	Necessary data	Source
Water consumption for plant cultivation	Proportions of specific cultivated plants on agricultural land, specific weighting related to crop coefficients	Weighted percentage: $Ps = \sum_{i=1}^{n} A_i * w_i$ P: Plant indicator s: pilot site i: crop, n: number of crops A: Proportion of crop area w: crop specific weight derived from Kc crop coefficient	Agricultural land use data (ha of cultivated plants), crop classification	Agricultural Census and/or Integrated Administration and Control System of EU Common Agricultural Policy
Water consumption for livestock husbandry	Proportions of specific livestock units, specific weighting related to water demand	Weighted percentage: $Ls = \sum_{i=1}^{n} U_i * w_i$ L: Livestock indicator s: pilot site i: livestock category, n: number of categories U: Proportion of livestock category w: livestock specific weight derived from m^3 of water demand per livestock unit	Specific livestock numbers, agricultural land use data, guideline values for animal water consumption	Agricultural Census and/or Integrated Administration and Control System of EU Common Agricultural Policy
Irrigation	Proportion of irrigated area on agricultural land	Percentage	Irrigation data	Agricultural census, interviews

Source: own elaboration

3.1.4.1 Agricultural outlook

Studies on agriculture in the overall economy (Banse & Grethe 2007, in: ECNC, LEI, ZALF 2009) confirm that the impact of agricultural policy on agricultural commodity output is relatively small in comparison with the influence of the macro-economic environment. Liberalisation will accentuate existing trends in commodity production and markets. The recent G20 Agricultural Ministers' declaration (G20 2011) states that food production has to increase by 70 % until 2050. The study of the research program Climate Change Agriculture Food Security revealed in June 2011 (CCAFS 2011) shows declining production potential for basic foodstuff like beans, maize and rice in Africa, India, Brazil and Mexico which will have impacts on the global market, prices and production in other parts of the world.

The Agriculture 2013 Foresight study (INRA 2008 in: ECNC, LEI, ZALF 2009) notes that the increasing world demand for agricultural commodities leads to increasing agricultural prices but confirms the long-term trend that the number of farms in the EU will decrease. At the same time specialisation increases. The study devotes particular attention to the future of cattle husbandry, regarding the reduction in beef and dairy herds within the EU. The report Agricultural Commodity Markets – Past Development and Outlook (European Commission 2006, in: ECNC, LEI, ZALF 2009) notes the past loss by the EU of market shares in the world market. It expects that the continuing Common Agricultural Policy (CAP) reforms will most likely accelerate the decrease in the EU's position in bulk commodity market and that its value added exports (such as cheese) will increase. With regard to biofuels, although the expected trend is that their consumption will increase, the impact on EU feedstock production is unclear; all depends on international trade tariffs. Somewhat in contrast with other previsions about the evolution of the meat market, the beef sector is expected to grow faster than in previous decades and the growth of the pig and poultry sector may well slow down, which is in line with scenario estimates of Sinabell et al. 2011b.

The OECD-FAO Agricultural Outlook (OECD 2011, OECD & FAO 2008, in: ECNC, LEI, ZALF 2009) report notes that the foreseen expansion in agricultural commodity demand in the developing and emerging economies will be driven principally by income growth, with a background of rural migration to higher income urban areas. A number of developing countries will not only become net importers for certain commodities but will be consolidating strong net-export positions as well for major primary and refined commodities. Most of agricultural prices are expected to remain higher than past averages, even after structural adjustment irons out the peak recently witnessed. Real prices for wheat and cereals will rise between 15 and 40 % until 2019; the same change is expected for milk products and vegetable oil but meat prices will increase less. Production of agricultural products will increase especially in countries like Brazil, China, India, Russia and Ukraine but the growth will slow down. Feedstock demand for biofuels is a major component of the price rise. World trade is expected to grow for all commodities, in particular for beef, pig meat, whole milk powder, and especially for vegetable oils. In IEEP, 2009, a further increase in agricultural productivity is expected which means that an expansion of agricultural area in spite of higher demand on products is not plausible.

World food prices considering the effects of climate change are higher than they would be without climate change. For instance, wheat prices in 2050 will be 194 % higher than in 2000 - this is 111 % more than the price would be in 2050 without climate change. Soybeans will have the lowest price changes compared to 2000 (92 % rise with and only 11 % rise without climate change) (IFPRI 2009). The demand for liquid biofuels is likely to compete with food production causing upward pressure on prices. Agricultural prices are also likely to become correlated with energy prices the more the biofuel sector expands.

Climate change will directly affect water availability for irrigated crops (IFPRI 2009). Climate scenarios show an increase of precipitation over land globally, but higher temperatures will cause higher water requirements of crops. The yields of irrigated maize in Europe will remain constant or even drop, while soybean yields will increase by one third until 2050, but wheat yields will decline. Production of irrigated maize and wheat will fall, but soybean production under irrigation systems will increase by about 7 %.

The FAO estimates that the meat output will have to rise by 74 % (200 mn tons) globally to meet the demand in 2050 due to population growth. In general, prices of meat will rise until 2050 compared to 2000. Notably, the price of poultry will grow (+64 % change from 2000 - 2050 respectively +21 % change until 2050 without climate change). The lowest price change will occur for lamb meat (+28 % change between 2000 - 2050, +12 % change until 2050 without climate change).

The overall results of the study Scenar 2020 (ECNC, LEI, ZALF 2009) indicate that structural changes in the agricultural sector, i.e. decline of agricultural contribution to total income and employment, will continue at the national level. In general, the share of the agri-food industries in the overall economy stays highest in a conservative CAP scenario and is lowest in a liberalisation scenario in the EU-27.

Production growth of all agri-food products (primary agriculture and processed food products) is about 4 % in the EU reference scenario. A small positive contribution to the production of agri-food products is due to the EU Renewable Energy Directive and to all rural development measures. The growth of agri-food production is lowest in the liberalisation scenario. In detail the demand for land for agricultural production decreases in all three scenarios, most in the liberalisation scenario (by -6 %), indicating that yield increase will outweigh the additional demand by population and income growth.

Table 5: Annual growth rate of production by 2017

Commodity	Annual growth rate, %
Wheat	+1.5
Maize	+1.3
Barley	+0.9
Sorghum	+1.2
Oilseeds	+3.5
Bio fuels	+10
Beef	+1.3
Pork	+1.8
Poultry	+2.3
Dairy products	+1.9

Source: Commission of the European Community 2009

The evolution of real prices for arable crops is generally negative up to the horizon of 2020 in the reference scenario, with the exception of soybean, rapeseed and sunflower seed, as the planting of these crops is directly related to the Renewable Energy Directive; with regard to livestock, the liberalising trend affects milk, beef and sheep prices substantially. Prices in the conservative CAP scenario in general increase or are more or less unaffected when compared with the reference scenario. This is explained by a (small) decrease in supply and increased production costs. The driving factor behind this are decreased investments in efficiency and productivity in agriculture resulting from the switch from rural development measures to Pillar1 payments in the conservative CAP scenario as compared with the reference scenario. Prices in the liberalisation scenario decrease when compared to the reference scenario. Under liberalisation there will be a strong cut on import tariffs of ethanol. This also leads to lower cereal prices. There will be limited growth in crop production and stable production in livestock, except under full liberalisation under which poultry and pork production decline a bit; but there will be a big drop for beef even with a shift in consumption towards beef because of a change in relative prices for the consumer. Land area sown to non-biofuel and biofuel crops witnesses no strong inflections neither in a positive or a negative sense, except that a full liberalisation of biofuels would severely limit the production of ethanol, and this would reflect on land requirements.

Table 6: Projected changes in producer prices for agricultural and food products in the EU-27 under different scenarios (per cent changes)

Commodity	Reference scenario (2004/5 to 2020)	Liberalisation scenario (relative to reference scen. 2020)
Soft wheat	-8.9	-7.8
Barley	-14.7	-9.8
Corn	-6.5	-3.4
Sugar	-12.9	-7.1
Soybean	4.9	-5.0
Rapeseed	5.8	-7.0
Sunflower seed	1.0	-9.3
Milk	-21.4	-1.3
Beef	-15.4	-33.4
Sheep	-19.9	-16.5
Pork	1.3	-3.1
Poultry	3.1	-5.4
Eggs	13.6	-1.3

Source: ESIM results, in: ECNC, LEI, ZALF 2009

As regards Natura 2000, the abolition of direct support under the liberalisation scenario releases land from the obligation of keeping in good agricultural and environmental condition with the effect that quite some agricultural land will be taken out of production; in combination with reduced market support this leads to abandonment of marginal land in particular.

3.1.4.2 Agricultural scenario assumptions

Since agriculture was only one part of the investigations in the Alp Water Scarce project it was not possible to implement various scenarios only for this sector in order to keep the overall number and wealth of detail limited. Existing studies, scenarios and forecasts for the agricultural sector point out the strong impact of global markets, prices and agricultural policy measures on land use and livestock. Decreasing trends of CH4 and N2O emissions of agriculture are evident but future restrictions concerning the greenhouse gases are expected (Möller 2011). For Austria, projections until 2030 come up with a relative stable (Anderl 2011) or increasing (Sinabell et al. 2011b) population of cattle (with a decreasing share of cows) and a slight decrease in pig and poultry production, in combination with a slight decrease of nitrate fertilizing. The agricultural area will continue to decrease with higher rates for grassland than for arable land but an intensification will take place (Sinabell 2011).

The various study results give hints to create two different general scenarios for the agricultural development in alp water scarce pilot regions but they are too vague and general and sometimes contradictory to deduce concrete figures for the plant and animal categories to be used in quantitative estimations.

1: A conservative scenario can show a similar situation of agricultural production as it can be observed in the reference period because of price stabilisation effects due to agricultural policy measures. Farm structures and land use will further develop to a certain extent but the level of production of commodities will stay relatively constant. Especially in naturally disadvantaged mountainous regions the chances for intensification are limited; further abandonment of agricultural areas is assumed to be kept low through policy measures. Advantaged valley grounds and flatlands will be restricted in intensification by environmental and market regulations. Because of these reasons, the agricultural water demand will stay constant at the current level.

2: A liberalisation/specialisation scenario with growing market pressure and less policy interventions will lead to shifts in prices and production. In advantaged regions the production will be more intensive for example in pork, poultry and beef production as well as for perennial and specialised crops. On the other hand an ongoing and increasing development towards low input farming or abandonment in disadvantaged regions and marginal agricultural land will take place. Water consumption of agriculture will depend on the shares of intensification and low input sectors within specific regions. A certain percentage of marginal agricultural area will be abandoned or afforested; the regional specific percentage depends on the current share of low input grassland. The other agricultural area will largely remain as it is although a certain percentage will be turned into settlements and infrastructure; but this may be compensated by an increase in yields. For example, the short term outlook (European Commission 2011) states a reduction of agricultural area for cereals by 1.1 % but an increase of 1.0 % in yields per year. Animal production will fall with low absolute rates but at higher stocking density per agricultural area, which decreases. In general, agricultural development results in slightly decreasing absolute water demand but various regional shifts in the vulnerability classes of the land use and therefore varying regional vulnerability in comparison to the current situation.

3.1.5 Soil indicator

Different kinds of land use systems require differing water supply. Availability during the course of the year rather than overall is important. Soils in good conditions with a high capacity of water retention are able to store water (e.g. winter precipitation) and provide it for the start of crops' growing period. They are able to infiltrate heavy rain and save nutrients too (Lebensminsiterium 2011a). Thin and poor soils with low water saving capacity cause problems when precipitation fails during crops' specific phases of the vegetation period. In Austria's low precipitation regions a clear relation of water retention capacity of soils and climate change problems is evident (Eitzinger, Kubu, Thaler. 2008).

An established indicator that integrates all different soil properties related to water retention is the “capacity of available water”. It has been calculated e.g. for Austria from the Institute for Land and Water Management Research (Murer et al. 2004) and is available for all agricultural areas of Austria based on the digital soil map in a scale of 1:25.000. In the regional context of Alp Water Scarce pilot sites this indicator can be expressed as the sum of weighted proportions of soil classes. Its variance suggests a classification into three classes.

$$Ss = \sum_{i=1}^{n} B_i * w_i$$

S: Soil indictaor
s: pilot site
i: soil category, n: number of categories
B: Proportion of soil category
w: soil specific weight

Table 7: Soil indicator: capacity of available water

Capacity of available water in mm	Risk classification and weight
<60	very high (5)
60 - 140	high (4)
140 - 220	Middle (3)
220 - 300	Low (2)
>300	very low (1)

Source: Murer et al. 2004

3.1.6 Climate indicators

The focus of the Alp Water Scarce project lies on the threat of water scarce. Precipitation and water availability at certain periods of the year in combination with other climatic conditions define the scope of the agricultural sector. Especially in precarious alpine regions small changes in preconditions may have great impact. The parameters aridity index and heat sum are proven as meaningful to show the water-balance and the influence of climate on the agricultural production potential (Flückiger and Rieder 1997). The aridity index (TI-value, Harlfinger and Knees 1999, Bahrs and Rust s.a.) relates monthly average temperature and monthly precipitation to each other. It is used as an indicator for the climatic water balance to characterize dry conditions for agriculture in fiscal evaluation of agricultural parcels in Austria. For a regional comparison of the pilot sites the monthly average values of available representative gauging stations over the recent period (e.g. last 10 available years) are used for the analysis. For general purposes the aridity index may be aggregated over the whole year. In combination with the water capacity of soils it gives a good overview about regional specific drought vulnerability of agriculture due to natural conditions.

$$Am = 3Tm / Pm$$

A = Aridity index
T = Average temperature
P = Precipitation
m= monthly

More important than absolute values - because agriculture is more or less adapted to the situation - are the differences between the current situation and future scenarios to demonstrate possible effects of climate change. For this purpose the difference of the current aridity index and the one of future scenarios is calculated. Depending on the resolution of future scenarios this is currently done not monthly but seasonally. If more concrete future scenario data were available, it could be done more concretely and could be related to specific monthly water demands of cultivation types.

3.1.6.1 Climate change outlook

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and a rising global average sea level (IPCC 2007). Climate variability and climate change is closely related to the long term warming trend visible in seasonal and annual mean temperature time series. Further studies show that precipitation does not follow these trends. Two antagonistic centennial precipitation trends have been analysed (EUROPEAN ENVIRONMENT AGENCY 2009). A wetting trend in the north west alps (eastern France, northern Switzerland, southern Germany, western Austria) and a drying trend in the south east (Slovenia, south-eastern Austria). Also OECD (2010) describes these two diverge trends: higher temperatures and higher water availability and yield potentials in Northern Europe but higher temperatures combined with lower water availability and yield potentials in Southern Europe.

While global climate models can give a consistent picture of general patterns, they are still much too coarse in resolution for precise regional applications. Regional specific climate estimations are subject to very high uncertainty, depending on the applied models, the combination of global and regional models and their assumptions as well as on very specific regional and local influences on and interactions with the climate (Solomon et al. 2007; Eitzinger et al. 2008). Because of these reasons the 4 different IPCC main scenarios are used to show possibilities or paths of further development and future risks in agriculture. The recent series of scenarios depend mostly on various economic and population developments. The emissions of CO_2 and SO_2 differ correspondingly in strengths and timing (Jacob 2009; IPCC 2007). No likelihood has been attached to any of the scenarios, and uncertainties existat every stage of modeling (Vahrenholt and Lüning, 2012).

Scenario A1 describes quick economic development and a population which decreases after the peak in 2050, and at the same time quick and efficient implementation of new technologies. **A1B** assumes balanced use of different energy resources.

Scenario B1 is similar to A1 but takes a rapid shift of economy to the service and information sectors into account.

Scenario A2 describes a very heterogeneous world with high population growth, attempts of autarky, local identities and regional oriented economic growth with slow technological change.

Scenario B2 describes a world with intermediate population and economic growth, emphasising local solutions to economic, social, and environmental sustainability.

For the next two decades a warming of about 0.2°C per decade is projected for most of the scenarios, especially for summer in the southern alps. Only afterwards, temperature projections increasingly depend on specific emission scenarios, resulting in the highest increase of temperature in scenario A2 and the lowest in B1. It is very likely that hot extremes, heat waves and heavy precipitation events will become more frequent. For local mean temperature rises of up to 1° to 3°C, and at mid- to high latitudes, crop productivity is projected to increase slightly depending on crop. At lower latitudes, for small local temperature increases of 1 to 2°C and especially in seasonally dry and tropical regions, crop productivity is projected to decrease. (IPCC 2007). In Kromp-Kolb (2008) Scenario A1B estimates a warming in Austria for 2030 of +1°C and for 2050 +2°C (in relation to 2010). Precipitation in Austrian average nearly stays the same until 2030 with a stronger decrease of summer precipitation after 2030 (2050: ~-20 % in relation to 2010).

Due to IPCC precipitation will slightly increase during winter in the southern alps (0 to +10 %) but will decrease especially during the summer period up to -50 % (EUROPEAN ENVIRONMENT AGENCY, 2009). Available research suggests a significant future increase in heavy rainfall events in many regions, including some in which the mean rainfall is projected to decrease. The resulting increased flood risk poses challenges to society, physical infrastructure and water quality. Climate change is expected to magnify regional differences in Europe's natural resources and assets. Negative impacts will include increased risk of inland flash floods and more frequent coastal flooding and increased erosion (due to storminess and sea level rise). Mountainous areas will face glacier retreat, reduced snow cover and extensive species losses.

