Publizierbarer Endbericht

Gilt für Studien aus der Programmlinie Forschung

A) Projektdaten

Allgemeines zum Projekt	
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Projekt- und KooperationspartnerIn (inkl. Bundesland):	Wharton Risk Management and Decision Processes Center of the University of Pennsylvania
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B) Projektübersicht

1 Kurzfassung

Dürre stellt zunehmend auch in Österreich eine große Herausforderung sowohl für LandwirtInnen als auch für den Staat dar. Wissenschaftliche Untersuchungen belegen, dass aufgrund des Klimawandels Trockenzeiten in Zukunft wahrscheinlich zunehmen und intensiver ausfallen werden. Die ungewöhnlich trockenen und sehr heißen Sommer der letzten Jahre zeigten bereits die finanzielle Verletzlichkeit landwirtschaftlicher Produktion. In jüngster Zeit wurde deshalb eine zusätzliche subventionierte Dürreversicherung in Kombination mit bereits vorhanden Hagel- und Frostversicherungen gefordert. Diese Forderung steht im Einklang mit dem Europäischen Aufruf nach einer landwirtschaftlichen Mehrgefahrenabdeckung durch Versicherungen für ganz Europa.

Allerdings haben subventionierte Lösungen den Ruf erhebliche Marktverzerrungen zu verursachen, sowie Anreize zur Risikoreduktion zu mindern. Überdies muss diese Maßnahme im Zusammenhang mit anderen Dürrerisikomaßnahmen, sowie im Licht der Einschränkungen, die LandwirtInnen durch Marktmechanismen und Vorschriften der Agrarpolitik unterliegen, gesehen werden. Wenn schließlich die unterschiedliche Risikowahrnehmung, Weltanschauungen, und Präferenzen der relevanten AkteurInnen in Betracht gezogen werden, ergibt sich ein komplexes Bild landwirtschaftlichen Dürrerisikomanagements. Um der Komplexität Rechnung zu tragen, wurden in FARM neueste Ansätze der Katastrophenmodellierung mit systematischer qualitativer und quantitativer Erhebung empirischer Daten der wichtigsten StakeholderInnen in Verbindung gebracht. Ziel des Projektes war die Entwicklung von Dürrerisiko im Ackerbau unter Berücksichtigung des Klimawandels und unterschiedlicher finanzieller und landwirtschaftlicher Managementmethoden sowie die Entscheidungsmöglichkeiten, Motivationsfaktoren und Präferenzen betroffener LandwirtInnen zu untersuchen. Die einzelnen spezifischen Fragestellungen wurden innerhalb von 3 Arbeitspaketen analysiert.

Arbeitspaket 1 fokussierte auf quantifizierbare Effekte von Dürren und Klimawandel auf staatlich unterstützte Versicherungslösungen. Zur modellierten Abschätzung von Dürrerisiko unter Berücksichtigung des Klimawandels, wurde das Hauptaugenmerk auf das 2°C Klimaszenario gelegt. Die Anwendung fünf verschiedener Klimamodelle sollte den Unsicherheiten in der Modellierung Rechnung tragen. Darüber hinaus wurden verschiedene landwirtschaftliche Managementszenarien, wie etwa die Benutzung von Bewässerungssystemen, mitberücksichtigt. Basierend auf den Klimaszenarien auf lokaler Ebene, wurden mittels eines landwirtschaftlichen Agrarmodells (EPIC) derzeitige und zukünftige Ernteerträge für neun verschiedene Getreidearten simuliert. Besonders im Burgenland und in Niederösterreich können große Ertragseinbußen für alle Getreidesorten durch Dürre entstehen. Genaue Änderungen sind allerdings stark von den verwendeten Klimamodellen und den entsprechenden Regionen abhängig. Wie in den meisten Ländern, wird in Österreich landwirtschaftliche Versicherung staatlich subventioniert. Deshalb wurde ein Risikomodell entwickelt, dass die zusätzlichen Kosten einer subventionierten Dürreversicherung (speziell fuer Mais) für den Staat berechnen konnte. Neben den gesteigerten Erträgen ist für Mais in

Zukunft ein erhöhtes Risiko bei Dürre zu erwarten. Außerdem ist Mais die anteilig zweitgrößte Getreideart in Österreich. Anders als in bisherigen Arbeiten, kann das Risikomodell berücksichtigen, dass Dürren keine lokalen Phänomene sind, sondern zumeist große Landstriche betreffen. Dies führt zu hohen Kosten, die in Versicherungslösungen mitberücksichtigt werden müssen. Die Analysen zeigen, dass das Risiko auf Bundesebene in Zukunft steigen wird und der Staat sich deshalb auf höhere Subventionierungen einstellen muss.

Um optimale öffentliche Unterstützung zu gewährleisten, muss gleichzeitig berücksichtigt werden, wie LandwirtInnen Versicherung als Instrument für Dürrerisikomanagement im Verhältnis zu anderen möglichen Maßnahmen bewerten. Dies wurde im Arbeitspaket 2 untersucht. Ein Optimierungsmodell für Landwirte mit verschiedenen Betriebsgrößen, das Ambiguität explizit berücksichtigen kann (etwa durch Klimawandelmodelle) wurde erstellt. Es ergab sich, dass vor allem kleinere Betriebe subventionierte Versicherungslösungen in Zukunft benötigen werden. Jedoch muss auch festgestellt werden das betriebliches Risikomanagement von unterschiedlichen Faktoren beeinflusst wird. Natürliche Gegebenheiten und Witterung sind zwar offenkundig Gegenstand jeglicher landwirtschaftlichen Produktion, allerdings können Wetterextreme diese in Zukunft stärker herausfordern. Gleichzeitig haben sowohl agrarpolitische Maßnahmen als auch die Märkte beachtlichen Einfluss auf den Entscheidungsspielraum von LandwirtInnen. Vor allem der tatsächliche Raum, in dem sich LandwirtInnen bewegen und Maßnahmen zum besseren Umgang mit Dürre setzen können, ist sehr eingeschränkt. Von 40 teilstrukturierten Interviews mit österreichischen Landwirten, die von einer repräsentativen standardisierten Umfrage unterstützt wurden, haben wir erfahren, dass Dürre das Hauptproblem bei wetterbedingten Risiken ist. Es stehen verschiedene Risikomanagementmaßnahmen zur Verfügung, die auch Maßnahmen im Zusammenhang mit der Bodenbewirtschaftung, der Ernteauswahl sowie der Wahl der Aussaat- und Erntezeiten umfassen. Bewässerung wird immer relevanter; Aufgrund seines Zeit- und Kostenaufwands ist es jedoch keine Maßnahme, die Landwirte mit Bedacht wählen.

Im Arbeitspaket 3 wurden Dürreversicherungssysteme in Österreich, der Schweiz, Deutschland und den Vereinigten Staaten beleuchtet. Wir fanden keinen direkten Zusammenhang zwischen Versicherung und Dürrerisikominderung. Die Versicherer zeigen jedoch ein zunehmendes Interesse an der Förderung der Risikominderung in landwirtschaftlichen Betrieben. Gleichzeitig wurden wenige Maßnahmen identifiziert, die Moral Hazard explizit vermeiden, wie unter US-amerikanischen Landwirten vermutet wird. Dürreindexprodukte sind häufiger erhältlich, befinden sich jedoch noch im Entwicklungsstadium. Sowohl Landwirte als auch Experten aus anderen mit dem Dürrerisiko zusammenhängenden Entscheidungsbereichen haben Schwierigkeiten, Pläne für das Dürrerisikomanagement auf integrierte Weise umzusetzen, und konzentrieren sich weiterhin weitgehend auf die Produktion.

2 Executive Summary

Drought is increasingly a major challenge for both farmers and the state in Austria. Scientific research has shown that due to climate change, dry seasons are likely to increase and become more intense in the future. The unusually dry and very hot summer of recent years already showed the financial vulnerability of agricultural production. Recently, additional subsidized drought insurance was required in combination with existing hail and frost insurance schemes. This requirement is in line with the European call for multiple agricultural cover by insurance for the whole of Europe.

However, subsidized solutions have a reputation for causing significant market distortions as well as incentives to reduce risk. Moreover, this measure must be seen in the context of other drought-related measures, as well as in the light of restrictions imposed on farmers by market mechanisms and agricultural policy. Finally, taking into account the different risk perceptions, beliefs, and preferences of the relevant actors, a complex picture emerges of agricultural drought risk management. In order to take the complexity into account, FARM has brought together the latest approaches to disaster modeling with the systematic qualitative and quantitative collection of empirical data from key stakeholders. The aim of the project was to investigate the development of drought risk in agriculture taking into account climate change and different financial and agricultural management methods as well as the decision-making possibilities, motivational factors and preferences of affected farmers. The individual specific questions were analyzed within 3 work packages.

Work Package 1 focused on quantifiable effects of drought and climate change on state-supported insurance solutions. For the modeled assessment of drought risk taking into account climate change, the main focus was on the 2 ° C climate scenario. The application of five different climate models should take into account the uncertainties in the modeling. In addition, various agricultural management scenarios, such as the use of irrigation systems, have been taken into account. Based on the climate scenarios at the local level, an agricultural model (EPIC) was used to simulate current and future crop yields for nine different cereals. Especially in Burgenland and in Lower Austria, large yield losses for all cereals can be caused by drought. Exact changes, however, are highly dependent on the climate models used and the regions concerned. As in most countries, agricultural insurance in Austria is subsidized by the state. Therefore, a risk model was developed that could calculate the additional cost of a subsidized drought insurance (especially for corn) for the state. In addition to the increased yields, an increased risk of drought is to be expected for corn in the future. In addition, corn is the proportionately second largest cereal species in Austria. Unlike in previous work, the risk model can take into account that droughts are not local phenomena, but mostly affect large areas of land. This leads to high costs, which must be taken into account in insurance solutions. The analyzes show that federal risk will increase in the future and that the government must therefore adjust to higher subsidies.

At the same time, in order to ensure optimal public support, account must be taken of how farmers rate insurance as a tool for drought risk management in relation to other possible measures. This was examined in work package 2. An optimization model for farmers with different farm sizes that can explicitly consider ambiguity (such as through climate change models) has been created. It turned out that especially smaller companies will need subsidized insurance solutions in the future. However, it must also be noted that operational risk management is influenced by different factors. Obviously, natural conditions and weather conditions are the subject of any agricultural production, but weather extremes may be more challenging in the future. At the same time, agricultural policy measures as well as the markets have considerable influence on the decision-making power of farmers. Above all, the actual space in which farmers move and can take measures to better deal with drought is very limited. From 40 semi-structured interviews with Austrian farmers who were supported by a representative standardized survey, we have learned that drought is the main problem with weather-related risks. Various risk management measures are in place, including measures related to soil management, crop selection and choice of sowing and harvesting times. Irrigation is becoming more relevant; However, due to its time and cost, it is not a measure that farmers choose wisely.

Work package 3 highlighted drought insurance systems in Austria, Switzerland, Germany and the United States. We found no direct relationship between insurance and drought risk reduction. However, insurers are showing increasing interest in promoting risk reduction on farms. At the same time, few measures have been identified that explicitly avoid moral hazard, as US farmers suspect. Drought Index products are more commonly available but are still in the developmental stage. Both farmers and experts from other drought risk-related decision-making areas have difficulties in integrating plans for drought risk management in an integrated manner and continue to focus largely on production.

3 Hintergrund und Zielsetzung

Climate change is a growing concern for European farmers, adding uncertainty to an already uncertain occupation. Weather extremes are expected to worsen in intensity and severity due to climate change and are already causing huge loss and damage to farmers in Europe. Globally, agricultural insurance, which is often highly subsidized in both high-income (e.g., United States, Italy, Spain) and developing countries, is a widely used risk-management instrument. Austria is one of the European Union (EU) countries where drought risk has surpassed other weather-related risks in the agricultural sector, and unusually dry and hot summers in recent years have drawn attention to the drought-related financial vulnerability of Austrian agricultural producers.

In the FARM project, we investigated the implications of comprehensively subsidized agricultural insurance in light of increasing drought. In addition, the costs, risks, and benefits of a subsidized drought insurance scheme were calculated. These results were complemented by qualitative and quantitative studies of farmers' drought management behavior. Together with experts from the agricultural sector, we developed different feasible policy options to manage drought risk in Austria.

There were three overarching objectives. The first objective (within work-package 1, WP1) was to estimate the risks of drought and corresponding agricultural impacts at the national level. This should form the basis to calculate additional annual costs to the public budget for expanding Austria's subsidized crop insurance scheme to include drought risk and benefits to insurers and farmers (small and large). The second objective (WP2) was to identify factors that motivate or de-motivate Austrian farmers to implement on-farm climate adaptation measures. The third and final objective (WP3) was to identify and assess alternative risk management policy options for providing income stability/support to farmers and creating incentives to implement adaptation measures.

In WP1, we developed a novel risk-based drought model that was able to estimate large-scale drought losses and corresponding costs in a probabilistic way for Austria at the country level. This was one of the first models worldwide to clearly incorporate the dependent nature of large-scale extreme events through a so-called copula approach. Through a detailed agricultural model (Environmental Policy Integrated Climate [EPIC]) and this risk-based setting, we were able to take climate change impacts into account. As a next step, the annual premium and fiscal costs for subsidized insurance focusing on corn were calculated for current and future landscapes in exceptional detail, considering the probability that drought-related losses (amplified by climate change) may occur.

In WP2, we developed a novel stochastic, optimization-based risk management modeling approach that clearly takes into account the ambiguity of future risk. Additionally, from 40 semi-structured interviews with Austrian farmers supported by a representative standardized survey, we learned that drought has become the number one concern among weather-related risks. A diverse set of risk management measures is available and being employed, including measures related to soil management, crop selection, and the choice of sowing and harvesting times. Irrigation is increasingly relevant; however, due to its time and cost requirements, it is not a measure farmers choose lightly.

In WP3, a review of drought insurance systems in Austria, Switzerland, Germany, and the United States was conducted. We found no direct link between insurance and drought risk reduction; however, insurers showed increasing interest in promoting risk reduction on farms. At the same time, few measures that explicitly avoid moral hazard were identified, as is suspected among U.S. farmers. Drought index products are more frequently available but are still in the developmental stage. Both farmers and experts from other decision areas related to drought risk have difficulties implementing drought risk management plans in an integrated fashion and remain largely focused on production.

Our research results provide a comprehensive overview of the status of drought risk and its management in Austria at the country and local scales. The insight we gained is also useful for other European countries, particularly those with a similarly structured agricultural sector. Drought risk management practices currently focus on established methods that can be limited in their effectiveness with respect to future drought risk. Further increases in drought risk may soon surpass the limits of what currently preferred measures can handle. Understanding and informing complex systems thinking is required for integrated drought risk management and resilience among farmers as well as public and private policy decision makers. Therefore, future research needs to focus on better predicting drought and drought risk, and also on developing innovative measures and providing a better understanding of synergies and trade-offs between these measures.

4 Projektinhalt und Ergebnisse

WP1: Fiscal implications and equity considerations of subsidized multi-peril insurance in Austria

The first objective of the FARM project was to estimate current and future probabilistic drought risk (2030 and 2050) in Austria, taking into account climate change and corresponding yield losses at the national level (Task 1.1). This should form the basis to calculate additional annual costs to the public budget for expanding Austria's subsidized crop insurance scheme to include drought risk (Task 1.2), as well as the benefits to insurers and farmers (small and large) under different pricing regimes (mutual insurer, monopoly insurer, competitive market) (Task 1.3).

Past modeling approaches have focused on average changes as well as local scales and do not explicitly incorporate regional dependencies, making it impossible to analyze risk-based instruments such as insurance on the large scale. For our research questions, a new model approach needed to be developed to attain risk-based changes including climate change (Figure 1). We used the EPIC agricultural model and state-of-the-art copula approach to upscale regional crop yield distributions at the national scale. Then the results were used to identify monetary losses and possible insurance premiums, and thus the subsidy loads to the federal budget. A risk-layer approach was applied to provide some estimates for different types of realization of drought risk (e.g., frequent or very extreme events determined by their probability of annual occurrence).

Based on the simulation results from the EPIC model, crop yield distributions were calculated for current and future landscapes. Given marginal crop distributions on the local scale, we used the the Standardized Precipitation-Evapotranspiration Index (SPEI) as a proxy for the spatial dependency structure for drought hazard among regions. Finally, we used a copula approach to upscale the crop distributions at the country level, clearly taking these dependencies into account.

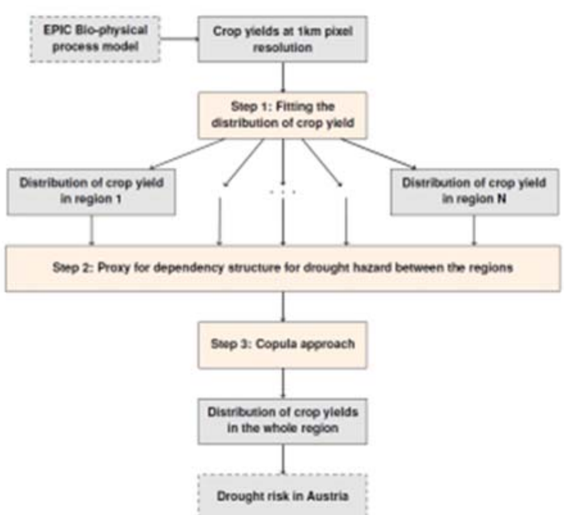
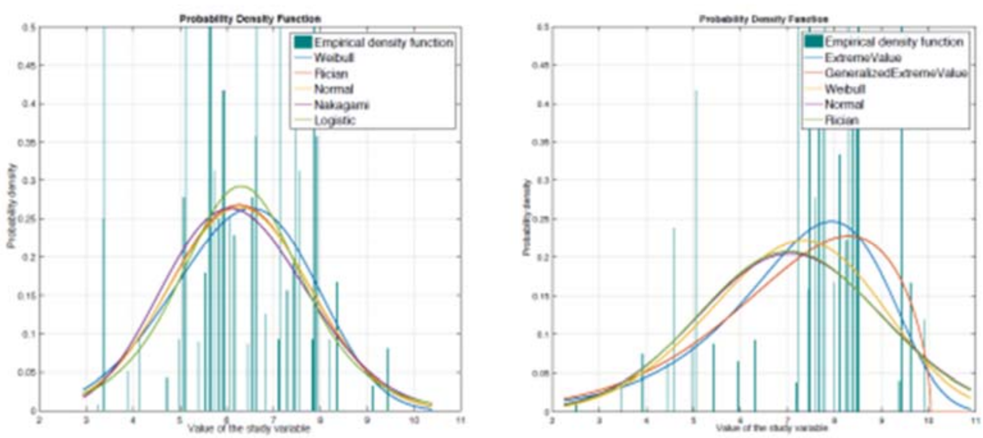


Figure 1: Methodological steps for fulfilling the objectives in WP1.

To calibrate the model for the Austrian case, we used five bias-corrected EURO-CORDEX regional climate projections (CSC-REMO/MPI-ESM-LR, SMHI-RCA4/EC-EARTH, KNMI-RACMO22E/EC-EARTH, SMHI-RCA4/HadGEM2-ES, IPSL.INERIS-WRF331F/IPSL-CM5A-MR; all RCP 4.5) to account for climate change, and recalculated crop yield projections using on-ground data of the SPEI. All projections encompassed a time period from 1971 to 2011 with a +0.25-degree resolution. We also identified three different crop management scenarios, further distinguishing between irrigated and rainfed scenarios (also used as input for WP3):

(i) business-as-usual (BAU) fertilization without soil degradation, both irrigated and rainfed (BAU-IR-con, BAU-RF-con),
(ii) BAU fertilization accounting for soil degradation, both irrigated and rainfed (BAU-IR-dyn, BAU-RF-dyn),
(iii) sufficient fertilizers supply on all available cropland, both rainfed and irrigated, to estimate the crop yield potential (POT-IR-con, POT-RF-con).

In total, 30 different climate and management scenarios were considered (five regional climate projections times six management scenarios). Based on the estimated crop yields, we calculated probability distributions for different time scales. Figure 2 shows corn yield distributions for a small region in Lower Austria for the time periods of 1971–2010 and 2041–2070 for the CSC-REMO2009 projection and BAU-IR-con management scenario.



a. Time horizon: 1971-2010. *b. Time horizon: 2041-2070.*

Figure 2: Probability density estimation for local regions for climates considering different time horizons.

These crop distributions were upscaled via the copula approach, which can model the dependency among regions. Having crop distribution at the country level available, we transformed the yields into monetary terms (including different assumptions of prices and uncertainties) and analyzed different insurance schemes. For example, as planned in Austria (and implemented in 2016 just after the project started), drought insurance schemes should be subsidized by 50%. Assuming that insurance provides relief for yields below the 5-year average and using the average selling price per ton of corn for the same period, we were able to calculate the risk as well as the expected costs for insurance to the Austrian government (or the insurance) that includes claim payments over different time periods.

Changes in precipitation patterns are quite variable in Austria. Drought extremity in the 2030s (2016–2045), 2050s (2036–2065), and historic period (1971–2000) were evaluated with respect to the long-term mean of 1971–2000 for which EURO-CORDEX projections exist. We found that the simulated yields performed well compared to reported yields (Figure 3), confirming the applicability of our new approach as described above.