As a scenario referring to a regional context, the results of Loibl and Gobiet (2006) in the RECLIP project have been taken as source for seasonal future values of temperature and precipitation (figures 4 and 5), which have been the basis for the data in the reclip:century project (Loibl et al. 2011).

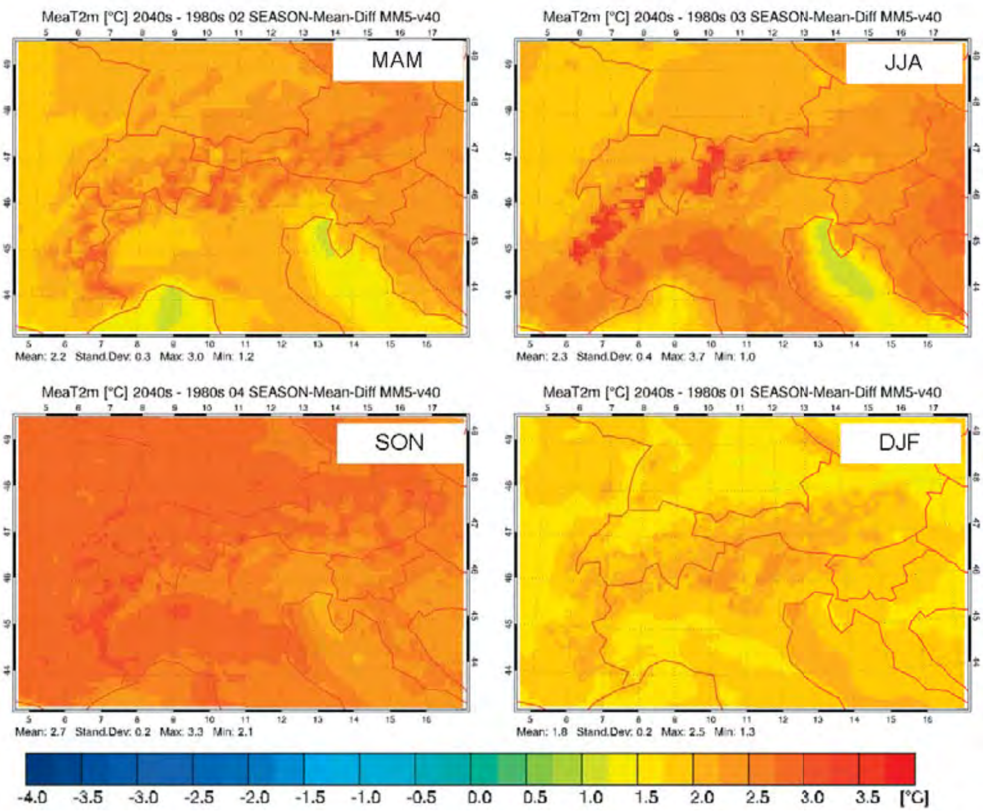


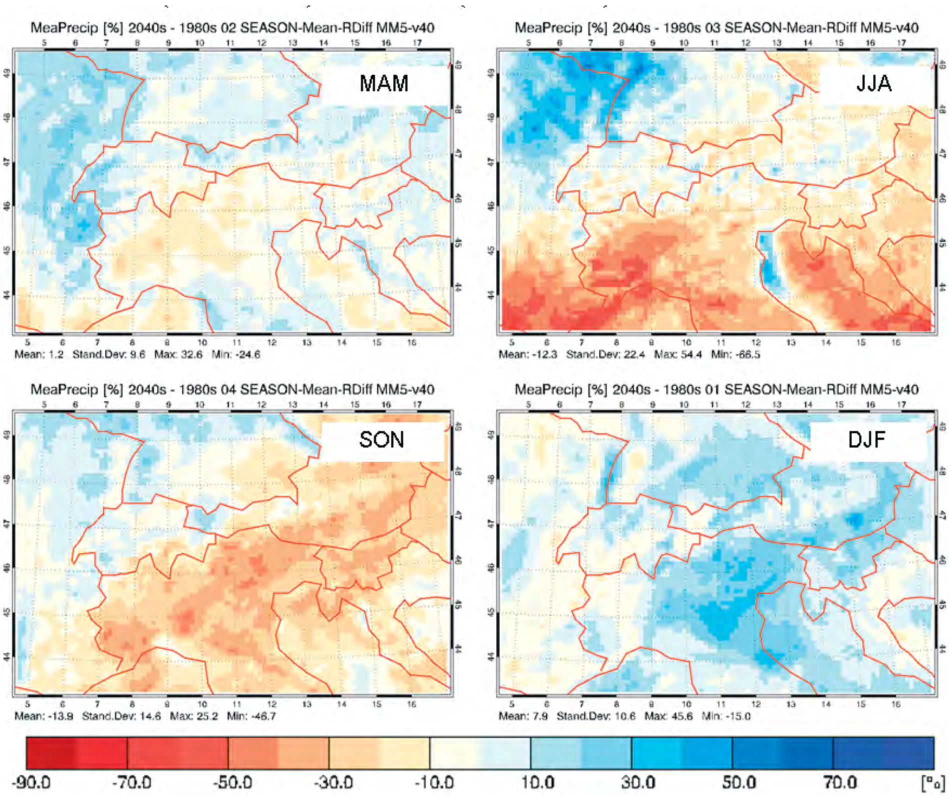
Figure 4: Seasonal changes in mean temperature between 2041-2050 and 1981-1990 (M, A, M, J, J, A, S, O, N, D, J, F: months)

Source: Loibl and Gobiet 2006.

Also the study "Adaptation strategies for Climate Change for the Austrian Water Management (BUNDESMINITERIUM für LAND- und FORSTWIRTSCHAFT, UMWELT und WASSERWIRTSCHAFT 2010) confirms the slight increase of temperatures and that winter precipitation and the related amount of ground water especially in the south and east of Austria will decrease in the period until 2050. The transpiration will increase correspondingly. It also points to the big uncertainties of climate models, even more of regional climate models and states that there is no evidence for an increase of extreme weather events.

Another possibility for generating regional future climate data (only for Austria) has evolved out of the results of the project "Tools for models of a sustainable land use" (Sinabell 2010). The method is different to the ones above: On the base of long time data series the trends for climate parameters are extrapolated. Various scenarios for general precipitation and temperature development offer numerous variants of the regional distribution of precipitation and temperature. This method is useful for short and middle term prognosis (10-30 years) but offers all imaginable scenarios without prioritization.

Figure 5: easonal changes in mean precipitation between 2041-2050 and 1981-1990 (M, A, M, J, J, A, S, O, N, D, J, F: months))



Source: Loibl and Gobiet 2006.

3.2 Vulnerability of agriculture concerning water scarce

To generalise and to rise the awareness for the entire vulnerability of the agricultural sector in a regional scale concerning water scarce, the different partial risks are made comparable through a common view. To get the different types of scale into one common scale, the estimated partial values are standardised (transformation to average =0 and standard deviation and variance = 1). This gives a clear picture of the various patterns in the Alp Water Scarce pilot sites. Keeping the indicators for land use, livestock and soil constant and changing only the aridity index shows the relevance of the changing water balance for the agricultural vulnerability.

For some purposes (general comparison of pilot sites, integration of agriculture in general scenarios) it may also be of use to aggregate the partial risks to one value per pilot site, i.e. to take the average of partial vulnerability is taken. However, it is necessary to keep in mind that not all pilot sites data sets cover the whole range of indicators.

4 Agricultural vulnerability characterisation in Alp Water Scarce pilot sites

The Alp Water Scarce project endeavors to demonstrate climate change and water management concerns by the examples of pilot sites in France, Switzerland, Italy, Slovenia and Austria, see also www.alpwaterscarce.eu. Altogether there are 23 pilot sites; not for all of them data for the agricultural elaborations were available, and not for all of the agricultural pilot sites the data sets were complete. The following pilot sites were subject to closer examination in the agricultural sub-project (see table 8):

Table 8: Alp Water Scarce pilot sites overview

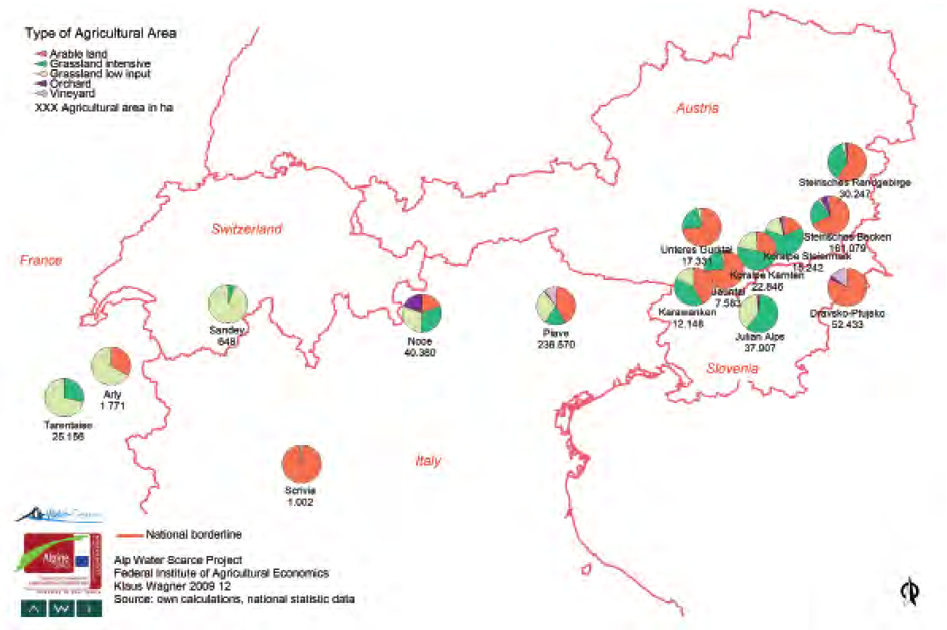
Country	Alp-Water-Scarce pilot site	Area, km²	Altitudinal range, m above sealevel	Precipitation, mm/year, avg.	Climatic zone (Histalp)
Austria	Steirisches Randgebirge	650	330-1,470	846	Northeast
	Koralpe Kärnten	~500	340-2,100	841	Northeast
	Koralpe Steiermark	~300	340-2,100	1,150	Northeast
	Karawanken	1,270	400-2,558	1,528	Southeast
	Jauntal	134	~500	1,057	Southeast
	Unteres Gurktal	80	~500	889	Southeast
	Steirisches Becken	3,700	200-1,040	821	Northeast
France	Tarentaise	13	860-1,300	941	Northwest
	Arly	47	1,000-2,525	1,424	Northwest
Italy	Piave	3,900	n.a.	1,114	Southeast
	Noce	1,367	~1,624	972	Southwest
	Scrivia	1,237	60-1,700	737	Southwest
Slovenia	Julian Alps	1,600	180-2,864	1,600-4,000	Southeast
	Pohorske-Dravsko-Ptujsko Polje	593	~232	914	Southeast
Switzer-land	Sandey	2	790-910	1,449	Northwest

Source: www.alpwaterscarce.eu, accessed 9.12.2011; own survey among project partners; http://www.zamg.ac.at/histalp/, accessed 9.12.2011

4.1 Land Use

The alp water scarce pilot regions with available data for agricultural land use cover a representative range of various types of alpine regions (fig.6). The possibilities of diverse land use types are limited by natural conditions. In the regions at higher altitudes, e.g. Tarentaise, Sandey and Julian alps, agriculture only exists in the form of grassland farming, with varying shares of intensively used grassland and low input grasslands. The southerly exposed and partly flat regions Scrivia, Noce, Piave, Dravsko-Ptujsko and Steirisches Becken have their focus on arable land with various proportions of orchards, vineyards and vegetables. Most of the Austrian regions show considerable shares of all types of cultivation, related to their proportions of high- and flatlands and bottom of valleys.

Figure 6:
Agricultural land use - overview



The results of classifying the land use types due to their water demand (fig. 7) show high proportions of high vulnerability classes in most of the project regions because of their high share of water demanding grassland. Lower situated regions are adapted to lower water supply with low demanding types of crops but rely more on irrigation – especially in the case of the southern regions Dravsko-Ptujsko, Noce, Piave and Scrivia. In telephone interviews with experts of the agricultural chambers in concerned districts of the Austrian pilot sites it has been stated that irrigation plays only a minor role. Irrigation is necessary only during dry years and only for efficient production of special crops (orchards, vegetables, maize seed). Only in the pilot region Steirisches Becken there is a considerable irrigated area of ~3,000 ha which represents a share of 1.9 % of the agricultural area in this region. In sum (fig. 8) the land use vulnerability classes show that agriculture with its choice of land uses has already adapted very well to the given water supply. Nevertheless, if the water regime will change due to very high demand, difficulties may occur.

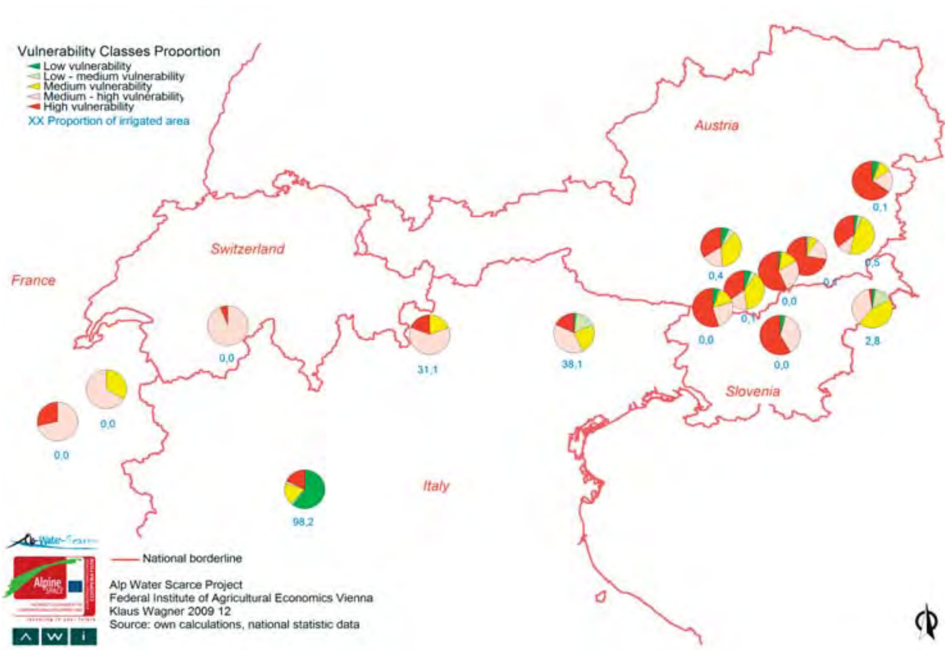
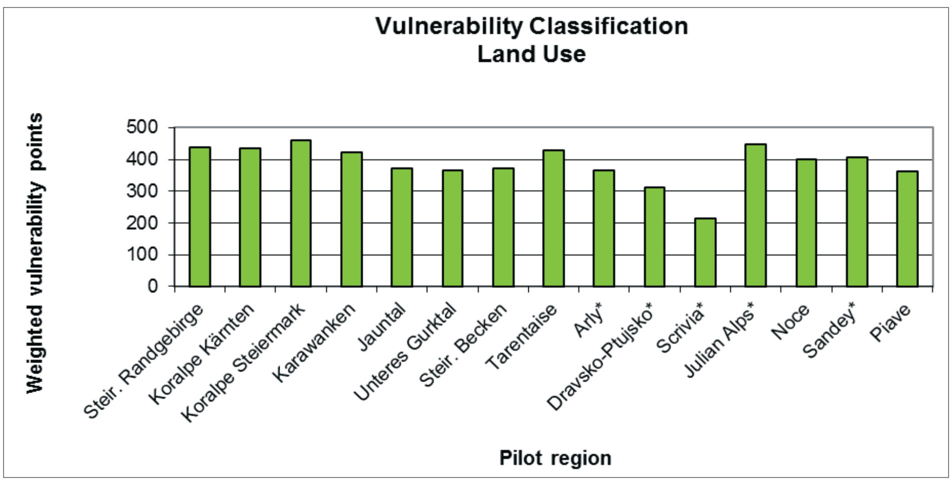


Figure 7: Agricultural land use - vulnerability classes



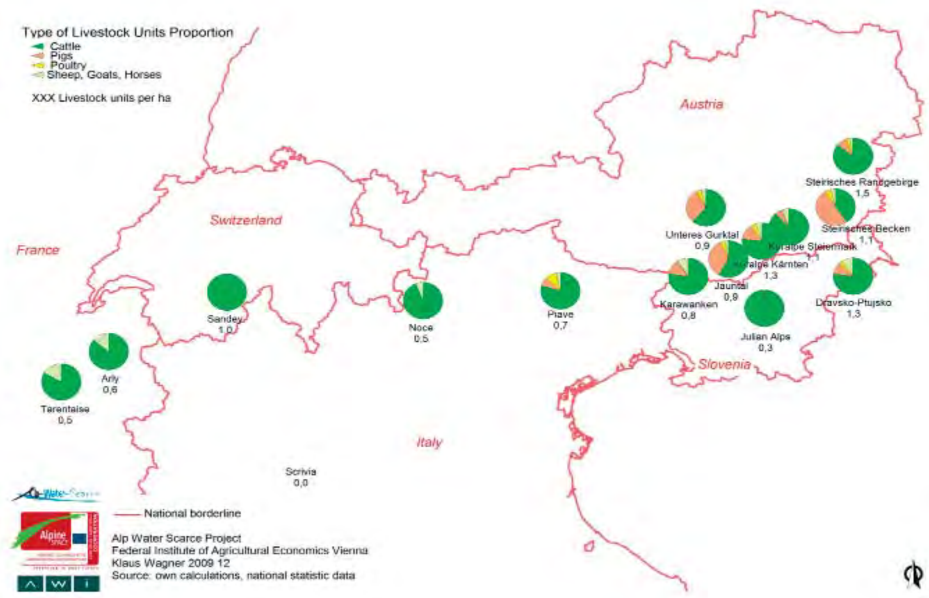
*: incomplete data set

Figure 8: Summarised land use vulnerability

4.2 Livestock

Corresponding to the land use in many of the regions (fig. 9) cattle is the most common livestock, in many cases in low density below 1 livestock unit per ha agricultural area. In most of the Austrian pilot sites as well as in Dravsko-Ptujsko and Piave the category pigs and poultry show considerable proportions. Proportions above 10 % of the category sheep, goats and horses can be found in Tarentaise, Arly, Karawanken and Dravsko-Ptujsko.