The crop-specific yield results pointed to high variability in crop yield vulnerability among individual climate change projections, contributing to the overall uncertainty of the ensemble-mean signal. Nevertheless, vulnerabilities estimated from CGMS and EURO-CORDEX climate data showed a high level of agreement for all crops, with the exception of maize in Burgenland and Niederösterreich and some potatoes in Steiermark. For example, in 2030, sugar beet will be extremely vulnerable to drought spells in Burgenland, Niederösterreich, and Wien regions, where more than 60% of the yield may be lost if not prevented by irrigation. Moderate vulnerability of more than 20% was simulated for soya and maize in Niederösterreich and Wien regions and maize in Vorarlberg. In general, crops are less vulnerable in regions with a cooler climate including Kärnten, Steiermark, Oberösterreich, Salzburg, and Vorarlberg. In some cases, crop yield may be even higher in a regionally dry year than in a normal year in these regions, such as maize yield in Oberösterreich in the time periods of 2030 and 2050. Furthermore, in 2050, high yield vulnerability of 50% and more was estimated for sugar beet in Burgenland and Niederösterreich, and moderate vulnerability was estimated for maize and soya in Niederösterreich. Crops are less vulnerable in regions of cooler climate zones. Skewed and bimodal yield distributions of some crops demonstrate scenario-based and sub-regional heterogeneity in some counties. Supplementary irrigation may eliminate drought vulnerability in all regions of Austria by the 2050s.

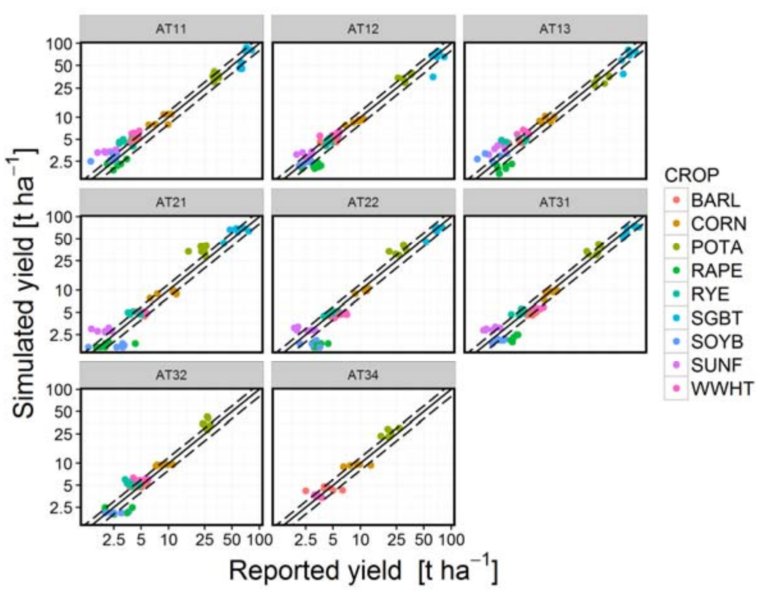


Figure 3: Simulation against reported crop yields; all years from 2010 to 2015 are plotted; dashed lines represent the 20% confidence interval (AT11: Burgenland, AT12: Niederösterreich, AT13: Wien, AT21: Kärnten, AT22: Steiermark, AT31: Oberösterreich, AT32: Salzburg, AT34: Vorarlberg).

Applying the multi-regional approach, we estimated current and future crop yield probability distributions for Austria corresponding to 2-, 5-, 10-, 50-, 100-, 250-, 500, and 1000-year events for corn. Average corn yields for the ensemble mean were about 5.2 million tons, slightly higher than the 5.1 million tons on average over the last 5 years. Due to climate change, on average, future corn yields significantly increase. Our novel risk-based perspective allows for the comparison of yields considering drought events of different magnitudes (=return period), resulting in a more disconcerting picture. Considering past records only, a 500-year event (representing low yields due to drought occurring only once in 500 years on average, and hence an example of extreme drought) would cause total yields to decrease by 15% compared to the average. Considering climate change, a future 500-year event would cause yield losses of more than 19%, while average yields are expected to increase. These results indicate higher yield fluctuations and hence more and larger extreme events comparing future projections with the current situation.

Table 1 presents the risk-based costs for including current and future probabilistic drought risk losses of different magnitudes (=annual return period) at the country scale for Austria, taking into account climate change impacts. Regarding the costs of insurance schemes, in the case of a 50 year event the government would step in with around 69 million Euros and costs would increase to around 103 million Euros in 2050. For a more extreme event such as the 500 year event costs today for the government would be 94 million Euros and would increase to around 155 million Euros in 2050. Table 1 presents current and future risk-based costs to the government participating in a subsidized insurance scheme for corn.

Table 1: Current and future (2050) costs of financing 50 percent of Corn yield losses (defined to be crop yields below the long term average). Mean Ensemble and Business as usual scenario, minimum and maximum values due to model ambiguity and corn prices in brackets.

Costs to the government (in million Euro)		
Annual return period	Costs to the government Current	Costs to the government Future 2050
5	25 [18 34]	33 [25 46]
10	42 [30 57]	58 [45 81]
20	55 [40 75]	79 [62 111]
50	69 [50 93]	103 [81 144]
100	78 [56 105]	120 [95 167]
250	88 [63 119]	140 [112 193]
500	94 [68 127]	155 [128 212]
1000	100 [72 135]	175 [161 228]
Actuarial fair premium	13.4 [9.7 18.3]	19.9 [15.7 27.8]

These numbers provide detailed information on drought losses from a country-level perspective and can be used by the government and insurance providers to design future risk management strategies. In addition, one can determine the backup capital needed to cover losses and resulting insurance claims for extreme events. For example, the actuarial fair premium for the government subsidizing insurance would be around 13.4 million Euros today and would increase to around 19.9 million Euros in the Future. Applying a 250 year event as a reference point for determining necessary backup-capital for the government it would be around 88 million Euros today and 140 million Euros in the future. These numbers also provide insights regarding the potential subsidy burden to the federal budget as well as the potential costs to farmers. Regarding the latter, we used the information in WP2 to determine risk management strategies under different subsidy considerations, which are subsequently explained in more detail.

Milestones:

- Development of an integrated risk modeling approach for large-scale drought events
- Development of a modeling approach that clearly takes climate change impacts into account
- Calculation of the annual burden to the federal budget for subsidizing insurance.

  Estimation of risks to different types of farmers (see WP 2)

WP2: Farmer risk-management behaviors and the role of insurance pricing

The objective of WP2 was to identify factors that motivate or de-motivate Austrian farmers to implement on-farm climate adaptation measures. While subsidized insurance is a common instrument in agricultural risk management, there is growing concern about its impact beyond the financial implications (as estimated in WP1). In theory, insurance puts a “price” on risk and sends a signal to farmers to take on-farm protective adaptation measures to lower their risk. Subsidies distort the price signal, sometimes with high costs. Remarkably little is known about the role that insurance pricing plays in the risk-management decisions of European farmers. WP2 aimed to fill this gap by answering the question of what factors motivate or de-motivate Austrian farmers to adopt risk-reducing measures (i.e., what are farmers’ diverse risk management strategies). In Task 2.1, we evaluated how a “rational farmer” would adopt risk-reduction behavior given different insurance subsidy levels, whereas in Task 2.2, we empirically identified the drivers of farmers’ stated risk management strategies and how they are influenced.

We used different methodological approaches to answer the questions raised in the objectives and corresponding tasks: one sophisticated optimization modeling approach was developed for Task 2.1, and a detailed qualitative semi-structured interview method as well as a standardized large-scale questionnaire were developed for Task 2.2. In Task 2.1, we examined how an economically rational farmer would behave in the face of drought risk, given a choice between risk reduction and insurance. We looked at excess-of-loss insurance contracts, which are most appropriate for natural disaster-related purposes. Mathematically they have been shown to be the optimal insurance scheme for extremes.

A typical excess-of-loss contract requires the insured to retain a specified level of risk with the insurer covering all losses between an attachment point and exit point. First, we determined how the attachment point should be selected. As marginal cost curves are not on hand in most cases for such a task, we suggested a different approach based on the average discretionary budget of a farmer. We assumed that a farmer will behave in a risk-averse manner if drought losses are above the discretionary budget available. The underlying heuristic of this approach is that a farmer acts in a risk-neutral manner for all losses, which can be financed with the available budget and starts to become risk-averse if this is not the case. The argument comes from the resource gap literature, which argues that resource gaps will cause additional long-term or indirect effects the decision maker wants to avoid. This also fits the risk-layering approach as it is usually frequent events that a risk bearer wants to decrease by risk reduction, subsequently focusing on risk financing instruments.

The basic methodology used is briefly discussed below. Given attachment point d_1, distortion function g, budget B, and different loss distributions F_n that stem from modeling ambiguity (these are the costs to farmers due to drought events; their loss distributions are omitted here but were calculated in WP1), we formulated the following optimization problem to derive exit point d_2.

$$\underset{F1,\dots,Fn}{maximize} \quad d_2$$

$$subject\ to \int_{d_1}^{d_2} g\big(1 - F_i(c)\big)dx \ \leq \ B, \quad i = 1, \dots, n$$

As loss distributions are usually represented through discretization of points, we calculated the distribution premium via a piecewise approximation

$$\int_{d_1}^{d_2} g\big(1 - F\ \ (c)\big)dx \approx S + rest_2$$

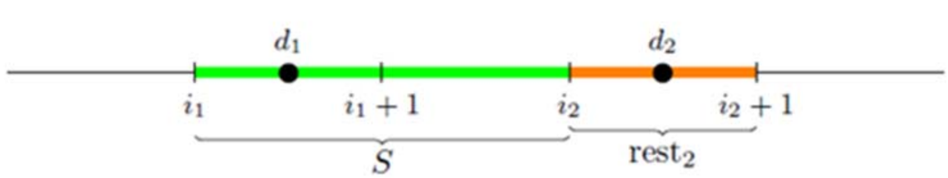
,

where

$$S = \sum_{i_1}^{i2} \frac{g\big(1 - F_j\big) + g\big(1 - F_{j+1}\big)}{2} (x_{j+1} - x_j)$$

$$i_1 = \max\{\, i | Loss(i_1) - d_1 \leq 0\} \text{ and } i_2 = \max\{\, i | Loss(i_2) - d_2 \leq 0\}$$

and $rest_2$ is the amount of the budget not used as the optimal exit point may not fall exactly on the breakpoints of the losses, or in other words there is no index I such that Loss(i)=d_2. This is more informally illustrated in the following graph.