Figure 9
Livestock - overview



The livestock vulnerability classification (fig.10) - taking into account the various types of livestock keeping and its specific water demand – shows relatively high proportions of the highest vulnerability classes in some of the Austrian pilot sites. Proportions of more than two thirds in the middle vulnerability class can be found in Tarentaise, Arly and Noce. The summary of livestock vulnerability (fig. 11) classifies Steirisches Randgebirge, Koralpe Kärnten and Steiermark and also Dravsko-Ptujsko as highest vulnerable regions with respect to this concern, also expressed in an water demand of livestock per ha agricultural area and year higher than 20 m³. The Julian Alps, Tarentaise, Arly, Sandey, Noce and Piave with their low input livestock systems show only low vulnerability for water scarce.

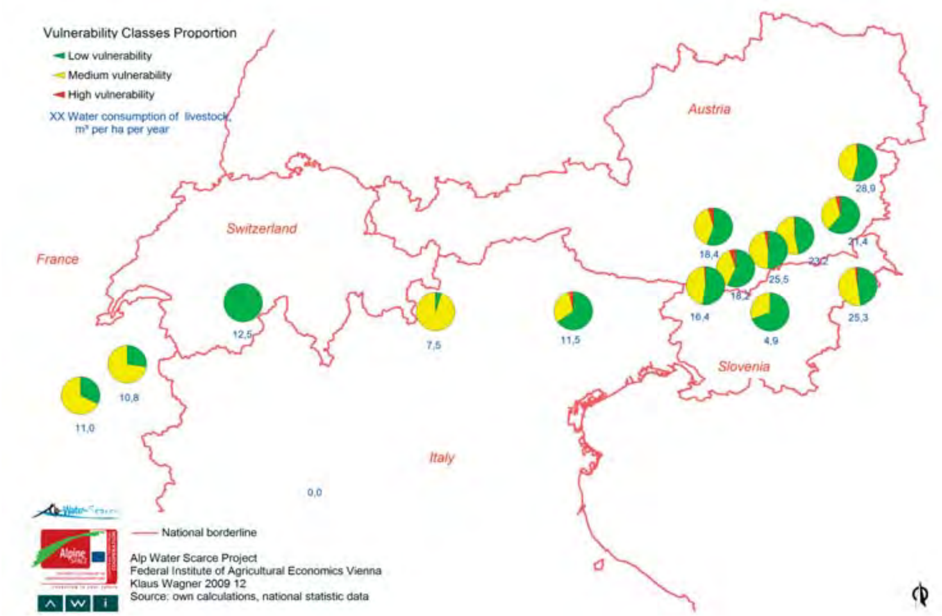


Figure 10: Livestock - vulnerability classes

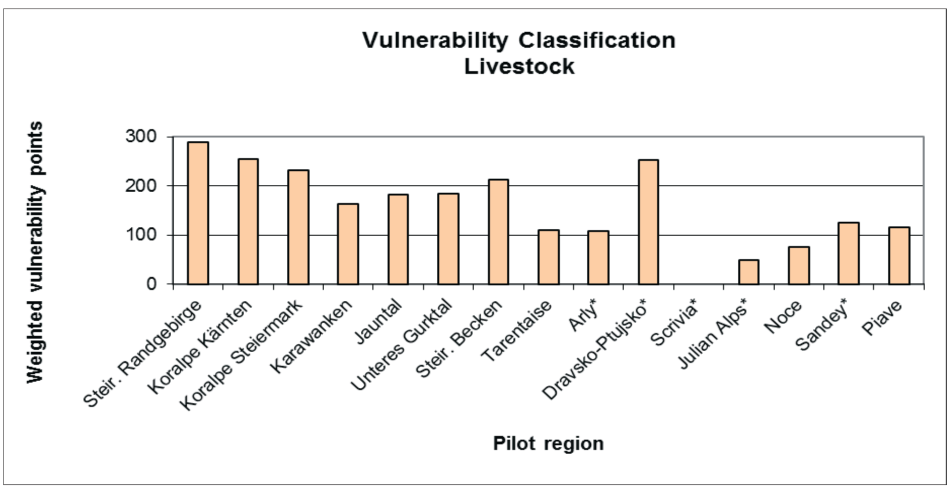


Figure 11: Summarised livestock vulnerability

incomplete data set

4.3 Soil

The soil conditions in the pilot regions give hints to mostly difficult situations in higher alpine regions (Tarentaise, Noce, Julian Alps, Karawanken) and better conditions in regions with higher proportions of flatlands and valley floors which allow higher rates of water saving and compensation of dry periods.

Figure 12: Soil - vulnerability classes

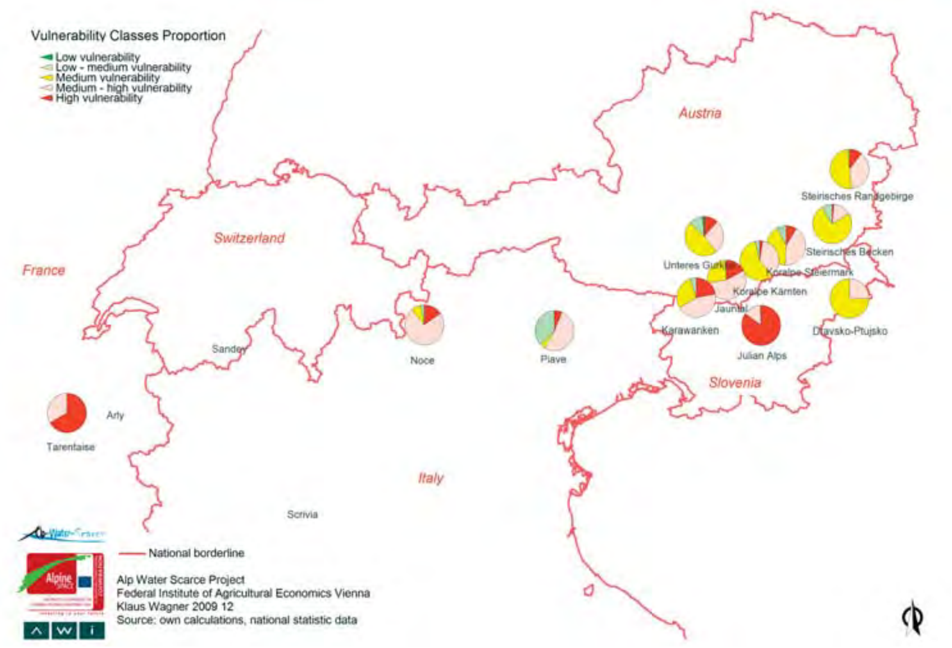
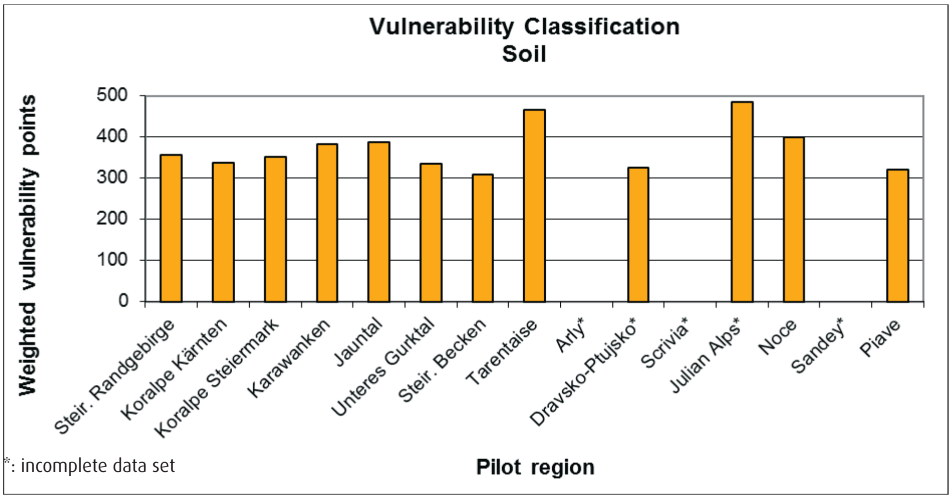


Figure 13: Summarised soil vulnerability



4.4 Climate

Climate conditions (fig. 14) vary widely for different sites of the alp water scarce regions. The pilot sites Arly and Sandey, situated on high sea level, receive the biggest yearly amounts of precipitation. The most southern region Scrivia copes with very low precipitation while the others exhibit average precipitation but with strongly varying seasonal distribution. In most cases the situation with respect to temperatures is vice versa. The southern exposed regions Scrivia and Dravsko-Ptujsko have the highest average temperatures, Arly the lowest. The seasonal distribution of temperatures among the regions differs not as much as precipitation.

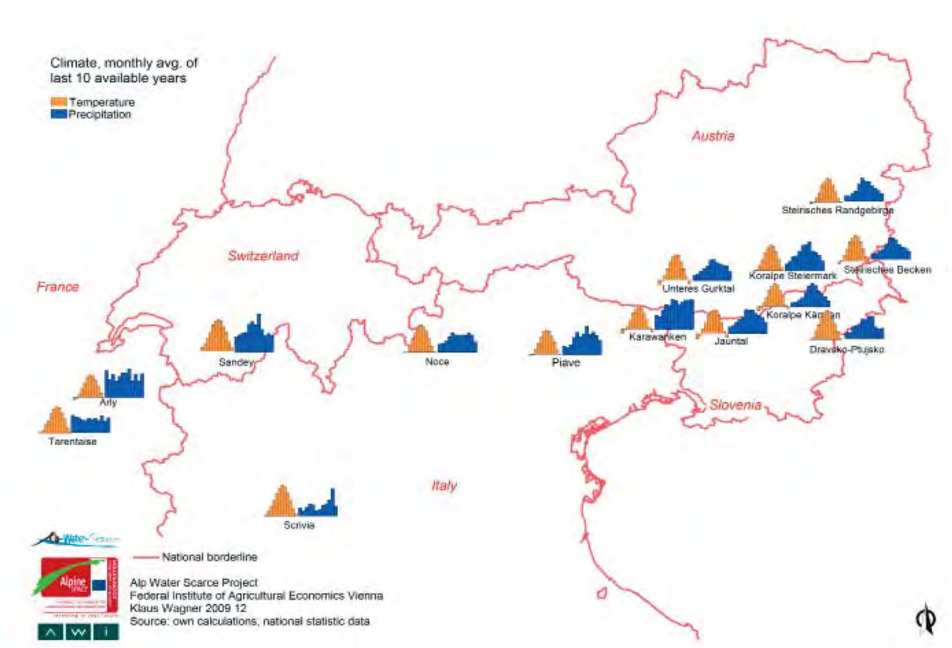
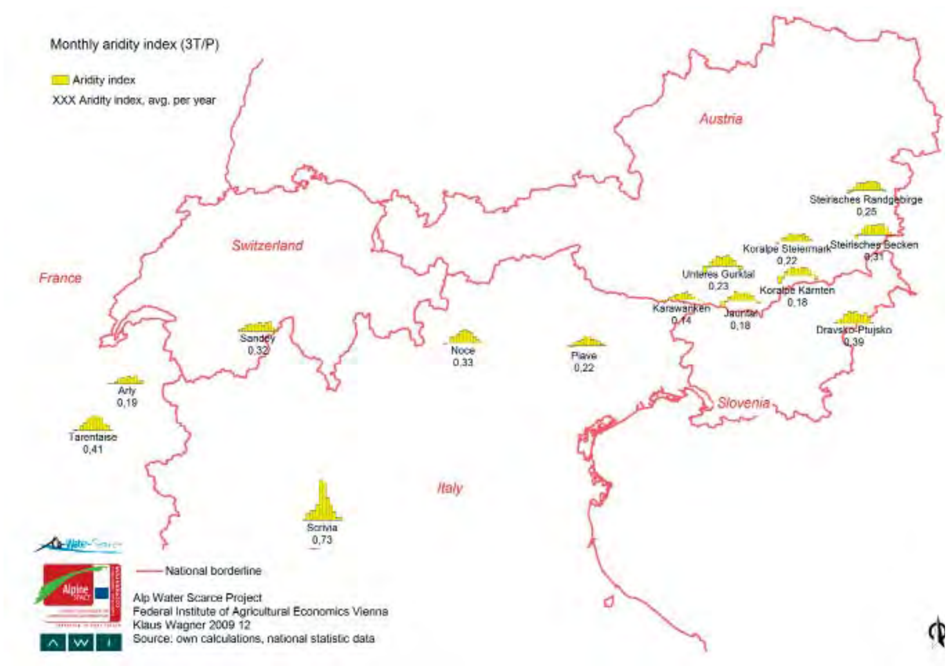


Figure 14: Climate - overview

The aridity index (fig. 17) as a combination of temperature and precipitation gives an overview about potential vulnerability of water shortage. The vulnerability is above average in Tarentaise, Sandey, Noce, Steirisches Becken, Dravsko-Ptujsko and extremely high in summer in Scrivia. More important than the average aridity risk per year is the seasonal course in combination with the water capacity of soils.

Figure 15: Climate - vulnerability classes



4.5 Vulnerability assessment for a future scenario

As data for regional climate change scenarios the results of the RECLIP:more project (Loibl and Gobiet 2006) have been used to calculate the seasonal aridity index and the differences and fluctuations compared to the current situation (fig. 16). It should be pointed out that this is an exemplary work because of the high uncertainties of regional models, mentioned already in chapter 3.1.6. The results show an increase of aridity in all pilot sites. Only minimal changes in aridity are estimated for Tarentaise, Arly, Sandey and Karawanken but stronger changes for the other pilot sites. The most important changes can be predicted especially for Steirisches Randgebirge, Jauntal, Lower Gurktal, Steirisches Becken, Noce, Spöl, Dravsko-Ptujsko. Of high importance is the seasonal distribution of the aridity index. While in some regions winter and spring aridity will increase (for example in Lower Gurktal, Koralpe Kärnten, Jauntal) in others aridity will increase more in summer or autumn, for example in Steirisches Randgebirge, Steirisches Becken, Dravsko-Ptujsko). An extreme increase of aridity is estimated for Scrivia, where the aridity indexs already is very high in summer at present.