It is worth noting that for the current situation, we assumed no model ambiguity, and therefore the distortion premium was easily computed using the results from Asimit et al. (2017). For optimization under ambiguity, however, we used the approach discussed above. The full model parametrization as well as proofs can be found in papers mentioned in the reference sections below.

For Task 2.2, we initially focused on creating the baseline for this work using a combination of desktop research and key informant interviews. We created a stakeholder map as a backdrop for our data collection, which allowed us to highlight any gaps and biases. We interviewed policymakers from the BMLFUW; representatives of the chambers of agriculture in Upper Austria, Lower Austria, and Burgenland; representatives from the Austrian Hail Insurance; researchers from BOKU, WU, and AGES; and individual farmers in Upper and Lower Austria. Then we conducted 40 semi-structured (face-to-face) interviews with farmers to collect their individual narratives on climate change, their risk perceptions and concerns, and ultimately, to identify their risk management strategies (both intended and actual) and the role of insurance and insurance pricing. Our research focused on predominantly cash crop-oriented farms to emphasize a diverse set of drought risk management options.

We limited the sampling to areas in Austria that are affected by precipitation deficits during the vegetation season. During the summer of 2017, ZAMG (2017) identified regions in the north and east of Lower Austria and Burgenland as the ones most deficient in precipitation compared to the average precipitation from 1981 to 2010 as the reference period. In Lower Austria, we focused on regions both affected by precipitation deficits and where cropping farms are dominant, which included Waldviertel, Marchfeld, and the region south of the Danube ranging from Eastern Vienna to Northern Burgenland.

We initially used the snowballing method to get in touch with farmers who fit our profile. For the interview itself, farmers had the opportunity to come to the International Institute for Applied Systems Analysis (IIASA), conduct the interview via skype or on the phone, or (preferably) be visited at their farm. We organized interviews using a loosely standardized semi-structured protocol, which was developed and tested on five farmers. The benefit of semi-structured interviews is that they create less bias by providing predetermined answer categories. Thus, the results reflect issues that are most salient and important to the farmers.

To obtain a more standardized understanding of the topic, we designed a questionnaire for a large-scale Austria-wide survey with three main aims. The first was to describe the use and perception of agricultural management practices and their relevance for drought risk, as we had a particular interest in farmers' preferences with respect to insurance, premium subsidies, and alternative compensation schemes. The second was to test the usefulness of some of the common theories used to analyze the drivers of individual behavior, most importantly the Protection Motivation Theory and the Theory of Planned Behavior. The third was to explore the communication channels used by farmers to gather information with respect to drought risk and drought risk management.

For data collection, we subcontracted KeyQuest, a market research company that specializes in agricultural topics. In its 10 years, the staff has accumulated vast experience on the Austrian agricultural sector, as well as a comprehensive and up-to-date database of Austrian farmers. They collected data between October 31 and November 19. A representative sample of 500 cropping farmers was collected via computer-assisted telephone interviews using a combined process of random selection and quotas for farm size, conventional versus organic farming methods, and cropping region. The sample population was Austrian cropping farms with more than 5 ha total agricultural area.

Of the 2014 successful contacts, 50% refused to participate in the interview and 24% could not be interviewed as they were outside the target group or in a quota that had been fulfilled. Thus, 25% of interviews were successfully completed and are the basis for the following statistics. KeyQuest provided us with a summary of the most important survey characteristics and the entire dataset in the format of SPSS files. Based on that, we conducted descriptive statistical analysis in SPSS to gain an understanding of the most prominent divers for drought risk decision making. We also performed preliminary analyses of the relationship and dependency among different influencing factors using the chi-square test and factor analysis. However, a detailed analysis will be developed into a scientific paper only after the project has ended.

In Task 2.1, we used two types of farmers, small and large, which have the same risk in relative terms but different absolute magnitudes. Furthermore, and as indicated earlier, we had different loss distributions for the 2050 period due to modeling ambiguity from WP1 Task 1.3. The two groups of farmers were selected according to the statistical definition of such farmers in Austria and were related to the available discretionary budget taken from official statistics from the agricultural sector (Grüner Bericht 2016). Farm characteristics, available budget, drought events, ambiguity, and respective losses for the two groups of farmers are shown in Table 2.

Table 2: Farm characteristics, available budget, drought events, ambiguity, and respective losses used as input for the optimization model.

Small-sized farmer 1 with 30 ha and available budget of 4847 Euro							
RP	**1000**	**500**	**250**	**100**	**50**	**20**	**10**
Current	7303	6890	6429	5687	5030	4001	3057
Model 1	11909	10855	9926	8520	7440	5722	4220
Model 2	16369	13014	11456	9631	8237	6286	4577
Model 3	11670	10889	9914	8563	7394	5680	4161
Model 4	11209	10474	9579	8294	7210	5542	4050
Large sized farmer 2 with 100 ha and available budget of 29,291 Euro							
Current	24344	22967	21429	18957	16767	13336	10189
Model 1	39698	36182	33086	28400	24799	19073	14068
Model 2	54564	43380	38186	32105	27458	20954	15255
Model 3	38901	36298	33045	28543	24646	18934	13870

We were especially interested in risk management strategies according to the risk layering approach. Given the available budget of about 4800 Euro for farmer 1, we selected a 20-year event as the attachment point for farmer 1 for the current situation. We did not assume that a farmer will use the entire available budget for insurance, but rather, that he/she would be able to invest a maximum of 10% of the budget for insurance purposes (i.e., about 480 Euro). This would lead to an investment up to the 50-year event for the current situation. For the future, situation modeling results showed that while the risk of drought-related losses increases, the average income also increases by about 28% (Hochrainer-Stigler et al. 2018). Therefore, we increased the available budget accordingly. Considering this budget increase, the 20-year event will still be selected as the attachment point as we assume risk aversion and therefore the lowest attachment point of all models would be chosen by the farmer. For the distortion premium, we used a standard potential function for all models available indicating a large increase in the future (Figure 4).

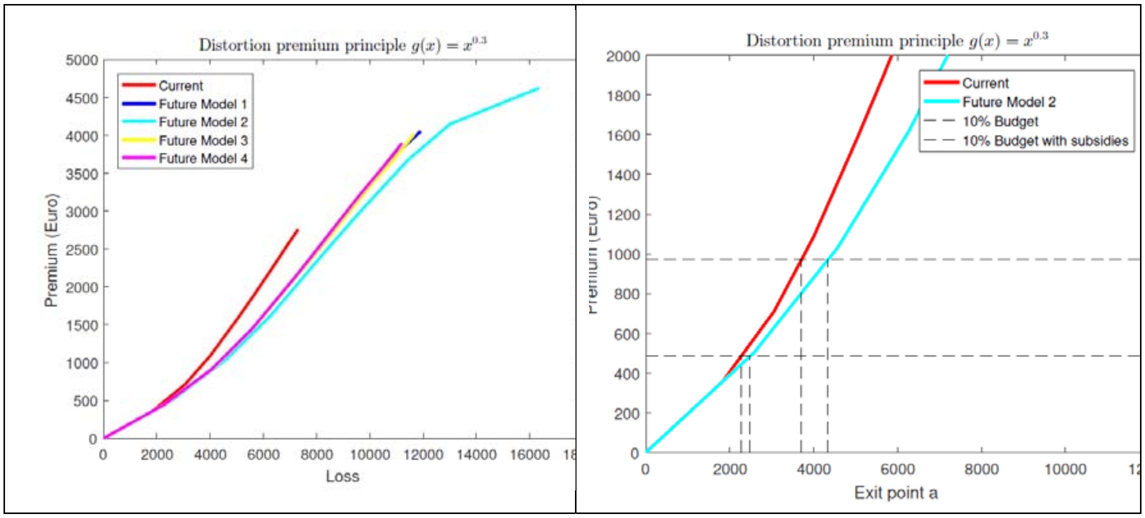


Figure 4: Left: Relationship between losses and premium based on the distortion principle. Right: Premium and exit point relationship for two selected models.

In Figure 4, the also relationship between exit point and premium for two different models is shown. However, it is worth noting that the optimization had to be conducted for all four available models simultaneously. The results of the optimization procedures are shown in Table 3.

Table 3: Summary of results of the optimization for different farmers and corresponding subsidies.

	Attachment point α	Exit point d	$\mathbb{E}(\cdot) + 0.5V@R0.9(\cdot)$
Farmer 1			
No subsidies Current Future	 4001 5542	 4307 5891	 1281 2234
Subsidies Current Future	 4001 5542	 4637 6261	 1221 2153
Farmer 2			
No subsidies Current Future	 26262 33086	 26362 37287	 5224.8 8413
Subsidies Current Future	 26262 33086	 26362 42530	 5224.8 8393

According to these results, farmer 1 could invest in insurance up to the 26-year event, which is in monetary terms, up to d_2 = 5891 Euro. As discussed, the Austrian government promised to subsidize insurance premiums by 50%; hence, we repeated the calculations under this setting. While the 20-year event still served as the attachment point, for the current situation, the exit point could be increased up to the 40-year event. The future situation is less optimistic considering even subsidized insurance and the farmer’s increased budget. The exit point would decrease due to modeling ambiguity costs to the 26-year event or in monetary terms of 6261 Euro. Interestingly, in the current situation, the large farmer would be able to insure all risk layers, or in other words, does not need to insure due to his large discretionary budget. However, when we consider the ambiguity of future models, this situation is no longer accurate; the large available budget allows a high attachment point around a 250-year event, but the exit point increases considerably when the subsidies are applied (i.e., from d_2 = 37287 exit point without subsidies to full coverage by insurance). This shows that subsidies and corresponding budgets have quite different effects on different types of farmers. In particular, small farms need subsidies the most today and even more so in the future.

In Task 2.2, we found that Austrian farmers mostly rely on well-known measures that can be directly implemented in the farming process. Measures, which foremost and (almost) exclusively address drought risk, were termed single-purpose measures. Single-purpose measures are not only limited in number but may also come at high costs such as irrigation or drought insurance. Comparably larger numbers of measures not only improve drought risk management but also serve different purposes at the same time. Such multi-purpose measures include the selection of drought-tolerant crops and breeds, soil management, diversification, and financial hedging instruments.

Figure 5 summarizes drought risk management measures taken by the interviewed farmers. Across the board, we found that the most often mentioned measures were irrigation, soil management, and crop/variety selection; 39.5% of our interviewees first mentioned irrigation as a measure to deal with drought, 21.1% referred to soil management and crop/variety selection, 7.9% named insurance, 10.4% named other measures (e.g., diversification, plant protection, sowing rate, and additional fodder purchase) as the first measure, and 5.3% of farmers initially felt that there is nothing they can do to protect against drought.