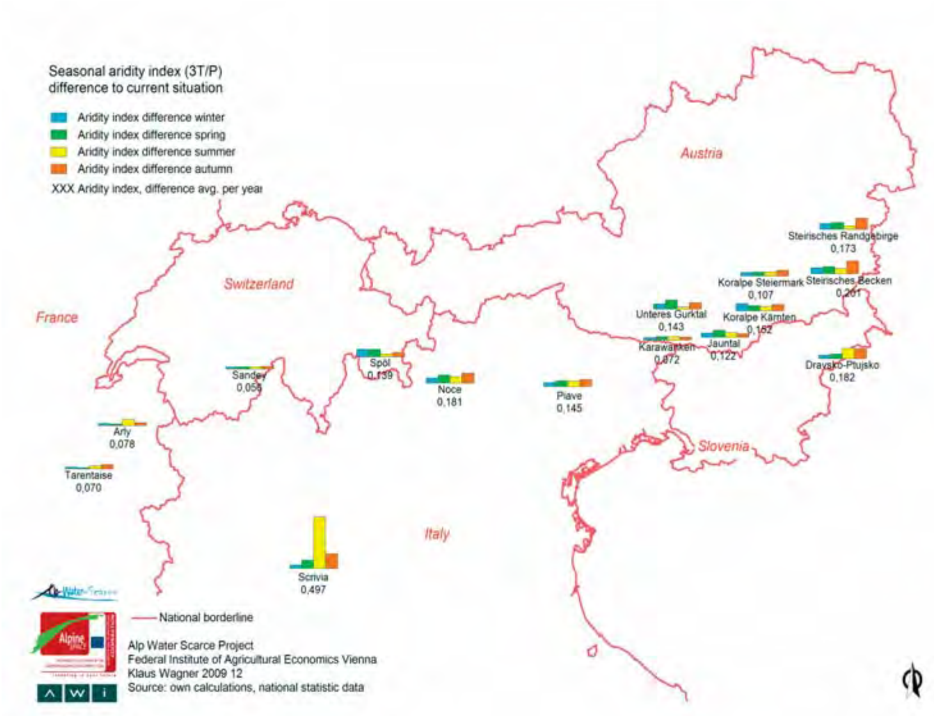


Figure 16:
Climate change scenario 2050 – Seasonal change of aridity index in selected Alp Water Scarce pilot regions

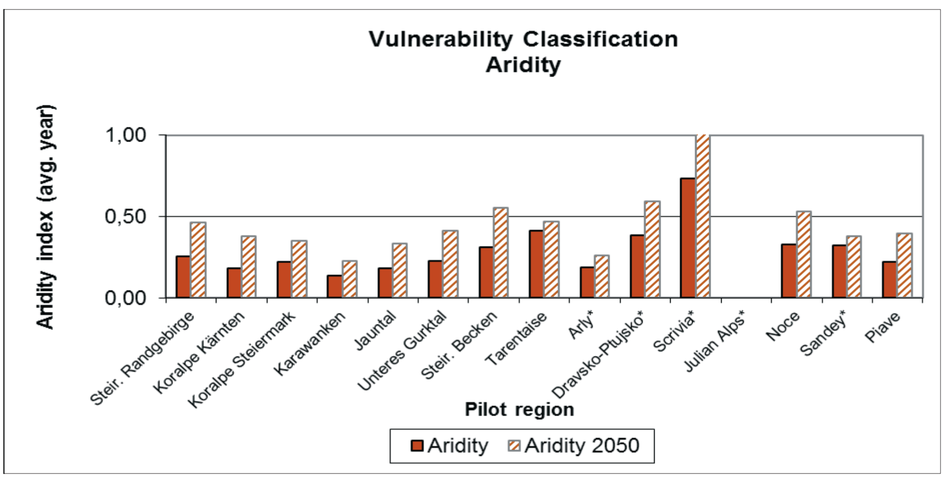


Figure 17:
Summarised climate vulnerability

*: incomplete data set

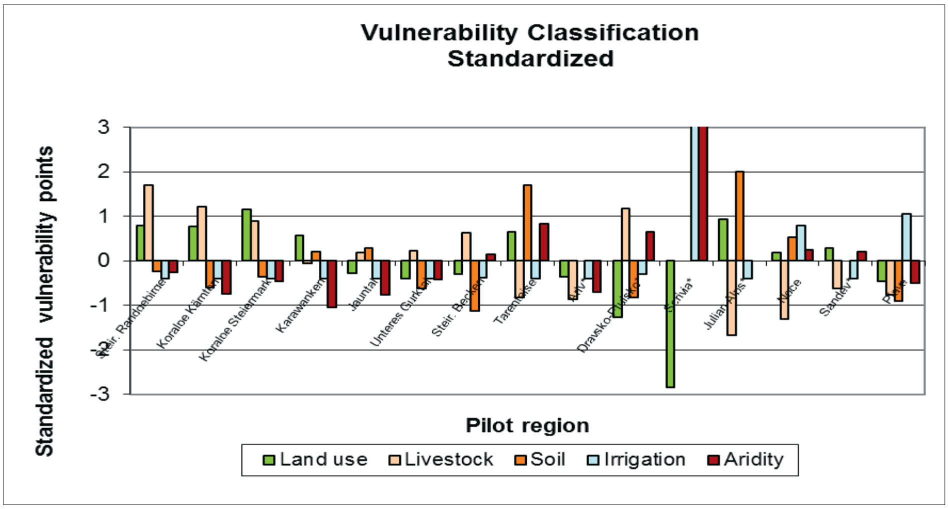
There are no unified and precise enough long term estimations of agricultural development until 2050. Therefore only a qualitative description is outlined here. The various agricultural land use categories will develop differently. Intensively used areas in advantaged regions will decrease less than low input farmland in disadvantaged regions, which could lead to less water consumption by agriculture. But in the same way an intensification of remaining agricultural land in advantaged regions will take place which requires a higher demand for water. These circumstances may lead to higher proportions of more water demanding categories and a slightly higher vulnerability classification than in the current situation, for example in Tarentaise, Dravsko-Ptujsko, Noce, Lower Gurktal and Steirisches Becken.

Also livestock will decrease in absolute numbers, and the general water consumption for livestock will decrease. Because of intensification tendencies for livestock husbandry as well as for agricultural areas which decrease, water consumption per ha agricultural area will grow. This trend concerns especially the eastern pilot sites like Piave, Dravsko-Ptujsko and the Austrian pilot sites. This fact may be of special importance in regions with high competition for areas among the sectors of regional development.

4.6 Vulnerability assessment results

Following the method described in chapter 3 the pilot regions with available data have been analysed due to their vulnerability concerning the relation between agriculture and water scarce. For comparison figure 18 shows the various sectorial vulnerabilities of the pilot sites in one common scale and after standardization. It gives hints to the regional priorities for implementing adaptation measures.

Figure 18: Standardized vulnerability classification for the current situation



*: incomplete data set

In generalised assumptions, the aggregation into one agricultural vulnerability indicator concerning water scarce may be used (avergage of the standardized partial vulnerabilities). It shows the highest vulnerability in Steirisches Randgebirge, Tarentaise and Scrivia - because of specific land use and livestock characteristics in Steirisches Randgebirge and because of worse soils and climate conditions in Tarentaise. In Scrivia the high aridity blots everything else. Also the Slovenian regions Dravsko-Ptujsko and Julian Alps show vulnerabilities above average. The lowest risk of all pilot sites is given in Arly and Piave. However it has to be mentioned that not all regional data sets cover all details.

Summarizing, we can identify more or less concerned regions facing future water scarce in comparison to the current situation. In Tarentaise a slight increase in aridity comes together with a presumably higher vulnerability classification in land use. In Noce a considerable increase in aridity goes hand in hand with a higher vulnerability classification for agricultural land use. Livestock plays no important role there. In Scrivia the land use vulnerability classification will drop a little but the aridity will increase heavily and the amount of irrigation (which currently is very high) already will increase accordingly; livestock there is not important. The Slovenian region Dravsko-Ptujsko will suffer from higher aridity, and agricultural land use will have a higher vulnerability classification in the future. Livestock is of high importance there. Also the Austrian regions will face higher aridity (very different depending on seasons). There livestock is very important and the water consumption per hectare agricultural area will probably increase. But at least the vulnerability classification of agricultural land use in most of the Austrian regions is not expected to increase.

5 Strategies and measures for mitigating water scarce in agriculture

Alongside climate change prevention and mitigation strategies, the EU member states must also prepare regional adaptation strategies that specifically address water supply shortages. Adaptation actions are needed to cope with changing climate, and these must aim at reducing the risk of, and damages from, potentially harmful climate-change impacts both now and in future. Strategies and measures may work on different levels of implementation – from general EU policy objectives down to practical farm management advisory recommendations. Early action will bring clear economic benefits by anticipating potential damages and minimising threats, whereas market forces alone are unlikely to lead to efficient adaptation because of the high degree of uncertainty in climate projections. Importantly, adaptation measures will involve all actors, starting with individual citizens and through to local, regional, national and EU-level stakeholders.

Adaptation strategies in agriculture must take into account socio-economic constraints that vary widely depending on production systems, types of cultivation and the competitive situation regarding water consumption versus other sectors, but also depending on the level of intervention. The mapping of vulnerable areas, hazard assessments, forecasting and appropriate spatial planning should serve as a basis. In the case of agriculture, it makes sense to integrate adaptation goals directly into the Common Agricultural Policy (CAP). The EU green paper on adapting to climate change (European Commission 2007) formulates four pillars of EU actions:

- Early action in the EU, which means integrating adaptation when implementing and modifying existing and forthcoming legislation and policies. In the case of agriculture, climate change will add to the pressures of liberalisation and international competition, while the role of agriculture as a provider of environmental and ecosystem services will gain further importance.
- Integrating adaptation into EU-external actions, which means influencing EU relations with third-party countries.
- Reducing uncertainty by expanding the knowledge base through integrated climate research.
- Involving European society, business and the public sector in the preparation of coordinated and comprehensive adaptation strategies. This could induce significant restructuring, especially in the agriculture, renewable energy and tourism sectors.

The Austrian strategy for adaption to climate change (Lebensministerium 2011a) states some general principles of adaptation (e.g. information, responsibility, co-operation, including uncertainties, integration of measures into existing instruments and structures, avoiding conflicts in objectives and exploitation) and criteria for the prioritization of measures (e.g. relevance, pressure, resilience, flexibility, cost-benefit). The scientific literature offers no unanimous judgement as to whether autonomous (private sector) adaptation or planned public sector measures are most effective (Schaller, Weigel 2007). However, in any case, adapted extension services, policy options, monitoring and management plans are deemed essential. Concrete actions could include soft and inexpensive measures, for example employment of drought tolerant crop varieties, land-use planning, awareness raising, direct seeding during winter planting and measures to change farmers' attitudes and provide them with advice. In addition to their water-saving potential, these measures would help farmers save labour and money. Adaptation can also bring about new economic opportunities, such as adapting local agricultural management practices to longer growing seasons (European Commission 2007).

Numerous possibilities exist for influencing water consumption in agriculture. The first is related to the farmers' decision as to which kind of production they wish to rely on. In general, winter crops, C4 plants and perennial plants (especially deeply rooting ones) use water much more efficiently. Sowing spring crops earlier and using early ripening varieties would also be beneficial, as this mitigates water stress during summer. By selecting drought-tolerant species and varieties, crop failure and water consumption can be reduced (Bates et al. 2008; Zebisch et al. 2005). Climate change alters the availability of nutrients and shifts vegetation periods and yields. In general there will be higher risks of heat stress and heat damages, and new breeding efforts should therefore result in less water consumption, higher water efficiency, tolerance against dehydration and escape strategies – all leading towards the goal of quick development and early ripening (Flamm 2010). For example, wintercereals consume more water overall but on the other hand are increasingly tolerant against heat stress.

Of course, important determinants of wather consumption are land-use systems (conventional, integrated or organic), plant cultivation measures, the selection of species in crop rotations, plant and livestock density, yield and fertilising levels, and management and soil cultivation (WIFO 2004, CIPRA 2011). In detail, measures need to improve irrigation efficiency (reduced water losses, recycling and better storing of water) and promote water-efficient techniques to conserve soil moisture, as well as modification of crop calendars with respect to timing, location and cropping activities (Bates et al. 2008, European Commission 2009). Also important are nutrient, weed and pest management methods (Schönberger 2008, Kromp-Kolb 2004) as well as mowing times and grazing systems (Schaumberger, Buchgraber 2008). Landscaping measures can provide better protection against wind and water erosion and evapotranspiration (Eitzinger 2007, ADAGIO 2009) while implementing buffer zones can reduce water run-off (European Environment Agency 2009).

Many measures are necessary and make sense even without the impact of climate change, but the effects of climate change will increase the stress on natural resources and render adaptation measures more urgent (Balas 2010). In order to save water and to conserve soil moisture, several possibilities for practical land management exist. The minimisation of tillage (chisel plough, ridge till, strip till and mulch till) reduces evaporation and enhances the soil's water-storage capacity. Therefore, techniques for achieving a high water-absorption capacity of the soil and low site sensitivity to water erosion should be applied whenever possible (Schaller, Weigel 2007). As far as land-use systems are concerned, organic farming positively influences soil structure and thus the soil's water storage and absorption capacity (Schaller, Weigel 2007). In addition, renouncing the use of chemical fertilisers in organic farming can save water in the upstream production process of fertilisers (Zebisch et al. 2005). Due to the higher CO_2-concentration, nitrogen fertilising will still be beneficial in conventional farming. At the same time, increased plant growth causes higher water consumption, so fertilising needs to be handled with care (Zebisch et al. 2005).

Furthermore, landscaping measures like terracing, furrow diking, land contouring (Smith, Lenhart 1996) and planting hedges (Formayer 2007) can bring about better wind and evaporation protection. For instance, hedges acting as windbreaks also decrease soil erosion and increase the water-use efficiency of crops (Gerersdorfer et al. 2009). However, all measures carry the risk of lower outputs for the farmers (Strauss et al. 2011). Under environmental and economic constraints, the option of irrigation is, for the most part, not a viable solution because the marginally higher crop yields often cannot compensate for the higher production costs.

In order to mitigate water scarce, efficient and economical water use in agriculture is essential. This goal can be achieved in many ways, for example by efficient water pricing policies (European Commission 2007) and by improving existing, and/or appropriately dimensioning and funding new, agricultural irrigation infrastructure (Bates et al., 2008). On farm level, irrigation should be minimised to an unavoidable amount and area only. Farmers could collect storm water (Schaller, Weigel 2007) and recycle wastewater (e.g. in local reed beds) to obtain additional water for irrigation. Government may support these measures by providing financial incentives and information.

In order to reduce and compensate damage caused by water scarce, the terms of crop insurance and emergency aid could be adapted. For reducing vulnerability to water scarce, diversification and the spreading of risks are crucial. Diversifying crop and livestock types and varieties (Smit, Skinner s.a.) as well as farmers' sources of income (e.g. farm holidays, snow clearance, etc.) may minimise the risk of total loss of income due to changing weather conditions (Formayer 2007, Smith, Lenhart 1996).

Wherever applicable, water-intensive production lines (e.g. livestock husbandry, orcharding) should be relegated to regions with abundant water. Similarly, water can be saved by increasing the husbandry of animals with a relatively low water demand – for instance cattle instead of more water-demanding poultry or hogs (KTBL 2008) – or by decreasing husbandry overall. Of course, these adaptation measures need to be aligned with the farmers' and consumers preferences.

It is important to emphasise that the mentioned measures at producer and public level may not only be adopted due to climate change, but also due to a wide variety of other determining factors such as economic conditions, institutional arrangements, social norms and politics (Smit, Skinner s.a.).

The study "Climate change adaptation strategies for Austrian water management" (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft 2010) offers a bundle of adaptation measures related to future flooding, ground and surface water, water temperature, amount and quality, and the effects of water use. Concerning agriculture and water scarce, the study very generally mentions that regional strategies for decreasing water consumption seem necessary and that priorities for water use during times of scarcity should be set as a precaution.

Table 9: Potential water scarce adaptation and mitigation measures in agriculture, source: Authors' own elaboration

Type of strategy	Arable land and perennial culture measures	Grassland measures	Livestock husbandry measures
1. Land /stable management, soil cultivation	Adapted nutrient, weed and pest management; adapted growth regulators; technologies for a sustainable soil structure and conserving soil moisture (conservational tillage, mulching, organic farming); landscaping measures; adapted crop calendar (earlier sowing of spring crops, later sowing of winter crops, early ripening varieties).	Adapted nutrient, weed and pest management; mowing times and grazing systems; landscaping measures.	Adapted grazing systems; adapted stable systems.
2. Intensity	Adapted nutrient management; plant density; reduced yield levels.	Adapted nutrient management; reduced cutting frequency.	Reduced livestock density; extensive grazing management; nutrient management.
3. Varieties, species	Adapted varieties, species, cultivars; enhancement of seed banks.	Adapted varieties or species with higher drought tolerance; enhancement of seed banks.	Drought tolerant species.
4. Products	Adapted crop rotation (adapted use of winter/ spring crops, perennial plants and C4 crops); reduction of bare fallow; abandonment with green cover.	Adapted production system; temporary grassland; transformation of land use.	Less intensive production; replacing high waterdemand genera (hogs, poultry) with less demanding ones (cattle).
5. Farm management	On farm water collection facilities and reservoirs; terracing, land contouring and furrow dyking; hedge planting; farmer education and advice; weather risk management (e.g. insurance systems).		
6. Water management	Irrigation and its efficiency in dependence of sufficient ground water supply; water pricing.		
7. Policy and Administration	Eco labels for efficient water use; integration of adaptation goals into CAP; improvement of knowledge and data on water scarce and forecasting, on new diseases promotion of technological innovation; contingency planning for droughts, elaboration of risk mitigation plans; user-pays-principle and efficient water pricing schemes; Legal restrictions of water use and rationing of water; development of risk management systems; appropriate planning and dimensioning of agricultural infrastructure; establishment of technical standards; river basin planning and coordination; awareness raising and education, voluntary compliance, informing and gaining participation of stake-holders in order to develop a "water-saving culture"; evaluation and monitoring of measures.		

6 Current agricultural policy measures with an impact on water consumption

The present Common Agricultural Policy (CAP) provides a basic level of income security to farmers as well as a framework for sustainable management of the natural environment in which agricultural activity takes place. The shift from production-linked support to decoupled aid enables farmers to respond flexibly to external requirements, market signals and developments resulting from climate change. Cross-compliance links the full receipt of CAP payments – including some rural development payments – to the respective EU environmental legislation, to public, animal and plant health, including animal welfare, and to the maintenance of farmed land in good agricultural and environmental condition. Requirements governing the maintenance of permanent pastures, as well as those governing specific soil practices to avoid erosion and retain organic matter, contribute both to the sustainable use of resources and to adaptation. The Farm Advisory System ensures the availability of advice on the basic environmental requirements for farmers. Facilitating farmers' access to risk management tools, such as insurance schemes or mutual funds, also helps them to cope with the economic consequences of greater fluctuations in crop yields, animal diseases or weather events. In the CAP Health Check, EU member states have been given the option of using part of their national financial envelopes for risk management tools within CAP support. This represents a further step in the direction of sustainable agriculture with a specific emphasis on climate change mitigation and adaptation, as well as on water and biodiversity protection, for which additional rural development funding has been agreed on (European Commission 2009).