Traditional commodity-based contracts, in which farmers contract to sell a predefined amount of grain at a specific market price within a specific time period after harvest to their trading partner, were the preferred financial hedging instrument, used by 75% of farmers. They were not considered a risk management measure, at least not for drought, and were only discussed when prompted. Although many farmers were insured, they seemed reluctant to rely on it. For many, insurance was not a risk sharing tool, and farmers felt as if they were paying too much for little payout. Market-based hedging instruments were rarely used if at all, as most farmers preferred to rely on contracts with long-standing partners. These findings provide an overall picture of the risk-averse, conservative farmer and are in line with the survey results of Austrian farmers.

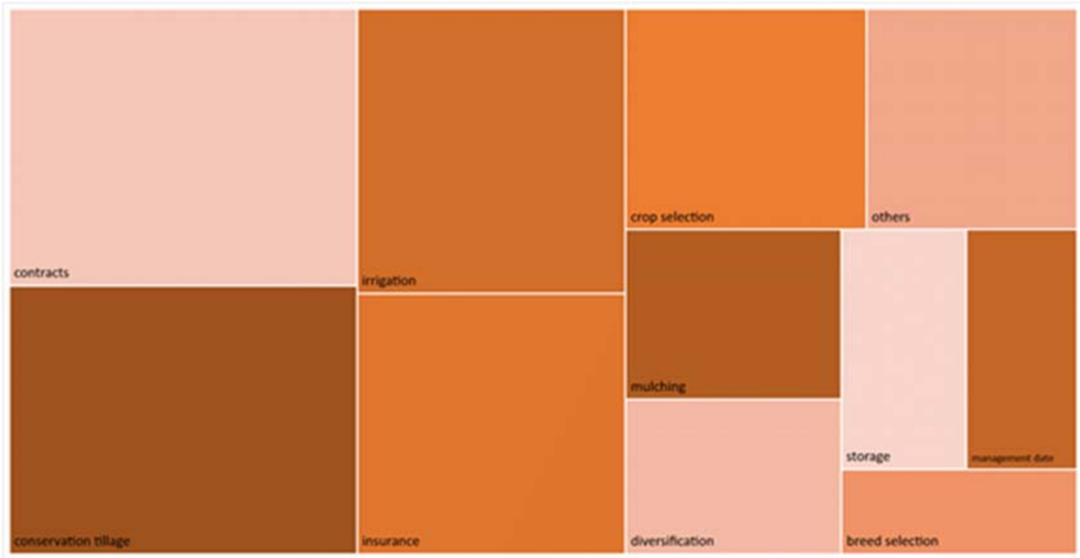


Figure 5: Drought risk management measures taken by interviewed farmers. The sizes of the squares indicate the relative frequency of each measure.

Options for managing drought during the production process are limited and tightly linked to other farm practices. These complexities and resulting trade-offs need to be considered to find concrete points of leverage and consequently policy interventions. This means that linear thinking is not useful for realistic drought risk management, and a systems perspective is a useful approach.

We found that farmers' decision spaces with respect to taking drought risk management measures were naturally dominated by a nature and production-centered view of drought risk management measures (Figure 6). Apart from the general climatic conditions and weather risks, which are constant companions over which farmers have no influence, this starts with soil characteristics and water availability, which determine the crops that can be produced. However, institutional enablers and constraints were very much on farmers' minds, including compliances to receive compensation payments and subsidies for measures supporting drought management (e.g., for electrified irrigation or drought insurance products) on the public side, and mainly regulations of retailers and insurance design on the private side.

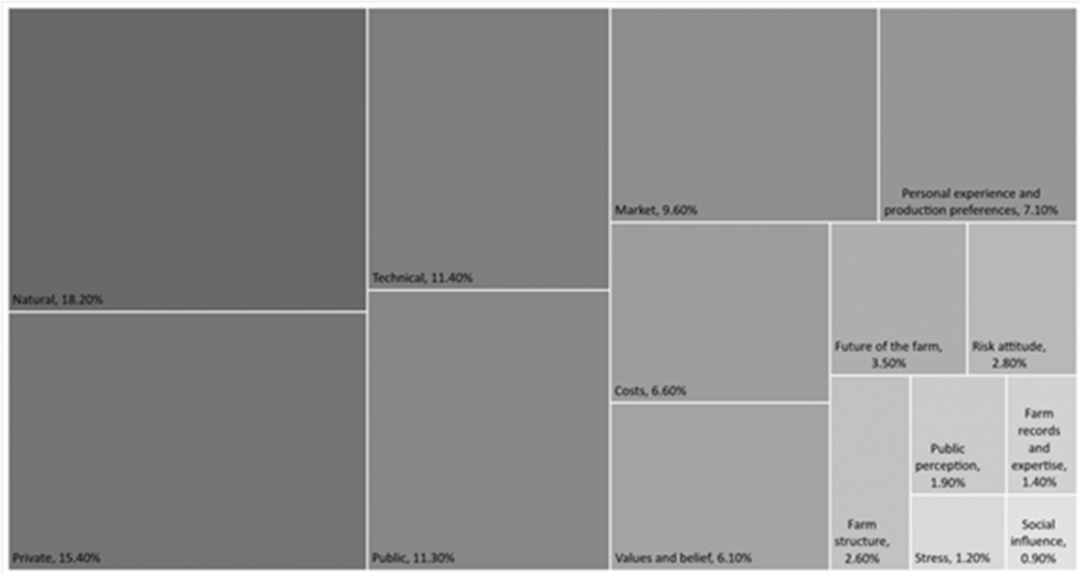


Figure 6: Farmers' mental decision spaces distinguished by dominant themes. Percentage of overall coded text. Multiple coding was used when categories of influence were mixed.

The results from the standardized survey (Figure 7) showed that, compared to other risks relevant at the farm level such as price fluctuations and unexpected legislative changes, extreme weather events including drought (as the most important), heat, hail, storm, and heavy rainfall are heavily affecting Austrian cropping farmers (93% of the respondents said they suffered from droughts at least occasionally). At the same time, farmers felt extremely powerless with regard to handling weather extremes (83%). Both findings also hold true for future risks as perceived by the farmers.

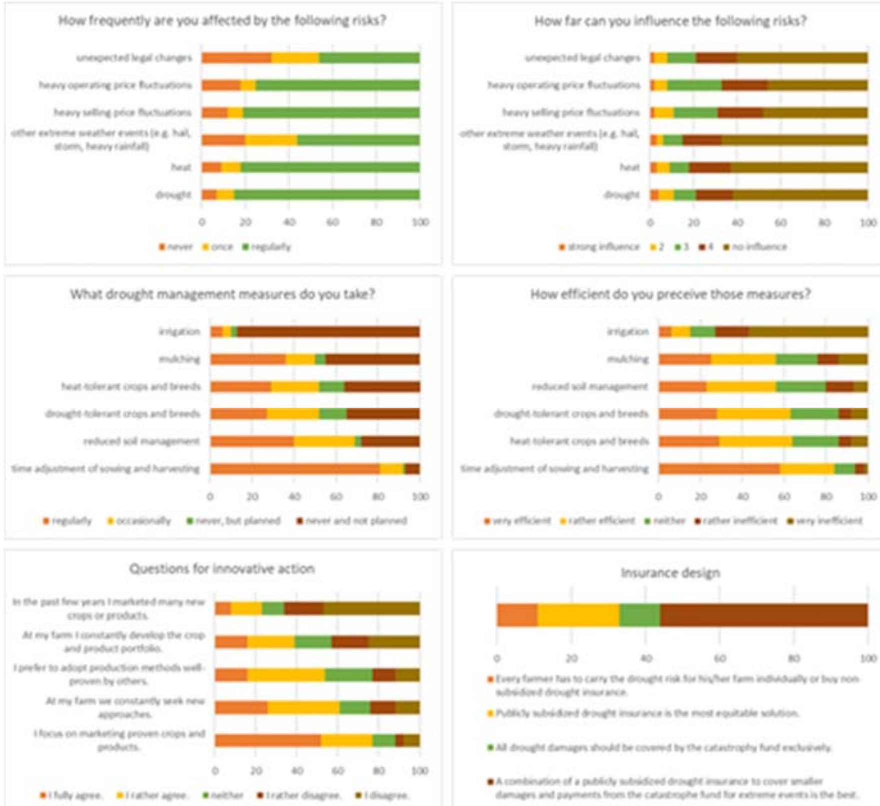


Figure 7: Selected results from the standardized survey.

The most commonly applied measures were those regarding individual, on-farm production-based actions, including time adjustment of tilling and harvesting (92% applied those at least occasionally), reduced tillage practices (69%), and mulching (50%). The least commonly applied was irrigation (only 10% irrigated at least occasionally), possibly due to the tedious nature of irrigation practices with working hours at night and the bulky equipment as found in the interview work. Additionally, the survey results showed that farmers perceived irrigation as the least cost-efficient measure; only 15% viewed it as rather efficient. In addition to those measures focusing on on-farm activities, farmers also used some marked-based measures such as having storage facilities for their yield (67% currently have such facilities) or insurance contracts (53% currently have indemnity-based drought insurance and 39% have drought index insurance provided by the Austrian Hail insurance company). Trading futures are still falling behind (21% hold future contracts).

Although farmers have experienced a change towards increased climatic insecurity (85% confirmed an increase in the emergence of extreme weather events), the majority of farmers still rely on farm operations that have proven well in the past and prefer careful decision making related to marketing strategies, insurance design, or information sources. A total of 77% of the respondents focused on marketing proven crops and products, and 89% preferred insurance designs with some type of public financial support involved. Personal records were the source of choice for reliable information.

The results from both the interview and survey will be presented in scientific publications, which are currently under review and in preparation, respectively.

Milestones:

- Development of an optimization model for risk management, including risk reduction and subsidized insurance, under ambiguity for farmers
- Development of stakeholder maps on multiple levels complemented with key stakeholder input using qualitative interview techniques
- Evaluation of a decision space for farmers based on a large-scale standardized questionnaire

WP3: Risk management policy options that provide income stability to farmers and incentives to implement on-farm adaptation measures

In WP3, we looked at risk management policy options on a broader scale to identify strategies that can support farmers from a holistic perspective. The research issue we addressed is what alternative risk management policy options are available in Austria for managing agricultural drought risk.

Our goal was to expand the drought risk management-drought resilience discussion beyond current policymaking and contribute to the scientific literature on the topic. Therefore, we wrote a book chapter on drought risk resilience with Austria and the findings from the project as a case study (Task 3.1). We based our analysis for the book chapter on an extensive scientific literature search on agricultural drought resilience, starting with a keyword search in Scopus including "Agriculture," "Drought," and "Resilience." Then we chose the most frequently cited papers together with the most recent ones. Our insights will be published in the book "Disaster Risk Reduction and Resilience" as part of the GADRI book series entitled "Disaster and Risk Research."

Second and based on Task 3.1, we organized an expert workshop to bring integrated issues of drought risk management to the attention of the experts present. Most of them were part of important multiplication platforms, deliberately chosen to bring a more integrated view into relevant policy processes (Task 3.2). We approached Austrian experts for the workshop, focusing on the national level, to represent diverse decision areas associated with agricultural DRM. Farmers were not our explicit target group, as in related work we focused heavily on farmers' perceptions. Our rationale was to have a small number of participants, who would all actively participate in the workshop, rather than a large audience that would listen to a set of presentations. This set a limit to the different decision areas represented at the workshop. We considered experts to be those who were not necessarily academicians or researchers, but rather, who were knowledgeable in their decision areas. Moreover, we asked participants to self-determine whether they felt capable of addressing the questions posed in the workshop. Thus, we tried to achieve diversity across a public–private spectrum of decision areas, with research and civil society as overarching domains. We approached the heads of departments of institutions and companies, whom we knew from prior research in the FARM project.

The workshop followed an exploratory approach, identifying trade-offs and synergies faced by actors in various areas of drought risk management in Austria. We did not generate quantitative data, quantitatively analyze results, or generate consensus on topics. Rather, we followed a set of pre-elicitation activities including problem definition, identification and recruitment of experts, and development of an elicitation protocol and briefing material. In addition, we designed a group elicitation session (the workshop) that included motivating experts, as well as information presentation and discussion. Finally, post-elicitation activities included individual debriefing based on the workshop protocol to elaborate on and confirm insights.

We also surveyed the literature on agricultural insurance practices in Austria, its two German-speaking neighboring countries Switzerland (with a similarly small-structured agricultural sector but no EU member state) and Germany (with a comparably large-structured agricultural sector and an important EU member state), and the United States as a country with one of the most elaborate agricultural insurance schemes in place. We summarized the country-specific insurance information in comprehensive fact sheets, focusing on the comparison of agricultural insurance design and public support measures across countries with differently structured agricultural sectors (Task 3.3).

From our literature review for the book chapter, we found that drought risk emerges slowly as a concern across various policy areas in Austria. Targeted efforts, however, are still rare or in the pilot stages, and most risk management occurs indirectly in the context of other policymaking such as that related to environmental protection, soil management, water, and climate adaptation policy. On one hand we can interpret this as a cross-cutting resilience-building approach; on the other hand, this may lead to oversight of the negative side effects and trade-offs between policies and insufficient actual drought risk management.
An understanding of the interactions among diverse policies incentivizing sustainable soil management, irrigation, and water use is important at the regional, national, and international levels to create coherent policies that do not lead to maladaptation with respect to drought. To what extent drought resilience will become an issue at the sectoral and societal levels is more difficult to predict and will require further inquiry. When the sector itself is as small as agriculture in Austria, this might not seem to be an immediate problem for the economy; however, agriculture worldwide is usually deeply rooted in the country's culture, thereby determining landscapes and traditions.

From the workshop, we found that current perceptions of and practices in drought risk management strongly build upon production-based efforts at the farm. We designed the workshop to allow for active involvement of all 13 participants. All experts who participated received our workshop rationale and a briefing document prior to the workshop to prepare for the contents to be discussed. This included instructions for the focus of their presentations as well as some stylized systems diagrams to illustrate how we would like them to think about synergies and trade-offs.
The experts provided their responses to our questions in the format of short presentations of about 10–15 minutes, with one per institutional department that was directly followed up with discussions of the respective contents. This

discussion followed a brief informal summary to allow enough flexibility for presentations and discussions given the short amount of time available. Together with the experts, we developed a joint policy brief that included a systematic summary of the presentations according to the three questions and including the discussions. This allowed us to systematically follow-up on inputs and ensured an accurate representation of the contents and issues presented. The joint policy-brief was written in German and was in evidence with all participants to serve as input for upcoming policy discussions.

The fact sheets provide a comprehensive overview of agricultural insurance in the selected countries. This type of background information has not been available in such a concise form and combination but is highly sought after in the face of current policy efforts across the EU. We found no direct link between insurance and drought risk reduction; however, insurers showed increasing interest in promoting risk reduction on farms. At the same time, few measures that explicitly avoid moral hazard were identified, as is suspected among U.S. farmers. Drought index products are more frequently available but are still in a developmental stage. All fact sheets were made available through the IIASA repository and were promoted via IIASA communication channels as important sources of basic information.

Milestones:

- Analysis of detailed studies of different insurance schemes in other countries and creation of fact sheets
- Workshop discussing the results and relevance for stakeholders and revised in an iterative fashion, resulting in a policy paper
- Development of a reference framework for integrated drought risk management across scales

5 Schlussfolgerungen und Empfehlungen

Regarding WP1, first we found different crop vulnerabilities within our future scenarios. For example, in 2030, the sugar beet will be extremely vulnerable to drought spells in the Burgenland, Niederösterreich, and Wien regions, where more than 60% of yield may be lost if not prevented by irrigation. Moderate vulnerability of more than 20% was simulated for soya and maize in the Niederösterreich and Wien regions and maize in Vorarlberg. In general, crops will be less vulnerable in regions with a cooler climate including Kärnten, Steiermark, Oberösterreich, Salzburg, and Vorarlberg. In some cases, crop yield may be even higher in a regionally dry year than in a normal year in these regions, such as maize yield in Oberösterreich by the period 2030 and 2050 for example. In 2050, high yield vulnerability of 50% and more was estimated for sugar beet in Burgenland and Niederösterreich, and moderate vulnerability was estimated for maize and soya in Niederösterreich. Crops will be less vulnerable in regions of cooler climate zones. Skewed and bimodal yield distributions of some crops have demonstrated scenario-based and sub-regional heterogeneity in some counties. Also, supplementary irrigation may eliminate drought vulnerability in all regions of Austria by the 2050s.

Second, based on these results we estimated large-scale drought risks at the country scale focusing on corn, which showed quite a subtle picture of future risks. By applying the multi-regional approach to the study of crop yields in Austria, we estimated current and future crop yield probability distributions at the national scale. Future corn yields will significantly increase on average in the future due to climate change; however, our risk perspective provides a more worrisome picture if one compares yields for different return periods. It can be noted that such an analysis would not be possible if a risk-based approach such as ours is not applied. For example, a 500-year event would cause total yields to be about 15% lower compared to the average. While larger averages can be expected in the future, there also seems to be higher fluctuations in the future compared to the current situation, with more and larger extremes.

Third, the costs for subsidizing drought insurance for corn, which is especially vulnerable to drought, were estimated. As planned by the Finance Ministry of Austria, current and future risk management strategies should support insurance schemes by subsidizing it by 50%. For example, in the case of a 50 year event the government would step in with around 69 million Euros and costs would increase to around 103 million Euros in 2050. For a more extreme event such as the 500 year event costs today for the government would be 94 million Euros and would increase to around 155 million Euros in 2050. The actuarial fair premium for the government subsidizing insurance for Corn would be around 13.4 million Euros today and would increase to around 19.9 million Euros in the Future. Applying a 250 year event as a reference point for determining necessary backup-capital for the government it would be around 88 million Euros today and 140 million Euros in the future. These numbers provide a detailed picture on drought losses at the country-level perspective, and also advise future risk management strategies for the government as well as insurance providers in more detail.

Regarding WP2, we introduced a risk-layer approach to protect against extreme drought events, where the insurance premium was robust under the possible uncertainty of future loss models. The proposed methodology showed how to determine an attachment point of an insurance contract and presented an optimization model to calculate the risk layer a farmer can afford, given future model uncertainty. We found that subsidies were especially important for small-scale farmers, who would benefit the most regarding additional investments in risk reduction (compared to large-scale farmers). However, the method employed was highly technical and therefore was complemented with other on-the-ground and empirical-based research. We also found that cropping farmers' decision spaces with respect to taking drought risk management measures were naturally dominated by a nature- and production-centered view. Apart from the general climatic conditions and weather risks, which are constant companions over which farmers have no influence, this started with soil characteristics and water availability, which determined the crops that can be produced. However, institutional enablers and constraints were very much on farmers' minds, including compliances to receive compensation payments and subsidies for measures supporting drought management (e.g., for electrified irrigation or drought insurance products) on the public side, and mainly regulations of retailers and insurance design on the private side.

From a methodological point of view, we conclude that the interview approach may be complementary to standardized surveys focused on behavioral and cognitive aspects of risk management. In addition, the major enabling, and constraining factors may account, at least in part, for those that remain largely unaccounted for in the respective statistical models analyzing these aspects. Indeed, the mental model approach applied highlighted the enabling and constraining factors that were most dominantly on farmers' minds when they were prompted to talk about drought risk management measures. These were mostly factors related to the natural and immediate production environment, as well as institutions. The approach also allowed risk attitudes to be considered to some extent. However, it was more difficult to identify cognitive factors this way, although they were sometimes implied, particularly financial and time constraints attached to decisions. Thus, from this perspective, we found that from farmers' perspectives, frequently investigated cognitive factors were overshadowed by market drivers, institutional enabling factors and constraints, and environmental limitations.

The limitations of this research were related to the mental model approach in particular and were associated with qualitative social empirical research in general. The major limitations of the mental model approach are the potential pitfalls of the elicitation method chosen, and the remaining question of whether a mental model is truly a representation of actual behavior (Jones et al. 2011). By indirectly eliciting answers, we tried to avoid creating a bias by introducing our own themes and categories for enabling and constraining factors. A direct approach may have provided a chance to proceed with a more systematic and facilitated data analysis. A combined approach requires considerably more time on all sides involved but might provide an ideal solution. We believe that our indirect approach helped reduce the potential additional challenge of potentially missing the actual models in use to some extent, as it allowed farmers to talk about what they felt most comfortable and familiar about. However, there is no guarantee that both mental and actual behavioral models completely overlap. This also means that we cannot say what influencing factors are ultimately decisive in a decision setting.

Our insights from WP3 indicated that while DRM measures related to plant production are well understood and managed, most of the so-called low-hanging fruits have been harvested, and less well-charted territory lies ahead and warrants further research and expanding the thinking beyond plant production. Our workshop results reflect how DRM is not an institutionalized policy field but happens in the context of various decision areas. This provides additional communication challenges, particularly in fields where it has not been a constant concern but may be increasingly relevant and frequent, as cascading consequences need to be considered such as in spatial planning, transport, data collection and monitoring, marketing, and trade.