With rural development policy gaining a higher share within the CAP, member states are now offered a range of measures providing targeted support for activities that also contribute to climate change adaptation. The rural development framework can make an essential contribution to adaptation, as farm-level, local and regional adaptation all require a policy environment that strengthens the conditions for adaptation actions. Under the competitiveness of pillar 2, support for farm modernisation and the restoration of agricultural production potential can promote adaptation to climate change. For example, preventive mechanisms against the adverse effects of climate-related extreme events (e.g. the setting up of hail nets) and the adaptation of buildings (e.g. for housing livestock) can be supported. Improved measures and the development of infrastructure together offer opportunities for addressing water management issues, thus complementing modernisation measures that provide support for water-saving investments and more efficient irrigation equipment. Support for diversifying crop patterns, structures and agricultural activities, as well as for diversification into non-agricultural activities, is available under axis 2 and 3. This helps make production systems more resilient to both economic and climatic factors, as diversification is a key factor for ensuring the stability of agricultural incomes. Within the environmental and land management axis, agri-environmental schemes targeted towards better management of soil, water and landscapes have an important role. Investing in human capital is an EU priority for rural development, and will also be a key factor with a view to coping with climate risks. All member states devote support to training, informing and generally diffusing knowledge that is oriented towards improving farm management, cropping and livestock production methods, and environmental land management. Support can also be provided for setting up farm management and advisory services, and for their use by farmers. Rural development furthermore plays a role in the conservation and sustainable use of genetic resources. This contributes to maintaining a broad genetic resource base which in turn can facilitate the selection of genetic material that is resistant to changing diseases and pests, as well as the development of varieties that are more tolerant to heat and water stress.

The currently heated discussion regarding the future CAP until 2020 shows that there will be some cuts and adaptations made which will affect the environmental and economic situation, as well as future expectations. Three main objectives (viable food production, sustainable management of natural resources and climate action, and balanced territorial development) have been set and three options (gradual changes and adjustments to the current policy, major policy overhauls for more sustainability and balance, and a strong focus on environmental and climate change) have been elaborated by the DG Agri (2010). As always, the final outcome will be a compromise between many different demands of the various lobbies. In general, it is probable that there will be more weight placed on environmental and sustainability criteria; but, since the financial constraints will be stronger, the amount of money for CAP measures seems likely to be smaller in future.

On EU level, the Nitrate Directive (91/676/EEC) focuses more on water quality than on water quantity, although it does indirectly influence agricultural water consumption by restricting nitrate input. In this manner, it also restricts agricultural yields on the one hand and livestock intensity on the other, both of which will lead to reduced water consumption. The EU Water Framework Directive (2000/60/EC) raises awareness on water consumption by obligating member states to survey and analyse water use and put water management plans into force, including protective and restrictive measures in specific areas.

Tables 10 and 11 below show the current measures of the CAP and their likely effects on water consumption and water scarce, respectively. The assessments of the effects of the different measure packages are based on plausibility checks and have two dimensions: One is the “direction” of the effects, as to whether the specific measure directly or circuitously affects water consumption, while the other is the direction of the effects, which implies whether the CAP measure influences water consumption positively (by decreasing water demand), negatively (by increasing water demand) or indifferently (water demand influenced positively and negatively at the same time, depending on the specific circumstances of implementation).

Table 10:
Current measures of the first pillar of the Common Agricultural Policy and their potential effects on water consumption

Category	Measure	Type of effect related to water scarce	Explanation of potential effects	Legal foundation
Decoupling	Decoupling of direct payments	Indirect, positive	Decoupling agricultural subsidies from production provides more flexibility for farmers. Production depends more on market demand, resources can be used more effectively and efficiently, and a reduction of surpluses also helps to save water resources.	Reg. (EC) 1782/2003 A: VO. 2007. BGBl II 322/2007
Coupled Income Aid	Quality premium for durum wheat	Direct, positive	Durum wheat consumes a relatively low amount of water.	Reg. (EC) No. 1782/2003 A: CAP aid regulation 2008
	Quality premium for protein crops	Direct, positive	Protein crops consume a relatively low amount of water.	Reg. (EC) No. 1782/2003 A: CAP aid regulation 2008
	Energy crop aid	Direct, indifferent	Subsidising energy crops has an indifferent effect on water consumption because of strongly varying water demand, depending on the crops (e.g. high water demand for rapeseed, low water demand for millet).	Reg. (EC) No. 1782/2003 A: CAP aid regulation 2008
	Cattle slaughter premium	Direct, indifferent	Cattle raising consumes a low amount of water - compared to other livestock sectors - but stimulates livestock farming.	Reg. (EC) No. 1782/2003 A: CAP aid regulation 2008
Market Regulation	Milk quota	Direct, indifferent	By limiting surplus milk production (and thus water use), consumption is avoided; but it also keeps milk production in regions that would concentrate on lower water-demanding production sectors if there were no quotas.	Reg. (EC) No. 1234/2007 Reg. (EC) No. 361/2008
	Export refund	Indirect, negative	Export refunds level the difference between lower world market prices and higher domestic prices, thereby giving incentives for domestic production and exports (which raises domestic production and water consumption).	Reg. (EC) No. 800/1999 Reg. (EC) No. 1043/2005 Reg. (EC) No. 1854/2006
	Customs duties and levies on imports	Indirect, negative	Customs duties and levies on imported products limit imports and give incentives to domestic production (and water consumption).	Reg. (EC) No. 1234/2007 Reg. (EC) No. 361/2008
	Customs duties on export	Indirect, positive	Customs duties on exports reduce domestic price and production (and water consumption).	Reg. (EC) No. 1234/2007 Reg. (EC) No. 361/2008
	Market intervention (e.g. wheat, barley, beef, butter, skimmed milk powder)	Indirect, negative	Through market intervention, prices are prevented to drop below a guaranteed level. This decreases production risks and gives incentives to produce (and consume water).	Reg. (EC) No. 1234/2007 Reg. (EC) No. 361/2008

Axis	Measure	Type of effect related to water scarce	Explanation of potential effects	Legal foundation
Axis 1 - Competitiveness	Knowledge and human potential, A: M111	Indirect, positive	Participation in vocational trainings and other information measures help increase the awareness of farmers for climate change, water consumption and the efficient use of water.	Reg. (EC) No. 1698/2005 Article 20 and 21 No. 1974/2006 Annex II
	Modernisation of agricultural holdings, A: M121	Direct, positive	Structural and technical investments can contribute to more efficient use of resources.	Reg. (EC) No. 1698/2005 Article 20 and 26 No. 1974/2006 Article 17, Annex II
	Adding value for agricultural products, A: M123	Direct, positive	Supports investment for increasing the positive environmental effects or the efficiency of resource use.	Reg. (EC) No. 1698/2005 Article 20 and 28 No. 1974/2006 Article 19, Annex II
	Improving and developing agricultural holdings infrastructure, A: M125	Direct, positive	Supports investment for irrigation systems, water retention and regional water management improvements.	Reg. (EC) No. 1698/2005 Article 20 and 30 No. 1974/2006 Annex II
Axis 2 - Envi-ronment and Countryside	Natural handicap payments in mountain and other areas, A: M211	Indirect, indifferent	Maintaining agriculture in naturally handicapped regions, which means agricultural production (and water consumption) in areas that may otherwise be abandoned.	Reg. (EC) No. 1698/2005 Article 36 and 37 No. 1257/1999 Article 13-15; 17-20 No. 1974/2006 Annex II
	Natura 2000 payments and payments linked to Directive 2000/60/EC (Water Framework), A: M213	Direct, positive	A positive influence on the water balance is assured by restricting the agricultural utilisation of certain protected areas.	Reg. (EC) No. 1698/2005 Article 36 and 38 No. 1974/2006 Article 26 Annex II
	Agri-environment payments, A: M214	Direct and indirect, positive	Farmers receive money (as beneficiaries) for implementing various environmental measures. See also below.	Reg. (EC) No. 1698/2005 Article 36, 39 and 40 No. 1974/2006 Article 27 Annex II
	Organic farming, A: UM1	Indirect, positive	Renouncing the use of chemicals and synthetic fertilisers reduces water consumption in upstream sectors and well-structured soils due to organic farming have a higher water capacity (Schaller, Weigel 2007)	Reg. (EC) No. 1698/2005 Article 36 and 39
	Environmentally friendly management, integrated production, A: UM 2, 6, 7, 9, 11, 12	Indirect, positive	Limiting fertilisers reduces water consumption in upstream sectors and in agriculture (due to limited yields).	Reg. (EC) No. 1698/2005 Article 36 and 39
	Renunciation of yield-increasing and other inputs, A: UM 3,4,5	Indirect, positive	Limiting fertilisers reduces water consumption in upstream sectors and in agriculture (due to limited yields).	Reg. (EC) No. 1698/2005 Article 36 and 39
	Erosion protection, A: UM 8, 10:	Indirect, indifferent	Erosion protection increases water retention, but planting consumes water.	Reg. (EC) No. 1698/2005 Article 36 and 39

Tab le 11:
Current measures of the second pillar of the Common Agricultural Policy and their potential effects on water consumption

Axis	Measure	Type of effect related to water scarce	Explanation of potential effects	Legal foundation
Axis 2 - Environment and Countryside	Renunciation of silage, A: UM13	Indirect, positive	The renunciation of grass silage leads to low-input production with less water demand.	Reg. (EC) No. 1698/2005 Article 36 and 39, Measure 214, Sub-measure 13
	Mowing steep areas, A: UM15	Indirect, indifferent	Mowing steep areas influences water run-off; areas that would otherwise be abandoned remain in production.	Reg. (EC) No. 1698/2005 Article 36 and 39, Measure 214, Sub-measure 15
	Mountain meadow management, A: UM16	Indirect, indifferent	Low-input management of mountain meadows reduces water consumption, but areas that would otherwise be abandoned remain in production.	Reg. (EC) No. 1698/2005 Article 36 and 39, Measure 214, Sub-measure 16
	Mountain grazing and herding, A: UM17	Indirect, indifferent	Low-input mountain grazing and herding in steep areas influence water run-off, but areas that would otherwise be abandoned remain in production.	Reg. (EC) No. 1698/2005 Article 36 and 39
	Ecopoints, A: UM18	Direct and indirect, positive	Various low-input farming measures that reduce water consumption.	Reg. (EC) No. 1698/2005 Article 36 and 39
	Greening of arable land, A: UM19	Indirect, Indifferent	Water retention by preventing complete fallow, but the plant cover consumes water.	Reg. (EC) No. 1698/2005 Article 36 and 39
	Seeding on mulch and direct seeding, A: UM20	Indirect, positive	Reduced soil management leads to a better soil structure with higher water retention capacity.	Reg. (EC) No. 1698/2005 Article 36 and 39
	Regional project for groundwater protection and grassland management, A: UM21	Indirect, indifferent	The maintenance of grassland maintains water-demanding grassland production but is positive for groundwater quality.	Reg. (EC) No. 1698/2005 Article 36 and 39, Measure 214, Sub-measure 21
	Preventive soil and water protection, A: UM22	Indirect, positive	The focus is on water quality, but the reduction of fertilisers (and yields) decreases water consumption.	Reg. (EC) No. 1698/2005 Article 36 and 39
	Management of specific arable lands threatened by erosion leaching, A: UM23	Indirect	Abandonment of specific areas reduces water consumption.	Reg. (EC) No. 1698/2005 Article 36 and 39
	Underseeding under maize, A: UM24	Indirect, indifferent	Water retention by preventing fallow, but plant cover consumes water.	Reg. (EC) No. 1698/2005 Article 36 and 39
	Rare productive livestock breeds, A: UM26	Direct, Indifferent	Water consumption relevance exists when low water-consuming breeds are subsidised.	Reg. (EC) No. 1698/2005 Article 36 and 39
	Rare agriculturally cultivated plants, A: UM27	Direct, indifferent	Water consumption relevance exists when low-input plants are subsidised.	Reg. (EC) No. 1698/2005 Article 36 and 39

Axis	Measure	Type of effect related to water scarce	Explanation of potential effects	Legal foundation
Axis 2 - Environment and Countryside	Maintenance and development of valuable areas important for nature or water protection, A: UM28	Direct, positive	Specific areas are either abandoned or managed with low-input methods, thereby reducing water consumption.	Reg. (EC) No. 1698/2005 Article 36 and 39
	Animal welfare, A: M215	Direct, indifferent	Subsidising animal grazing influences water consumption.	Reg. (EC) No. 1698/2005 Article 36, 39 and 40 No. 1974/2006 Article 27 Annex II
Axis 3 - Quality of Life and Diversification	Diversification into non-agricultural economy, A: M311	Indirect, indifferent	The measure is only relevant if high water-consuming agricultural activities are replaced by non-agricultural activities.	Reg. (EC) No. 1698/2005 Article 52 and 53 No. 1974/2006 Article 35 Annex II
	Support for business creation and development, A: M312	Indirect, indifferent	The measure is only relevant if high water-consuming agricultural activities are replaced by non-agricultural activities.	Reg. (EC) No. 1698/2005 Article 52 and 54 No. 1974/2006 Annex II
	Encouragement of tourist activities, A: M313	Indirect, indifferent	The measure is only relevant if high water consuming agricultural activities are replaced by non-agricultural activities.	Reg. (EC) No. 1698/2005 Article 52 and 55 No. 1974/2006 Annex II
	Conservation and upgrading of rural heritage, A: M323	Indirect, indifferent	The measure comprises a variety of nature protection and landscape management activities. It is only relevant if high water-consuming agricultural activities are restricted or replaced by other activities.	Reg. (EC) No. 1698/2005 Article 52 and 57 No. 1974/2006 Annex II
Axis 4 - LEADER	Local actions; development strategies, A: M421	Indirect, indifferent	The measure is only relevant if high water-consuming agricultural activities are replaced by other activities. It is integrated in all of the above rural development measures.	Reg. (EC) No. 1698/2005 Articles 61 to 65

Note: VO indicates the applicable Austrian Regulation, BGBl is the German abbreviation for (Austrian) Federal Law Gazette.

6.1 Implementation of current Common Agricultural Policy measures with an influence on water consumption in Alp-Water-Scarce pilot sites

Access to detailed data on agricultural policy measures in Alp-Water-Scarce pilot sites can only be found for Austrian pilot sites, thus enabling a more detailed evaluation (see Section 6.3). For pilot sites in France, Italy, Slovenia and Switzerland, only general data (for the entire member state or certain CAP regulations only) are available and thus only enable general assessments. There is no relevant agriculture in Swiss pilot sites.

In general, every measure that stimulates agricultural production is tantamount to higher water consumption, while market regulations in particular may stimulate domestic production to a high degree. This fact needs to be balanced with other policy objectives for rural areas (e.g. maintaining structures and settlements in peripheral regions, food security, regional production cycles, energy production, etc.). Because of these interrelationships and cross-effects, we do not take into account the general water consumption-stimulating aspect in our further considerations. Ultimately, the need for agricultural production is not under discussion, but we instead focus on how its orientation and performance can be adapted. Table 12 provides general information about the types of CAP measures implemented and their predominant effects in relation to water scarce. It shows that most of the implemented measures have a positive influence on water scarce, to mean they contribute to reducing water consumption in agriculture (as derived from Tables 10 and 11).

Table 12: Implementation of Common Agricultural Policy measures (and comparable measures in Switzerland) with potential effects on water consumption in countries with Alp-Water-Scarce pilot regions

Measure category	Effects related to water scarce		Austria	France	Italy	Slovenia	Switzerland
	Type of effect	Direction of effect					
Decoupled direct payments	Indirect	Positive	X	X	X	X	X
Coupled direct payments	Direct	Positive	X	X	X	X	X
Market regulation measures	Direct / indirect	Positive/ indifferent/ negative	X	X	X	X	X
Rural Development – Competitiveness	Direct	Positive	X	-	X	X	X
Rural Development - Environment and Countryside	Direct / indirect	Positive / indifferent	X	X	X	X	
Rural Development - Quality of Life and Diversification	Indirect	Indifferent	X	-	X	-	X
Leader	Indirect	Indifferent	X	X	X	X	-

Source: A: BMLFUW 2010a; F, I, Sl: DG Agri 2010, and information from pilot region project partners; CH: Swiss Federal Office for Agriculture 2010

The implementation of EU CAP measures differs among the countries with Alp-Water-Scarce pilot sites: Some (France, Italy) maintain a focus on the first pillar and others (Austria, Slovenia) on the second pillar. Concerning water consumption in agriculture, the analyses show there is no focus on agricultural measures which give direct incentives to higher water consumption, but there are a number of measures which are at least indifferent in their effect (on water consumption). Especially in France and Austria, measures whose effect is indifferent comprise between 2/3 and 3/4 of all subsidies; while in Italy and Slovenia the share of measures having an indifferent effect and those having a clear positive effect is more balanced (see Table 13).