We found most interesting the different responses to our question about risk management and trade-offs/synergies. We noticed that risks were rarely framed as probabilities, but rather, with a focus on expected negative impacts. Not surprisingly, drought risk was viewed slightly differently across decision areas. Moreover, experts seemed to have difficulties formulating concrete trade-offs, and mostly talked about barriers or negative impacts, possibly for two reasons, which both need to be explored further elsewhere. First, it may be due to the fact that experts are very much settled into their own respective decision areas and institutional set-ups, with limited time or capacity to consider cross-cutting issues. Second, it may be due to inappropriate framing on our side and/or the lack of time in preparing the input. The systems thinking tasks that we employed may require deeper preparation and include more time interacting with experts. This is an important finding, showing that we cannot assume that systems thinking will naturally take place in any given expert setting and that there is a need to develop adequate methods of encouraging a systems approach. To increase policy coherence, we need such methods, as well as increased opportunities (such as the FARM expert workshop) for experts in different decision areas to interact. Small platforms such as the FARM workshop may be useful to individuals and their perception of a topic simply by providing space for discussion and exchange. However, the establishment of effective and integrated drought risk management that has a wide and lasting impact requires interventions not only from research but in several relevant arenas such as policymaking, the third sector, and business platforms.

Drought risk emerges slowly as a concern across various policy areas in Austria. Targeted efforts, however, are still rare or in pilot stages, and most risk management happens indirectly in the context of other policymaking such as that related to environmental protection, soil management, water, and climate adaptation policy. On one hand, we can interpret this as a cross-cutting resilience-building approach; on the other hand, this may lead to oversight of negative side effects and trade-offs between policies and insufficient actual drought risk management.

If we look at the farm as the system of concern, drought risk management is mostly a result of broader targeted risk management and can be considered to a large extent a product of overall resilience building. Risk reduction and risk mitigation through adaptation of production are widely preferred, although increasing risk may require a more diverse set of risk management measures. In turn, this will need increased awareness-raising efforts for financial measures that are currently barely considered by farmers.

An understanding of the interactions of diverse policies incentivizing sustainable soil management, irrigation, and water use is important at the regional, national, and international levels to create coherent policies that do not lead to maladaptation with respect to drought. To what extent drought resilience will become an issue at the sectoral and societal levels is more difficult to say and will require further inquiry. When the sector itself is as small as agriculture in Austria, this might not seem to be an immediate problem for the economy; however, agriculture worldwide is usually deeply rooted in each country's culture, thereby determining landscapes and traditions. On a more practical note, ensuring a certain level of autonomy with respect to food production, as well as the benefits of producing fresh foods locally, are significant if not essential considerations that will increase the value and urgency of ensuring drought-resilient farmers and a drought-resilient agricultural sector.

The results have important implications on various levels. In regards to scientific outputs, the plan is to further develop this method for other disaster events and to apply this method on larger levels including the European and global scale. The question of decision making under ambiguity due to climate change has not been explicitly tackled in the research community, but our research has shown that this should not be neglected, as costs can be considerably higher if such effects are actually priced (e.g., within insurance contracts). This will also likely have effects on the uptake of insurance, and therefore will be especially important for subsidies. The solution space for agricultural risk management in Austria is much broader than insurance, and therefore it is imperative to develop integrative approaches that clearly take the reality of farmers as well as stakeholders on the ground into account. Stakeholder mappings as well as lessons learned from other countries including the interconnections between them from a Pan-European perspective need to be established in the future. We will also present our results to decision makers after the project, as we have produced several policy papers for these occasions (see the publication list).

Our results are especially important for mainstreaming climate risk management into budget-planning processes. We developed and presented a method that can achieve this in a risk-based fashion. Such risk-based methods are the primary choice, as suggested in relevant IPCC documents. They provide a comprehensive overview of the status of drought risk and its management in Austria at the country and local scales. The insight we gained is also useful for other European countries, particularly those with a similarly structured agricultural sector. Drought risk management practices currently focus on established methods that can be limited in their effectiveness with respect to future drought risk. Further increases in drought risk may soon surpass the limits of what currently preferred measures can handle. Understanding and informing complex systems thinking is required for integrated drought risk management and resilience among farmers as well as public and private policy decision makers. Therefore, future research needs to focus on better predicting drought and drought risk, and also on developing innovative measures and providing a better understanding of synergies and trade-offs between these measures.

C) Projektdetails

6 Methodik

WP1

Past modeling approaches have focused on average changes as well as local scales and do not explicitly incorporate regional dependencies, making it impossible to analyze risk-based instruments such as insurance on the large scale. For our research questions, a new model approach needed to be developed to attain risk-based changes including climate change (Figure 1). We used the EPIC agricultural model and state-of-the-art copula approach to upscale regional crop yield distributions at the national scale. Then the results were used to identify monetary losses and possible insurance premiums, and thus the subsidy loads to the federal budget. A risk-layer approach was applied to provide some estimates for different types of realization of drought risk (e.g., frequent or very extreme events determined by their probability of annual occurrence).

Based on the simulation results from the EPIC model, crop yield distributions were calculated for current and future landscapes. Given marginal crop distributions on the local scale, we used the the Standardized Precipitation-Evapotranspiration Index (SPEI) as a proxy for the spatial dependency structure for drought hazard among regions. Finally, we used a copula approach to upscale the crop distributions at the country level, clearly taking these dependencies into account.

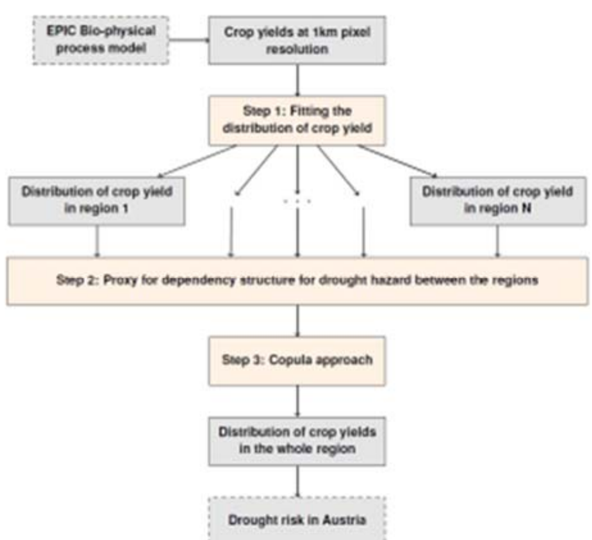
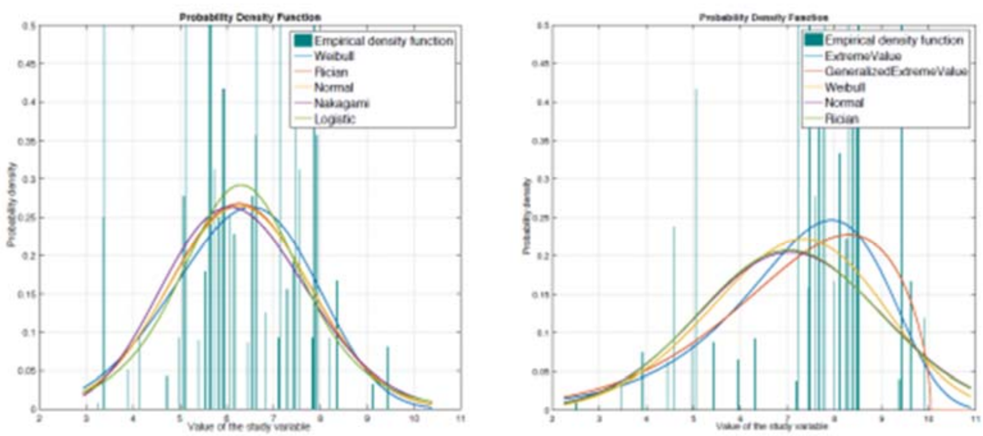


Figure 8: Methodological steps for fulfilling the objectives in WP1.

To calibrate the model for the Austrian case, we used five bias-corrected EURO-CORDEX regional climate projections (CSC-REMO/MPI-ESM-LR, SMHI-RCA4/EC-EARTH, KNMI-RACMO22E/EC-EARTH, SMHI-RCA4/HadGEM2-ES, IPSL.INERIS-WRF331F/IPSL-CM5A-MR; all RCP 4.5) to account for climate change, and recalculated crop yield projections using on-ground data of the SPEI. All projections encompassed a time period from 1971 to 2011 with a +0.25-degree resolution. We also identified three different crop management scenarios, further distinguishing between irrigated and rainfed scenarios (also used as input for WP3):

(i) business-as-usual (BAU) fertilization without soil degradation, both irrigated and rainfed (BAU-IR-con, BAU-RF-con),
(ii) BAU fertilization accounting for soil degradation, both irrigated and rainfed (BAU-IR-dyn, BAU-RF-dyn),
(iii) sufficient fertilizers supply on all available cropland, both rainfed and irrigated, to estimate the crop yield potential (POT-IR-con, POT-RF-con).

In total, 30 different climate and management scenarios were considered (five regional climate projections times six management scenarios). Based on the estimated crop yields, we calculated probability distributions for different time scales. Figure 2 shows corn yield distributions for a small region in Lower Austria for the time periods of 1971–2010 and 2041–2070 for the CSC-REMO2009 projection and BAU-IR-con management scenario.



a. Time horizon: 1971-2010. *b. Time horizon: 2041-2070.*

Figure 9: Probability density estimation for local regions for climates considering different time horizons.

These crop distributions were upscaled via the copula approach, which can model the dependency among regions. Having crop distribution at the country level available, we transformed the yields into monetary terms (including different assumptions of prices and uncertainties) and analyzed different insurance schemes. For example, as planned in Austria (and implemented in 2016 just after the project started), drought insurance schemes should be subsidized by 50%. Assuming that insurance provides relief for yields below the 5-year average and using the average selling price per ton of corn for the same period, we were able to calculate the risk as well as the expected costs for insurance to the Austrian government (or the insurance) that includes claim payments over different time periods.

WP2

We used different methodological approaches to answer the questions raised in the objectives and corresponding tasks: one sophisticated optimization modeling approach was developed for Task 2.1, and a detailed qualitative semi-structured interview method as well as a standardized large-scale questionnaire were developed for Task 2.2. In Task 2.1, we examined how an economically rational farmer would behave in the face of drought risk, given a choice between risk reduction and insurance. We looked at excess-of-loss insurance contracts, which are most appropriate for natural disaster-related purposes. Mathematically they have been shown to be the optimal insurance scheme for extremes.

A typical excess-of-loss contract requires the insured to retain a specified level of risk with the insurer covering all losses between an attachment point and exit point. First, we determined how the attachment point should be selected. As marginal cost curves are not on hand in most cases for such a task, we suggested a different approach based on the average discretionary budget of a farmer. We assumed that a farmer will behave in a risk-averse manner if drought losses are above the discretionary budget available. The underlying heuristic of this approach is that a farmer acts in a risk-neutral manner for all losses, which can be financed with the available budget and starts to become risk-averse if this is not the case. The argument comes from the resource gap literature, which argues that resource gaps will cause additional long-term or indirect effects the decision maker wants to avoid. This also fits the risk-layering approach as it is usually frequent events that a risk bearer wants to decrease by risk reduction, subsequently focusing on risk financing instruments.