Table 13: Share of Common Agricultural Policy measures with potential effects on water consumption in countries with Alp-Water-Scarce pilot regions

Percentage of subsidies with:	Austria	France	Italy	Slovenia
Indifferent effects	65	77	46	51
Effects of decreasing water consumption	35	23	54	49
Source: A: BMLFUW 2010a; F, I, Sl: DG Agri 2010, and information from pilot region project partners; CH: Swiss Federal				

6.2 Approach and data used for the CAP analysis

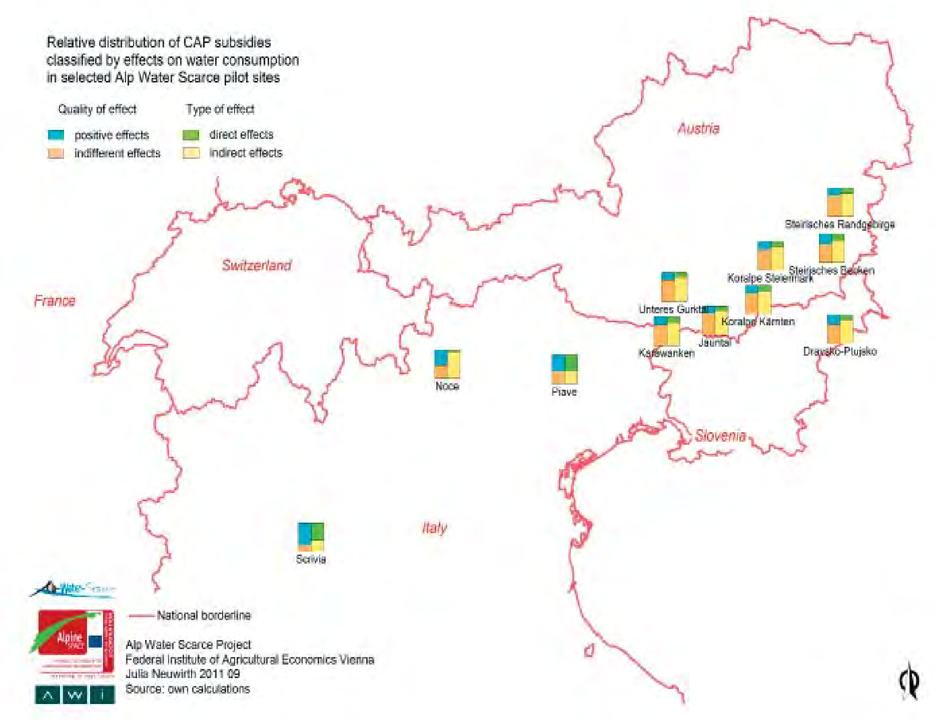
The following section focuses on the regional implementation of the measures mentioned in Tables 10 and 11 within the Alp-Water-Scarce pilot regions. Data sources for Austrian pilot regions are the Integrated Administration and Control System (IACS) (BMLFUW 2010d), the Austrian municipality database and the annual report on the situation of Austrian agriculture and forestry (BMLFUW 2010a). Information about the other pilot sites originated from a survey of project partners regarding the amounts of subsidies conducted in 2010. Deficiencies in data and interregional comparability occur firstly because not all of the selected CAP measures are implemented in each member state and region, and secondly because of the differing accessibility and aggregation levels of the data (nationwide, federal states, districts, municipalities). Information about the number of farms implementing CAP measures having effects on water scarce is only available for Austrian project sites. Not all of the CAP subsidies with effects on water consumption are locatable on the regional level for the pilot regions. For instance, export refunds and market interventions are paid to export companies and warehouses. Data about the amounts spent in this regard are only available on the level of federal states. Since these subsidies are not dedicated directly to agricultural enterprises and no regional data exist, they are excluded in the following regional analysis.

6.3 Distribution of water-relevant CAP subsidies in selected pilot sites

Figure 19 illustrates the relative regional distribution of subsidies with effects on water consumption that were paid in the selected pilot regions in 2009. Because the absolute amounts of disbursed subsidies depend on the size of the territory, the relative values are more meaningful and are shown below. In some pilot sites (Pohorje-Dravsko-Ptujsko Polje, Noce, Scrivia) only the total amount of subsidies within the framework of the agri-environmental programmes is available, but not the individual amounts for each sub-measure. For this reason, a subdivision into direct and indirect effects of subsidies spent within the framework of agri-environmental programmes was not possible. Subsidies with predominantly positive effects on water consumption are spent in the Italian regions Scrivia (77 %), Piave (56 %) and Noce (54 %). In the eastern pilot regions, the prevailing subsidies with indifferent effects range between 75 % in

Jauntal and Unteres Gurktal to 63 % in Steirisches Becken. Generally, most subsidies are spent for measures having indirect effects on water consumption. Only in Piave more than half of the total regional subsidies are spent on measures with direct effects (55 %).

Figure 19: Relative distribution of locatable water-relevant CAP subsidies in selected pilot regions according to their effects on water consumption



Comparing the regional distribution of CAP subsidies in terms of their effects on water consumption with the results of water-scarcity vulnerability derived from land use, livestock, soil and aridity, we can differentiate three clusters of regions:

The Italian sites Piave, Noce and Scrivia already apply most of the regional CAP subsidies to measures that help decrease water consumption. On the one hand, this means that these regions are aware of the vulnerability against water shortages and already have problems with adequate water supply (their agriculture relies very much on irrigation). On the other hand, the financial scope of the CAP budget available for shifting to water-saving measures is minimal, thus only increasing the budget for these measures would be an option. The aggregated water-scarcity vulnerability is relatively low in Piave and Noce but very high in Scrivia because of the current high aridity index – which is expected to increase significantly in future.

The Austrian pilot sites Steirisches Randgebirge, Koralpe Kärnten and Steiermark show a higher aggregated vulnerability of water scarce. They rely greatly on grassland farming and water-intensive livestock husbandry and may suffer from future water shortages. Only a small share of subsidies is dedicated directly to water saving measures, therefore shifting money from other measures or targeting them more precisely may be a viable option to minimise the effects of water scarce in future.

Regions with a relatively low aggregate vulnerability of water scarce, such as Karawanken, Jauntal, Unteres Gurktal, Steirisches Becken and Pohorje-Dravsko-Ptujsko Polje, are expected to face problems with water scarce in future only in especially water-sensitive sectors of agricultural production, such as the production of seeds.

In Austrian pilot sites data availability allowed an analysis of the share of farms implementing water-relevant CAP measures. The absolute number of farms is highest in Steirisches Becken and lowest in Unteres Gurktal and Jauntal. In most of the Austrian pilot sites, nearly all farms receive water-relevant CAP subsidies. For the regions Koralpe Kärnten alone, the share is 92 %. The share of farms implementing measures with direct effects on water consumption is highest in Steirisches Randgebirge (68 %) and lowest in Steirisches Becken (39 %). The share of farms implementing CAP measures that simultaneously have direct and positive effects on water consumption is lower (e.g. Karawanken, 34 %; Unteres Gurktal, 31 %). In general, most of the implemented measures have indirect and indifferent effects on water consumption in agriculture but fewer measures with positive and direct effects on water saving are implemented.

7 Economic analysis of selected agricultural adaptation measures on farm level in the case of Austria

Higher temperatures as a consequence of climate change induce threats, but they also imply new opportunities for agriculture in Alp-Water-Scarce pilot sites: in particular, for fruits, vege-tables and vineyards if the water supply does not become constraining. Certain species and varieties that, until now, have not yet had optimally warm temperatures could potentially become new options for farmers, while original species and varieties may be shifted into higher-altitude regions. The key factor, however, will be the water supply, which is predicted to decrease in summer especially. Therefore it will be most important to make use of winter humidity and, if economically expedient, to consider extending irrigation. In addition, risk management will need to improve. The dry summer of 2003 showed that, in times of high temperatures and insufficient water supplies, the potential for optimal yields may not be realised.

As an example of what could be done to minimise the future risk of water scarce in farm enterprises, several key measures will be discussed and assessed from an economic point of view in the following sections. These are: changes in crop rotations, water-saving land management measures, irrigation and weather risk management.

7.1 Changes in crop rotations

As an important example for the Austrian pilot sites, changing from maize-ear silage to whole-maize silage yields the advantage of making better use of winter humidity. The maize can be used as fodder in livestock farms (for milk cows, raising heifers, suckler cows and sheep) and can be sold on the market in the case of arable farms. In the analysis, the number and quality of livestock in the region is assumed to be stable under typical regional production conditions.

Table 14: Substitution from maize to whole plant silage

1. Assumptions	Maize silage - 32.5 % dry matter [1]	Whole plant silage [1]
Yield dt[1] / ha	506	245
MJ NEL[2] / ha	114,356	55,370
Variable Costs € / ha	980	978
Variable Costs € / MJNEL	0.009	0.018
Substitute Fodder Costs € /MJNEL Bales)	-	0.0231
2. Calculation of substitution effects , 1 ha		
Before: maize silage	Basic fodder ration, MJ NEL	-114,356
	Variable Costs, €	980
After: whole plant silage	Basic fodder ration, MJ NEL	55,370
	Variable Costs, €	-978
Difference	Saving of Variable Costs, €	2
	Substitute Fodder Costs, €	1,361
Balance (= annual disadvantage per ha in €)		*1,359*

[1] Source: Association for Technology and Structures in Agriculture (KTBL) 2010
[2] MJ NEL: Megajoule Net Energy Lactation (energy measure for basic fodder)

The cultivation of maize plays a central role in the crop rotations of several of the Austrian Alp-Water-Scarce pilot sites. If the change in cultivation (due to climate change and water scarce) will occur as described above, it would mean that the affected farm enterprises will face economic losses: A considerable yearly disadvantage of € 1,.359.- per ha agricultural area would be the result. It is therefore unrealistic to expect farmers to make use of this opportunity as long as other measures can prevent water scarce or if regulations are in place to set constraints.

7.2 Changes in land management

The Austrian Alp-Water-Scarce pilot sites are not located in the traditional arid regions of Austria. However, as the past years have shown, they, too, are confronted with longer dry periods and more extreme weather events having a negative impact on soils and erosion. Therefore the efficient use of water becomes more important than ever. The strategy is to minimise unproductive evapotranspiration using conservational land management techniques or direct drilling and at the same time to minimise surface water run-off via improved soil infiltration (depending on soil characteristics). This is especially important in soils with a high water retention capacity in order to save water for short-term deficits in precipitation. Without deep-rooting leguminous plants as part of the crop rotation, there is a risk of soil compression if only shallow treatment of the soils is applied, and this needs to be considered.

Comparison of conservational seeding and direct seeding

Tests with a four-part crop rotation provide a good example that good and stable yields are possible in the long term using conservational soil treatment and direct seeding. Conservational soil treatment is already "good agricultural practice", and more and more farmers are trying direct seeding, which needs a permanent soil cover. As an example, cultivating rapeseed with water-efficient management leads to higher yields and less stress due to aridity, and the number of seeds per pod and the weight of seeds is higher as well. This can be achieved by minimising water losses through land management without ploughing, and by using a protective straw mulch layer as soil cover. The number of plants per area should also be optimised.

Economic evaluation of soil treatment measures

An economic comparison of soil treatment takes into account the variable costs. The relevant specific costs comprise machine costs, costs for cover seeds and additional pesticides, with the other means of production remaining the same.

Table 15 shows "autumn ploughing without planting" as a reference treatment and compares it to the following alternative treatments: autumn cultivating in planting, autumn mulch seeding and direct seeding in winter planting. One hour of labour has been assumed to cost € 11.50, in accordance with the 2010 guidelines of the Austrian Council for Agricultural Engineering and Rural Development (ÖKL 2010). The amount is higher than normal because some special knowledge is necessary for this type of land management. The estimated seed costs for catch crops are € 45.- to 55.-/ha (for 20-25 kg of seeds). The machinery costs include fuel and repairs.

The results show that changing to this type of soil treatment does not always result in increased expenditures but may actually lead to their decrease in specific cases. In many agricultural locations, certain conservational soil treatment and crop rotation measures can be used to adapt to water scarce – or to a water surplus. By renouncing ploughing and cultivating catch crops, nitrate and pesticide leakage can also be reduced, with the strength of the effects depending on the type of soil. However, catch crop cultivation is constrained by water, demand and is therefore not possible in every region. Every type of soil treatment consumes some amount of water and direct seeding is not always practicable for the level of yields expected in Central Europe, but there are other measures to hinder the drying out of the uppermost soil. A shadow-spending cover of mulch decreases both dry-out and erosion. A negative effect is that the microclimate increases the shooting of volunteer cereals. Therefore, the capillarity should be cut off directly after harvesting and a flat stubble-field treatment is necessary for the entire area.

Table 15: Evaluation of various land management techniques

Treatment	Autumn ploughing without planting	Autumn cultivating in planting	Autumn mulch seeding in planting	Direct seeding in winter planting
Costs	€ per ha, incl. VAT			
Treatment after harvesting with heavy cultivator	25.7	24.1	24.1	
Seed for catch crop		44.6	44.6	44.6
Seeding catch crop with rotary harrow drill			35.3	
Seeding catch crop with direct drilling				32.4
Mulching catch crop / straw			30.3	
Spraying catch crop / volunteer cereals			44.3	
Ploughing before main crop	53.1			
Cultivating before main crop		24.1		
Seeding main crop with rotary harrow drill	35.3	35.3	35.3	
Seeding main crop with direct drilling				32.4
Sum of costs	114	128	214	109
Labour hours per ha	3.71	2.70	4.52	1.42
Additional expenditure per ha incl. labour hours (11.50 €/h)	-	2	109	-31

source: ÖKL 2007, BMLFUW 2008; authors' own calculation

7.3 Irrigation

Irrigation is one of the most expensive means of production in agriculture. Beside investments in techniques, the number of labour hours required is a decisive factor. New investments require location-specific technical equipment and economic planning. Irrigation may be crucial in dry years, but it also provides an advantage during average years in terms of stable crop quality and yields.

Depending on the regional water supply and legal situation, irrigation water is taken either from ground or surface water. In the Austrian pilot site Steirisches Becken, the share of irrigation water deriving from groundwater is 50 %. Irrigation is currently not relevant in the other Austrian pilot regions.

In some cases, 50 % of the investment in irrigation goes to supplying the water alone. The cost of the required technical equipment depends on many variables, such as pipe length and diameter, flow volume and specific equipment items required. For our purposes, a value of € 600.- to € 900.- per ha was assumed for equipment. Some regions have irrigation associations that calculate real water consumption. The current average price in the Steirisches Becken pilot region is € 0.20 per m³ of water. Here, irrigation is used in horticulture for the production of vegetables, fruits and grapes. For field crops, irrigation is used only in special seed-production applications. Drip irrigation and pipe irrigation systems are the most efficient in terms of labour hours, and they are often installed.

The typical pipe irrigation system comprises one or more pipes extending from a single main pipe measuring up to 400 m in length. For a system supplying an area of 5 ha, the average investment and operating costs range from € 4,850.- (70 mm diameter) to € 7,290.- (89 mm diameter) per ha.

Drip irrigation enables the targeted application of water and liquid fertilisers, and it requires only a low amount of energy to operate. For a drip irrigation system that supplies an area of 5 ha, the average investment and operating costs range from € 630.- to € 1,360.- per ha.

Mobile irrigation systems for large plots (circular or linear systems for >20 ha) are not installed in the Austrian pilot sites because of the very small-scale structure of plots. In other plot structures, they are the most efficient systems for irrigation.

Table 16: Irrigation system costs: 5 ha plot, 5 x 20 mm, water supply cooperative, source: KTBL 2010

System	Labour hours / ha/year	Labour [1] cost, €	COSTS Equipment €/(ha/year)	Water [2]	Sum	Irrigation costs €/mm	Field of operation
Pipe sprinkler with 70 mm inner diameter	4.83	48	594	200	842	8.42	field vegetable / fruit growing
Mobile machine, single sprinkler	2.75	28	164	200	392	3.92	maize / arable crops
Drip irrigation	16.7	167	1,662	140 [3]	1,969	19.69	horticulture

[1]) 15 €/ h
[2]) 0.20 €/m³
[3]) 70 mm irrigation water
source: KTBL 2010

Due to the expected lower natural precipitation (especially during the growing season), irrigation will gain in importance in future – all the more so on soils with a low water storage capacity. The experience gained in the drought years of 2003, 2006 and 2007 underlines the need for a viable irrigation strategy, as well as effective and efficient irrigation in practice, in the whole of Austria.

For the current analysis, an average water consumption of 3.5 to 4.0 mm/ha/day was assumed for all crops, and this value served as our basis for determining the required amount of irrigation water. However, in case of longer droughts and higher temperatures, the actual daily water demand may be much higher (up to 10 mm). Due to the lack of practical case studies in the pilot sites, we used standard data as the basis for calculating the profitability of irrigation systems.

The profitability of irrigation is crucial for farmers, as low profitability reduces the implementation of irrigation for intensive fruit, vegetable and sugar beet production; in the case of permanent crops, this is primarily due to reasons of frost protection. The preferred irrigation periods are during shooting, intensive growth and entry into the blossom phase. Irrigation is profitable only if the additional revenue (resulting from an improved yield or higher quality) exceeds the cost of irrigation; and, indeed, the extreme year of 2003 has shown that irrigation is able to increase the yield by as much as 30 %.

However, under the conditions of average farmgate prices between 2002 and 2010 in Styria, irrigation made no positive contribution to farmers' operating profits. This is one reason why the proportion of irrigated land for arable crops in Styria remains very low. Thus only under the assumption of a dry year and high producer prices (e.g. first quarter of 2011) can irrigation contribute positively to operating profit. In the case of forage cropping and permanent pastures, the performance of irrigation under option 2 (below) is undervalued because the substitute price of fodder increases during dry years. Ultimately, the sprinkling of fodder and permanent grassland is merely a fictitious example for Styria as farmers currently do not practice this technique.

Table 17
Profitability of irrigation – model calculations

Mobile irrigation machine - single sprinkler - dry location					
Option 1:	**Normal year**				
Average yields Styria 2002-2010, Average farmgate prices 2002-2009 Styria					
		arable land			Permanent
		Wheat	Maize	Fodder	grassland
				(Hay)	(Hay)
Yield (dt/ha)	- non irrigated	56.5	108.7	75.3	69.7
	- irrigated	67.7	130.4	98.0	90.6
Yield Difference (dt/ha)		11.3	21.7	22.6	20.9
Farmgate Price		12.67	14.20	10.66	10.66
Revenues (€/ha)	- non irrigated	715	1,543	803	743
	- irrigated	858	1,852	1,044	966
Rev.-difference €/ha		143	309	241	223
Irrigation	mm	40	100	100	100
Irrigation costs					
new plant - €/mm	**3.64**	146	364	364	364
Irrigation cost-free					
Performance €/ha		**-3**	**-55**	**-123**	**-141**
Irrigation costs					
existing plant €/mm	**2.50**	100	250	250	250
Irrigation cost-free					
Performance €/ha		**43**	**59**	**-9**	**-27**
Irrigation costs					
perational costs €/mm	**4.50**	180	450	450	450
Irrigation cost-free					
Performanc €/ha		**-37**	**-141**	**-209**	**-227**
Option 2:	**Dry year (Styria 2003)**				
High farmgate prices		arable land			Permanent
		Wheat	Maize	Fodder	grassland
				(Hay)	(Hay)
Yield (dt/ha)	- non irrigated	52.7	89.5	55.9	48.7
	- Irrigated	79.0	134.3	89.4	78.0
Yield difference (dt/ha)		26.3	44.8	33.5	29.2
Farmgate Price		22.00	25.00	13.00	13.00
					13.00
Revenues (€/ha)	- non irrigated	1,159	2,238	726	634
	- irrigated	1,738	3,356	1,162	1,014
Rev.-difference €/ha		579	1,119	436	380
Irrigation	mm	60	120	120	120
Irrigation costs					
New plant - €/mm	**3.64**	218	437	437	437
Irrigation cost-free					
Amount €/ha		**361**	**682**	**-1**	**-57**
Irrigation costs					
Existing plant €/mm	**2.50**	150	300	300	300
Irrigation cost-free					
Amount €/ha		**429**	**819**	**136**	**80**
Irrigation costs					
perational costs €/mm	**4.50**	270	540	540	540
Irrigation cost-free					
Amount €/ha		**309**	**579**	**-104**	**-160**

Apple production				
Option 1:	**Normal year, irrigation pipe system**			
	Yield (dt/ha) [1]	**average**	**low**	**high**
	- non irrigated	355.0	342.0	390.0
	- irrigated	372.8	359.1	409.5
Yield difference (dt/ha)		17.8	17.1	19.5
Farmgate price €/dt [2]	- non irrigated	27.53	23.94	37.07
	- irrigated	29.12	25.32	39.20
Revenues (€/ha)	- non irrigated	9,773	8,188	14,458
	- irrigated	10,854	9,092	16,052
Rev.-difference €/ha		1,081	903	1,594
Irrigation	mm	100	100	100
Irrigation cost free performance €/ha for Irrigation costs of € / mm				
existing sprinkler	**6.50**	**431**	**253**	**944**
new sprinkler	**8.42**	**239**	**61**	**752**
high operational costs	**10.50**	**31**	**-147**	**544**
Option 2:	**Dry year (Styria 2003), irrigation pipe system**			
	Yield (dt/ha)	- non irrig.	325.0	
		- irrigated	364.0	
	Yield Difference (dt/ha)		39.0	
	Farmgate price €	**average**	**low**	**high**
	- non irrigated	27.53	23.94	37.07
	- irrigated	29.12	25.32	39.20
			Revenues (€/ha)	
	- non irrigated	8,947	7,781	12,048
	- irrigated	10,600	9,216	14,269
	Rev.-difference €/ha	1,652	1,435	2,220
			Irrigated in mm	
		150	150	150
Irrigation cost free performance €/ha for irrigation costs of € / mm				
Existing sprinkler	**6.50**	**677**	**460**	**1,245**
New sprinkler	**8.42**	**389**	**172**	**957**
High operational costs	**10.50**	**77**	**-140**	**645**
[1] Average yield, Styria 2003 - Statistik Austria				
[2] Gross farmgate prices, Styria 2002-2010 - Statistik Austria				

Climate simulations show that climate-induced yield variations will increase. For example, the probability of hot summers – like the one in 2003 – has increased significantly since 1960. In recent decades in Austria, the occurrence of extreme events has led to a significant increase in medium-term yield fluctuations. In the drought year of 2003, the wheat yield was approximately 10 dt/ha (13 %) lower than the expected yield trend for the year. The regional yield losses varied greatly, with losses observed in both winter crops (wheat) and summer crops (maize). Given the high level of intensity of agricultural production in some pilot regions, together with the increase in agricultural prices, the production risk from climate-induced yield fluctuations will rise significantly in future. As a result, the profitability of irrigation investments is expected to increase and, in turn, so is the demand for irrigation water in Austrian agriculture.

Our calculations (see Tables 16, 17 and 18) show that the acquisition of a complete new irrigation system requires thorough planning and installation. Taking into account the required expenditures for equipment and labour costs, an irrigation system is one of the most expensive resources in agriculture. In the long term, however, irrigation can provide farmers with a higher level of income stability.

7.4 Weather risk management

In addition to the various processes required for adapting agriculture to long-term climate change, it appears important to minimise the risk of crop losses for farmers. The risk increases as a consequence of unpredictable and changing annual weather incidents.

Insurance systems may cover crop yield losses resulting from weather incidents, but they do not include direct income or price validation components. Table 19 provides an overview of insurance products in several member states. While the systems differ in type and number of included risks, insurance against hail damage is obtainable in most countries as an extension of other insurances. Some countries offer support for insurance costs from state budgets (see also Rentenbank 2008, pp. 14-16).

	Insurance protection	Premium support	Public emergency assistance	Participation of farmers	Reinsurance
France	Hail and additional insurance	no	Assistance in case of disasters (earth-quake, drought, tidal wave)	Data not available	Private market
Italy	Hail, frost, drought	50 % for hail, 80 % for multiple risks	Only in case of risks with no possibility for insurance	Data not available	Private market
Austria	Multiple risks	50 % for hail and frost	Only in case of risks with no possibility of insurance	78 % hail, 56 % multiple risks	Private market

Table 19 Agricultural Insurance Systems, source: Prettenthaler 2006

In contrast to several other EU member states, Austria has a multiple-risk insurance system that operates only through public support. It is organised as a risk partnership between the state, the insurance company and the farm enterprises. Multiple-risk insurance came into force in 1995 and it combines the risk of hail, frost, flooding and drought for certain cultivated arable lands. An important extension was added in the year 2000 to include drought damages for cereals and pumpkins. Excluded from the risk of drought are sugar beets, grasslands, vines and fruits. Money is paid for damages resulting from low precipitation in the period between April 1st and August 31st, including periods without precipitation for at least 30 days. Low precipitation is defined as a critical deviation from the long-term average, taking into account crop specifics. No money is disbursed when the damages are a consequence of improper land management.

The model year of 2003 in Styria

In addition to its insurance system, Austria has implemented a special fund for disaster events. This fund did not originally include damages occurring in agricultural areas, but under certain circumstances (damage exceeding 30 % of the average production in the last 3 years) agricultural damages are now also classified as natural disasters and can be compensated through public means.

Among Austrian alpine regions, south-eastern Styria is especially sensitive to drought. It holds only a small share of the total federal territory but is of great importance for agricultural production. In Styria, the dry period during the summer of 2003 had serious consequences for farmers: They had to cope with income losses of up to 40 %. In all, the province Styria suffered losses in crop production amounting to € 80 million. Because mainly crops that were not eligible for insurance were affected, farmers received compensation payments from the fund. There were 7,545 cases of payment, with € 549.- paid out on average.

Several special laws have been put into force on the federal and provincial level. For example, various measures have been set up for securing the livelihood of farms – such as subsidies for purchasing means of production, subsidies for fodder (for livestock farms with a certain amount of livestock), general payments during crises (if farmers lose more than 50 % of their yields) and grassland seeds in the case of strongly affected grassland areas.

By now, multi-peril insurance exists for the majority of arable crops, but there is still no drought insurance for farms with pastures, vineyards and orchards.

Since 2009, the EU CAP includes rules for assistance to sectors with special problems (so-called "Article 69" measures, Regulation (EC) No 73/2009). These permit EU member states to retain 10 % of the national direct payment ceiling for compensation of natural disadvantages or risk management in certain regions, including insurance against adverse weather conditions.

8 Regional-specific options for agricultural adaptation measures

8.1 Adaptation options for selected pilot sites

The short-term land management and soil treatment measures described in Section 1 contribute not only to water savings, but also towards maintaining a sustainable basis for production; they reduce leaking of nutrients and pesticides, decrease erosion and contribute to biodiversity and amenity of landscape, too. Therefore they require support in all cases – and not only for water scarce scenarios. They are relatively easy to implement in the short term and depend significantly on seasonal temperatures and precipitation distributions as well as changes thereto, both now and in future.

The long-term developments for the various Alp-Water-Scarce pilot regions specified below can contribute to maintaining sustainable agricultural production but intrude more on the agricultural production system with consequences for the whole regional production cycles and economy. Therefore more public discussion and participatory decision processes are needed.

Among the Austrian pilot sites, the aggregate water-scarcity risk value is highest in **Steirisches Randgebirge**. This high value results mostly from the elevated risk associated with the structure of livestock farming as well as some risks related to the specific types of land use. The future climate scenario forecasts relevant changes in the aridity index in autumn and spring but only minor changes in the other seasons. Potential adaptation measures include changing from intensively used grassland (currently 40 % of agricultural land) to low-input pastures and meadows, and a reduction of land under winter grain and field forage crops. As a result, less regional fodder would be available and the livestock density would have to be reduced – which would ultimately also contribute to lowering vulnerability to water scarce (current livestock units: LU/ha=1.63). For example, changing from dairy cattle to fattening cattle would also reduce agricultural water demand. The implementation level of CAP measures in this region is high, but the main share of CAP subsidies is not dedicated to measures considered positive for water consumption. Nevertheless, the high willingness of farmers to implement CAP measures is a good starting point for gaining acceptance for implementing more measures that could reduce water demand in future.

The **Koralpe Kärnten** region has a rather high water-scarcity vulnerability due to animal husbandry (predominantly dairy cattle), and an above average land-use risk (half of the agricultural land is intensively used grassland). Larger changes in the aridity index are expected future winter seasons as well as in spring and autumn. In the long term, three adaptation measures would make particular sense for reducing agricultural water consumption: changing from intensively used to low-input pastures and meadows, a reduction of land under field forage crops, and reducing livestock density (currently LU/ha=1.33).

A similar situation exists in **Koralpe Steiermark**. Because of the very high share of grassland (65 % of agricultural land), this region has the highest land-use vulnerability among the Austrian pilot sites. Livestock vulnerability is also quite high, mostly due to dairy cattle husbandry. The region will have to cope with increasing aridity (on a low level), especially in fall.

As above, adaptation options could be: changing from intensively used to low-input pastures and meadows, a reduction of land under field forage crops, and reducing livestock density (currently: LU/ha=1.18).

The **Karawanken** region is characterised by a high land-use vulnerability due to the high share of intensively used grassland (42 % of agricultural land). A slight increase in aridity (equally high in each season) is expected. Water scarce mitigation measures could comprise changing from intensively used to low-input pastures and meadows, and a reduction of land under field forage crops.

Jauntal has a low aggregate water-scarcity risk. Some vulnerabilities derive from livestock and soil conditions, but on a very low level. Negative changes in the aridity index are expected, mostly in spring. Only one-quarter of CAP subsidies is used for water-saving measures, and only a small number of farms implement such measures. If necessary, reduced water consumption could be achieved by changing from breeding pigs to fattening pigs (for example) and raising the willingness of farmers to implement water-saving measures.

The lowest aggregated water-scarcity vulnerability among the Austrian pilot regions is found in **Unteres Gurktal**. The only above average vulnerability originates from livestock (dairy cattle and pig breeding). Significant increases in the aridity index are forecasted for spring and autumn. Only a minor share of total CAP subsidies is dedicated to positive measures, and the number of farmers implementing them is low. In this Carinthian region, too, converting from breeding pigs to fattening pigs could reduce water consumption, assuming that the number of livestock units remains constant. Farmers could be motivated to implement more water-saving measures.

In the region **Steirisches Becken**, livestock vulnerability is quite high (predominantly pig keeping). Especially due to good soil conditions, a low aggregated water-scarcity vulnerability prevails. The aridity vulnerability is slightly above average and will increase in future, particularly in autumn and spring. 22 % of total subsidies are spent on the measure "modernisation of agricultural holdings," which, in terms of water consumption, has no direct effects on agricultural land. Therefore, the implementation of water-saving measures on agricultural land should be more intensively stimulated. In addition, reducing livestock density (LU/ha = 1.19) and for example changing from breeding pigs to fattening pigs could reduce the amount of water needed for agricultural purposes.

The French region **Tarentaise** is characterised by a very high soil vulnerability. Vulnerabilities of land-use and aridity are considerably above average as well. Based on the current situation, the aggregated water-scarcity vulnerability is the highest of all pilot sites. Only a slight increase in aridity, especially in fall, is forecasted in future. The agricultural land comprises only grassland, 28 % of which is intensively used. For this reason, and because of the bad regional soil conditions, we recommend reducing intensively used grassland further and changing to low-input grassland. Additionally, a transition from dairy cattle to sheep and goats could have positive effects on the soil conditions. Small ruminants have less negative effects on soil compaction and erosion and are able to use low-input grasslands and steep areas more efficiently.

Even though livestock density is at a low level (0.5 LU/ha), a further reduction could mitigate the strained water situation.

The second French region, **Arly**, has no above average vulnerabilities. Future aridity changes are expected to be low, with most of them occur in summer. Under these assumptions, it is the region with the lowest need for adaptation measures (to future water scarce) of all Alp-Water-Scarce pilot sites.

The current situation in the Italian region of **Piave** is mostly characterised by a low vulnerability for land use, livestock, soil and aridity. The most elevated vulnerability originates from a high amount of irrigation (38 % of agricultural land is under irrigation). An increase in aridity is expected, especially in autumn. The implemented CAP measures affect the already positive water-saving activities. Therefore, the focus should be on efficient irrigation technologies.

Noce demonstrates above average vulnerability values for land use, soil and aridity, but the aggre-gate vulnerability is below average. The share of irrigated land is quite high (31 %), and many orchards are cultivated (19 % of total agricultural area). Aridity will increase in future, especially in spring and fall. Therefore, efficient use of irrigation technologies and reducing intensive grassland are options for saving water. Slightly more than half of CAP payments are used for water-saving measures, and this share should increase in future.

The Italian pilot region of **Scrivia** is currently subject to the highest aridity vulnerability among all pilot regions. However, due to its adapted agriculture, Scrivia's land-use vulnerability is low in comparison to the other pilot regions. The share of irrigated areas on agricultural land is 98 %. In future the region will face an increase in aridity – particularly in autumn and extremely so in summer. Measures to cope with this situation would be more efficient irrigation technologies and reducing or abandoning field forage crops which consume a significant amount of water for cultivation. 77 % of CAP subsidies already go to supporting measures with positive effects on water demand.

The Slovenian region of **Julian Alps** currently has a high land-use vulnerability and the highest soil vulnerability among the pilot regions, while livestock vulnerability is the lowest of all regions. There are no data available on the future aridity vulnerability. If necessary, a change from intensive to low-input grassland could contribute to reducing water demand.

The other Slovenian pilot site, **Pohorske-Drvasko-Ptujsko Polje,** has a relatively high aggregate water-scarcity vulnerability due to the elevated livestock and aridity vulnerability. Aridity is expected to increase, especially in summer and autumn, and most CAP payments (67 %) go to "indifferent measures" – i.e. not directly dedicated to saving water. Potential water-saving measures in this region would be to adapt the relative share of winter and spring crops according to the seasonal distribution of precipitation, to reduce livestock density (currently 1.2 LU/ha) and/or to change from dairy cattle to fattening cattle, for example.

The Swiss project sites have only marginal agriculture. **Sandey** has slightly above average vulnerability values for land use and aridity. Future aridity will increase only very slightly and to an equal extent during the year. Since the share of intensive grassland (6 %) is already very low, no specific land-use measures are recommended – nor do they seem necessary.

Table 20:
Specific long-term water-scarcity adaptation options in countries with Alp-Water-Scarce pilot regions

Country	Alp-Water-Scarce pilot region	Above average risks related to water scarce and agriculture	Predominant effects of imple-mented CAP measures	Future development of risks (until 2050)	Long-term agricultural adaptation options	
					Land use	Livestock
Austria	Steirisches Randgebirge	Land use, livestock	indifferent	Aridity increase, especially in spring and autumn	Change from intensively used to low-input grassland; adaptation of the ratio of winter to spring crops; reduction of field forage crops	Reduction of livestock units/ha (1.63); change from dairy cattle to fattening cattle
	Koralpe Kärnten	Land use, livestock	indifferent	Aridity increase, especially in winter/spring/ autumn	Change from intensively used to low-input grassland; reduction of field forage crops	Reduction of livestock units/ha (1.33)
	Koralpe Steiermark	Land use, livetock	indifferent	Aridity increase, especially in autumn	Change from intensively used to low-input grassland; reduction of field forage crops	Reduction of livestock units/ha (1.18)
	Karawanken	Land use	indifferent	Slight aridity increase over entire year	Change intensively used to low-input grassland; reduction of field forage crops	-
	Jauntal	Livestock, soil condition	indifferent	Aridity increase, especially in spring	-	Change from breeding pigs to pig fattening
	Unteres Gurktal	Livestock	indifferent	Aridity increase, especially in spring and autumn	-	Change from breeding pigs to pig fattening
	Steirisches Becken	Livestock, aridity	indifferent	Aridity increase, especially in spring and autumn	-	Reduction of livestock units/ha (1.19); change from breeding pigs to fattening
France	Tarentaise	Land use, soil condition, aridity	no data	Slight aridity increase, especially in autumn; slight relative increase in risk due to agricultural land-use developments	Change from intensively used to low-input grassland	Change from dairy cattle to sheep and goats; further reduction of live-stock units/ha (0.5)
	Arly	No above average risks	no data	Slight aridity increase, especially in summer	-	-

Country	Alp-Water-Scarce pilot region	Above average risks related to water scarce and agriculture	Predominant effects of implemented CAP measures	Future development of risks (until 2050)	Long-term agricultural adaptation options	
					Land use	Livestock
Italy	Piave	Irrigation amount	positive	Aridity increase, especially in autumn	Efficient irrigation technologies	-
	Noce	Livestock, soil condition, aridity, irrigation amount	positive	Aridity increase, especially in spring, summer and autumn; slight relative increase in risk due to agricultural land-use developments	Efficient irrigation technologies; change from intensively used to low-input grassland	Change from dairy cattle to fattening cattle
	Scrivia	Aridity, irrigation amount	positive	Aridity increase, especially in autumn - with extreme increase in summer	Efficient irrigation technologies; reduction of field forage crops	-
Slovenia	Julian Alps	Land use, soil condition	no data	no data	Change from intensively used to low-input grassland	-
	Pohorske-Dravsko-Ptujsko Polje	Livestock, aridity	indifferent	Aridity increase, especially in summer and autumn; slight relative increase in risk due to agricultural land-use developments	Reduction of intensively water-consuming crops	Reduction of livestock units/ ha (1.2), change to less water demanding livestock, i.e. from dairy cattle to fattening cattle
Switzerland	Spöl	No above average risks	no data	Aridity increase, especially in winter and spring	-	-
	Sandey	Land use, aridity	no data	Slight aridity increase over entire year	-	-

Source: Authors' own elaboration based on project results (Alp-Water-Scarce project, work packages 6 and 8)

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ID	Region	Agricultural area ha	Arable land %	Grassland intensive %	Grassland low input %	Orchard %	Vineyard %	Irrigated %	Vuln. 1** %	Vuln. 2 %	Vuln. 3 %	Vuln. 4 %	Vuln. 5 %	Weighted land use vulnerability	Standardized land use vulnerability
A10	Steirisches Randgebirge, A	30,247	63.3	39.6	3.4	1.5	0.3	0.1	5.3	1.1	10.0	18.2	65.3	436.7	0.651
A51	Koralpe Kärnten, A	22,846	31.6	50.1	23.2	0.2	0.0	0.0	1.9	0.7	13.5	27.0	56.9	436.3	0.647
A52	Koralpe Steiermark, A	15,242	18.3	65.4	16.3	1.8	1.8	0.1	0.7	1.8	6.9	18.1	72.4	459.1	0.918
A60	Karawanken, A	12,148	44.8	41.9	18.7	0.1	0.0	0.0	5.2	1.1	13.9	24.9	54.8	423.0	0.488
A70	Jauntal, A	7,583	80.9	26.1	2.6	0.0	0.0	0.1	5.8	3.8	38.1	17.0	35.1	371.5	-0.126
A80	Lower Gurktal, A	17,331	80.0	24.2	4.4	0.0	0.0	0.4	6.5	5.3	36.9	17.2	33.7	364.9	-0.205
A90	Steirisches Becken, A	161,079	70.1	23.7	2.9	5.5	2.6	0.5	2.8	3.4	47.3	10.6	35.4	370.5	-0.138
F02	Tarentaise, F	25,156	0.1	28.4	71.5	0.0	0.0	0.0	0.0	0.0	0.0	71.5	28.4	428.1	0.548
F04	Arly, F	1,771	33.4	0.0	66.6	0.0	0.0	0.0	0.0	0.0	33.4	66.6	0.0	366.6	-0.184
S12	Dravsko-Ptujsko, Sl	52,433	80.0	0.0	0.0	2.5	14.0	2.8	2.5	14.5	42.2	35.2	2.5	311.2	-0.844
I14	Scrivia, I	1,002	98.2	0.0	1.8	0.0	0.0	98.2	29.5	0.9	8.7	1.0	8.8	105.1	-3.301
S15	Julian Alps, Sl	37,907	1.2	57.3	36.8	1.3	0.0	0.0	3.8	0.0	0.8	36.8	58.6	446.3	0.765
I18	Noce, I	40,380	19.3	31.5	30.0	18.7	0.5	31.1	0.0	0.0	19.3	61.5	19.2	399.9	0.212
C27	Sandey, CH	648	0.0	6.2	93.8	0.0	0.0	0.0	0.0	0.0	0.0	93.8	6.2	406.2	0.287
I19	Piave, I	236,570	42.0	17.6	29.6	0.9	10.0	38.1	2.1	16.7	24.8	39.7	18.5	361.1	-0.250

*) no data available; **)vulnerability classes: 1: lowest vulnerability, 5: highest vulnerability

Table A1: Land use current

Table A2:
Livestock current

ID	Region	Livestock units nr.	Livestock units per ha AA	Cattle %	Pigs %	Poultry %	Sheep goats horses %	Vuln. 1** %	Vuln. 3 %	Vuln. 5 %	Weighted livestock vulnerability	Standard-ized livestock vulnerability	Livestock water consumption m³ per ha AA per year	Standardized livestock water consumption
A10	Steirisches Randgebirge, A	45,461	1.5	85.5	8.5	3.1	2.9	54.3	44.6	1.0	193.3	-0.191	28.9	1.688
A51	Koralpe Kärnten, A	28,974	1.3	76.9	14.0	4.1	5.0	50.3	46.3	3.3	206.0	0.108	25.5	1.217
A52	Koralpe Steiermark, A	17,352	1.1	88.1	5.3	0.8	5.7	46.9	52.7	0.4	207.0	0.131	23.2	0.895
A60	Karawanken, A	10,315	0.8	77.2	13.0	0.7	9.2	52.6	46.4	1.0	196.7	-0.110	16.4	-0.068
A70	Jauntal, A	7,111	0.9	58.2	35.1	3.9	2.8	57.1	37.7	5.2	196.3	-0.120	18.2	0.179
A80	Lower Gurktal, A	16,438	0.9	61.8	30.1	3.9	4.2	55.5	40.2	4.3	197.6	-0.091	18.4	0.215
A90	Steirisches Becken, A	183,081	1.1	40.2	51.1	4.8	4.0	61.1	34.7	4.2	186.3	-0.356	21.4	0.633
F02	Tarentaise, F	12,803	0.5	83.1	0.1	0.1	16.8	32.4	67.6	0.0	235.3	0.799	11.0	-0.832
F04	Arly, F	1,046	0.6	85.7	0.0	0.0	14.3	27.3	72.7	0.0	245.4	1.037	10.8	-0.861
S12	Dravsko-Ptujsko, SI	70,320	1.3	76.9	10.7	2.9	9.5	47.8	50.0	2.2	208.8	0.174	25.3	1.179
I14	Scrivia, I	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			0.0	
S15	Julian Alps, SI	11,123	0.3	99.2	0.8	0.0	0.0	69.2	30.8	0.0	161.6	-0.941	4.9	-1.685
I18	Noce, I	11,108	0.3	93.7	0.1	0.0	6.2	4.9	95.1	0.0	290.2	2.095	7.5	-1.321
C27	Sandey, CH	648	1.0	100.0	0.0	0.0	0.0	100.0	0.0	0.0	100.0	-2.394	12.5	-0.618
I19	Piave, I	159,483	0.7	79.4	8.0	8.8	3.8	65.3	31.2	3.6	176.9	-0.575	11.5	-0.758

*) no data available; **) vulnerability classes: 1: lowest vulnerability, 5: highest vulnerability

ID	Region	<60mm Vuln. 5** %	60-140 mm Vuln. 4 %	140-220 mm Vuln. 3 %	220-300 mm Vuln. 2 %	>300mm Vuln. 1 %	Weighted soil vulnerability	Standardized soil vulnerability
A10	Steirisches Randgebirge, A	10.5	37.9	50.5	1.2	0.0	357.6	-0.247
A51	Koralpe Kärnten, A	2.7	35.8	57.8	3.6	0.0	337.5	-0.604
A52	Koralpe Steiermark, A	8.8	42.0	41.2	8.0	0.0	351.5	-0.355
A60	Karawanken, A	22.0	44.5	28.4	5.1	0.0	383.3	0.210
A70	Jauntal, A	17.3	55.0	26.1	1.6	0.0	387.9	0.291
A80	Lower Gurktal, A	11.7	27.7	47.2	11.9	1.5	336.0	-0.631
A90	Steirisches Becken, A	1.3	14.9	74.4	9.4	0.0	308.0	-1.128
F02	Tarentaise, F	66.7	33.3	0.0	0.0	0.0	466.7	1.691
F04	Arly, F							
S12	Dravsko-Ptujsko, Sl	0.0	25.0	75.0	0.0	0.0		-0.827
I14	Scrivia, I							
S15	Julian Alps, Sl	84.9	14.3	0.7	0.1	0.0	484.0	1.999
I18	Noce, I	15.3	73.2	8.4	3.1	0.0	400.6	0.518
C27	Sandey, CH							
I19	Piave, I	4.5	38.5	29.9	27.0	0.2	319.9	-0.917

*) no data available; **) vulnerability classes: 1: lowest vulnerability, 5: highest vulnerability

Table A3: Soil

Table A4:
Climate Scenario 0 (current)

ID	Region	Temp winter °C	Temp. spring °C	Temp. summer °C	Temp autumn °C	Precipit. Winter mm***	Precipit. Spring mm***	Precipit. Summer mm***	Precipit. Autumn mm***	Aridity index winter	Aridity index spring	Aridity index summer	Aridity index autumn	Aridity index avg. Year
A10	Steirisches Randgebirge, A	-0.8	7.5	16.6	8.0	33.4	43.1	109.9	85.9	-0.069	0.525	0.452	0.278	0.296
A51	Koralpe Kärnten, A	-2.4	6.9	15.9	6.9	30.0	40.9	108.9	91.6	-0.238	0.505	0.437	0.225	0.232
A52	Koralpe Steiermark, A	-0.2	9.1	17.9	8.9	48.7	70.9	130.5	122.2	-0.014	0.383	0.411	0.218	0.249
A60	Karawanken, A	-2.2	7.0	16.1	7.3	100.4	100.6	148.0	145.9	-0.065	0.209	0.327	0.149	0.155
A70	Jauntal, A	-2.7	8.0	17.1	7.5	47.6	61.5	116.8	111.5	-0.170	0.390	0.440	0.203	0.216
A80	Lower Gurktal, A	-2.7	8.5	18.0	7.9	38.3	50.0	103.2	90.4	-0.211	0.512	0.522	0.262	0.271
A90	Steirisches Becken, A	-0.6	9.3	18.3	8.9	34.2	43.9	103.2	83.2	-0.056	0.634	0.532	0.320	0.357
F02	Tarentaise, F	1.5	10.2	19.0	10.7	88.2	79.2	73.8	80.1	0.053	0.388	0.770	0.401	0.403
F04	Arly, F	-0.9	7.1	15.8	8.0	123.7	103.7	126.4	124.2	-0.022	0.204	0.375	0.194	0.188
S12	Dravsko-Ptujsko, Sl	1.2	11.3	20.9	10.8	41.7	56.0	96.6	103.7	0.088	0.607	0.648	0.313	0.414
I14	Scrivia, I	2.4	11.9	21.9	12.0	43.9	49.4	42.9	70.6	0.164	0.720	1.529	0.509	0.731
S15	Julian Alps, Sl													
I18	Noce, I	0.1	10.2	19.4	10.5	49.7	64.0	97.7	96.3	0.008	0.480	0.597	0.328	0.353
C27	Sandey, CH	3.6	14.5	22.9	13.8	87.4	100.5	154.3	137.5	0.124	0.433	0.444	0.301	0.326

*) no data available; ***) monthly average

ID	Region	Temp. winter °C diff	Temp. spring °C diff	Temp. summer °C diff	Temp. autumn °C diff	Precipit. Winter %diff	Precipit. Spring %diff	Precipit. Summer %diff	Precipit. Autumn %diff	Aridity index winter diff	Aridity index spring diff	Aridity index summer diff	Aridity index autumn diff	Aridity index avg. Year diff
A10	Steirisches Randgebirge, A	1.75	2.5	2.25	2.5	15	0	-5	-35	0.146	0.174	0.088	0.284	0.173
A51	Koralpe Kärnten, A	1.75	2.75	2.25	2.75	20	10	-10	-20	0.186	0.137	0.117	0.169	0.152
A52	Koralpe Steiermark, A	1.75	2.25	2.25	2.75	25	0	-10	-20	0.089	0.095	0.103	0.139	0.107
A60	Karawanken, A	1.75	2.5	2.25	2.5	20	0	-10	-10	0.054	0.075	0.087	0.074	0.072
A70	Jauntal, A	1.5	2.5	2.25	2.25	20	-10	-10	-10	0.107	0.179	0.113	0.090	0.122
A80	Lower Gurktal, A	1.5	2.5	2,0	2.25	20	-10	0	-20	0.133	0.224	0.058	0.159	0.143
A90	Steirisches Becken, A	2	2.75	2.25	2.75	15	0	-10	-35	0.160	0.188	0.132	0.325	0.201
F02	Tarentaise, F	1.5	2.0	2.0	3.0	0	10	0	0	0.051	0.034	0.081	0.112	0.070
F04	Arly, F	2.0	2.3	2.3	3.0	0	15	-20	0	0.048	0.030	0.161	0.072	0.078
S12	Dravsko-Ptujsko, Sl	1.8	2.3	2.8	2.8	20	0	-20	-30	0.090	0.120	0.269	0.248	0.182
I14	Scrivia, I	1.8	2.0	2.5	2.5	10	-10	-40	-30	0.094	0.215	1.311	0.370	0.497
S15	Julian Alps, Sl	2.0	2.5	2.3	2.5	10	0	-10	-30					
I18	Noce, I	2.3	2.8	2.5	2.5	10	-10	-10	-30	0.123	0.197	0.152	0.252	0.181
C27	Sandey, CH	1.5	2.0	2.5	3.0	0	0	0	0	0.051	0.060	0.049	0.065	0.056
*) no data available														

Table A5:
Climate Sceanrio 1 (2050 - differences to current situation, Loibl and Gobiet 2006)

Schriftenreihe Nr. 103

This study was conducted within the EU Alpine Space Project “Alp Water Scarce” under the coordination of the Mountain Institute, University Savoy. The project “Alp Water Scarce” investigates into water supply and water demand of alpine regions regarding the expected climatic conditions. In a sub-study the Federal Institute of Agricultural Economics assessed the vulnerability of agricultural systems within alpine pilot-sites via a set of developed indicators. Furthermore agricultural-political measures were analysed regarding their effects on the water consumption of agriculture. On the basis of these assessments region-specific recommendations for the adaption of agricultural systems towards a possible threatening water scarcity due to climate changes were developed.

Die vorliegende Studie wurde im Rahmen des EU Alpine Space Projektes Alp Water Scare unter Koordination des Mountain Institutes der Universität Savoyen durchgeführt. Das Gesamtprojekt untersucht Wasserangebot und Wasserverbrauch in alpinen Regionen unter den zu erwartenden Klimabedingungen. Im Teilprojekt der Bundesanstalt für Agrarwirtschaft wurden Empfindlichkeitsabschätzungen für das Agrarsystem in alpinen Pilotregionen anhand eines entwickelten Indikatorsets durchgeführt und agrarpolitische Maßnahmen auf ihre Wirkung hinsichtlich des Wasserverbrauches in der Landwirtschaft analysiert. Auf dieser Basis wurden regionsspezifische Empfehlungen zur Anpassung des Agrarsystems an eine mögliche drohende Wasserverknappung infolge des Klimawandels erarbeitet.

BUNDESANSTALT für Agrarwirtschaft