The basic methodology used is briefly discussed below. Given attachment point d_1, distortion function g, budget B, and different loss distributions F_n that stem from modeling ambiguity (these are the costs to farmers due to drought events; their loss distributions are omitted here but were calculated in WP1), we formulated the following optimization problem to derive exit point d_2.

$$\underset{F1,\dots,Fn}{maximize} \quad d_2$$

$$subject\ to \int_{d_1}^{d_2} g\big(1 - F_i(c)\big)dx \leq \ B, \quad i = 1, \dots, n$$

As loss distributions are usually represented through discretization of points, we calculated the distribution premium via a piecewise approximation

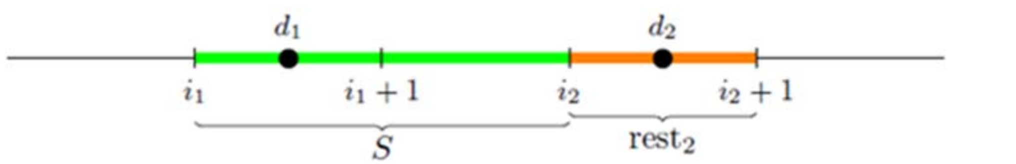
$$\int_{d_1}^{d_2} g\big(1 - F \quad (c)\big)dx \approx S + rest_2$$
,

where

$$S = \sum_{i_1}^{i2} \frac{g\big(1 - F_j\big) + g\big(1 - F_{j+1}\big)}{2} (x_{j+1} - x_j)$$

$$i_1 = \max\{\, i | Loss(i_1) - d_1 \leq 0\} \text{ and } i_2 = \max\{\, i | Loss(i_2) - d_2 \leq 0\}$$

and $rest_2$ is the amount of the budget not used as the optimal exit point may not fall exactly on the breakpoints of the losses, or in other words there is no index I such that Loss(i) = d_2. This is more informally illustrated in the following graph.



It is worth noting that for the current situation, we assumed no model ambiguity, and therefore the distortion premium was easily computed using the results from Asimit et al. (2017). For optimization under ambiguity, however, we used the approach discussed above. The full model parametrization as well as proofs can be found in papers mentioned in the reference sections below.

For Task 2.2, we initially focused on creating the baseline for this work using a combination of desktop research and key informant interviews. We created a stakeholder map as a backdrop for our data collection, which allowed us to highlight any gaps and biases. We interviewed policymakers from the BMLFUW; representatives of the chambers of agriculture in Upper Austria, Lower Austria, and Burgenland; representatives from the Austrian Hail Insurance; researchers from BOKU, WU, and AGES; and individual farmers in Upper and Lower Austria. Then we conducted 40 semi-structured (face-to-face) interviews with farmers to collect their individual narratives on climate change, their risk perceptions and concerns, and ultimately, to identify their risk management strategies (both intended and actual) and the role of insurance and insurance pricing. Our research focused on predominantly cash crop-oriented farms to emphasize a diverse set of drought risk management options.

We limited the sampling to areas in Austria that are affected by precipitation deficits during the vegetation season. During the summer of 2017, ZAMG (2017) identified regions in the north and east of Lower Austria and Burgenland as the ones most deficient in precipitation compared to the average precipitation from 1981 to 2010 as the reference period. In Lower Austria, we focused on regions both affected by precipitation deficits and where cropping farms are dominant, which included Waldviertel, Marchfeld, and the region south of the Danube ranging from Eastern Vienna to Northern Burgenland.

We initially used the snowballing method to get in touch with farmers who fit our profile. For the interview itself, farmers had the opportunity to come to the International Institute for Applied Systems Analysis (IIASA), conduct the interview via skype or on the phone, or (preferably) be visited at their farm. We organized interviews using a loosely standardized semi-structured protocol, which was developed and tested on five farmers. The benefit of semi-structured interviews is that they create less bias by providing predetermined answer categories. Thus, the results reflect issues that are most salient and important to the farmers.

To obtain a more standardized understanding of the topic, we designed a questionnaire for a large-scale Austria-wide survey with three main aims. The first was to describe the use and perception of agricultural management practices and their relevance for drought risk, as we had a particular interest in farmers' preferences with respect to insurance, premium subsidies, and alternative compensation schemes. The second was to test the usefulness of some of the common theories used to analyze the drivers of individual behavior, most importantly the Protection Motivation Theory and the Theory of Planned Behavior. The third was to explore the communication channels used by farmers to gather information with respect to drought risk and drought risk management.

For data collection, we subcontracted KeyQuest, a market research company that specializes in agricultural topics. In its 10 years, the staff has accumulated vast experience on the Austrian agricultural sector, as well as a comprehensive and up-to-date database of Austrian farmers. They collected data between October 31 and November 19. A representative sample of 500 cropping farmers was collected via computer-assisted telephone interviews using a combined process of random selection and quotas for farm size, conventional versus organic farming methods, and cropping region. The sample population was Austrian cropping farms with more than 5 ha total agricultural area.

Of the 2014 successful contacts, 50% refused to participate in the interview and 24% could not be interviewed as they were outside the target group or in a quota that had been fulfilled. Thus, 25% of interviews were successfully completed and are the basis for the following statistics. KeyQuest provided us with a summary of the most important survey characteristics and the entire dataset in the format of SPSS files. Based on that, we conducted descriptive statistical analysis in SPSS to gain an understanding of the most prominent divers for drought risk decision making. We also performed preliminary analyses of the relationship and dependency among different influencing factors using the chi-square test and factor analysis. However, a detailed analysis will be developed into a scientific paper only after the project has ended.

WP3

Our goal was to expand the drought risk management-drought resilience discussion beyond current policymaking and contribute to the scientific literature on the topic. Therefore, we wrote a book chapter on drought risk resilience with Austria and the findings from the project as a case study (Task 3.1). We based our analysis for the book chapter on an extensive scientific literature search on agricultural drought resilience, starting with a keyword search in Scopus including "Agriculture," "Drought," and "Resilience." Then we chose the most frequently cited papers together with the most recent ones. Our insights will be published in the book "Disaster Risk Reduction and Resilience" as part of the GADRI book series entitled "Disaster and Risk Research."

Second and based on Task 3.1, we organized an expert workshop to bring integrated issues of drought risk management to the attention of the experts present. Most of them were part of important multiplication platforms, deliberately chosen to bring a more integrated view into relevant policy processes (Task 3.2). We approached Austrian experts for the workshop, focusing on the national level, to represent diverse decision areas associated with agricultural DRM. Farmers were not our explicit target group, as in related work we focused heavily on farmers' perceptions. Our rationale was to have a small number of participants, who would all actively participate in the workshop, rather than a large audience that would listen to a set of presentations. This set a limit to the different decision areas represented at the workshop. We considered experts to be those who were not necessarily academicians or researchers, but rather, who were knowledgeable in their decision areas. Moreover, we asked participants to self-determine whether they felt capable of addressing the questions posed in the workshop. Thus, we tried to achieve diversity across a public–private spectrum of decision areas, with research and civil society as overarching domains. We approached the heads of departments of institutions and companies, whom we knew from prior research in the FARM project.

The workshop followed an exploratory approach, identifying trade-offs and synergies faced by actors in various areas of drought risk management in Austria. We did not generate quantitative data, quantitatively analyze results, or generate consensus on topics. Rather, we followed a set of pre-elicitation activities including problem definition, identification and recruitment of experts, and development of an elicitation protocol and briefing material. In addition, we designed a group elicitation session (the workshop) that included motivating experts, as well as information presentation and discussion. Finally, post-elicitation activities included individual debriefing based on the workshop protocol to elaborate on and confirm insights.

We also surveyed the literature on agricultural insurance practices in Austria, its two German-speaking neighboring countries Switzerland (with a similarly small-structured agricultural sector but no EU member state) and Germany (with a comparably large-structured agricultural sector and an important EU member state), and the United States as a country with one of the most elaborate agricultural insurance schemes in place. We summarized the country-specific insurance information in comprehensive fact sheets, focusing on the comparison of agricultural insurance design and public support measures across countries with differently structured agricultural sectors (Task 3.3).

7 Arbeits- und Zeitplan

Tables 4 and 5 show the original and actual work and time schedule. There are differences in the two schedules for three reasons. First, the proposals left some choices open, such as between a survey and focus group, which were made during the project and thus replaced or removed from the original schedule. Second, WP2 was delayed due to staff changes in 2017, as well as to a more detailed analysis of qualitative interviews than anticipated. The project extension (no cost) enabled us to finalize workshop results, particularly the engagement with experts and the extended interview analysis, as well as to complete the essential survey analysis, which was highly anticipated by stakeholders. Additional time was required in WP3 to provide key information in glossy, accessible formats.

Table 4: Original work and time schedule

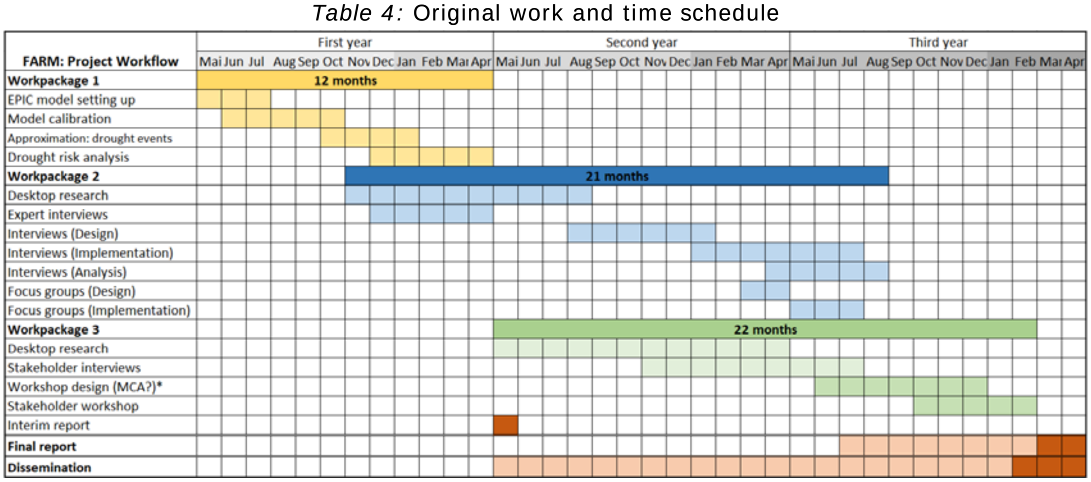
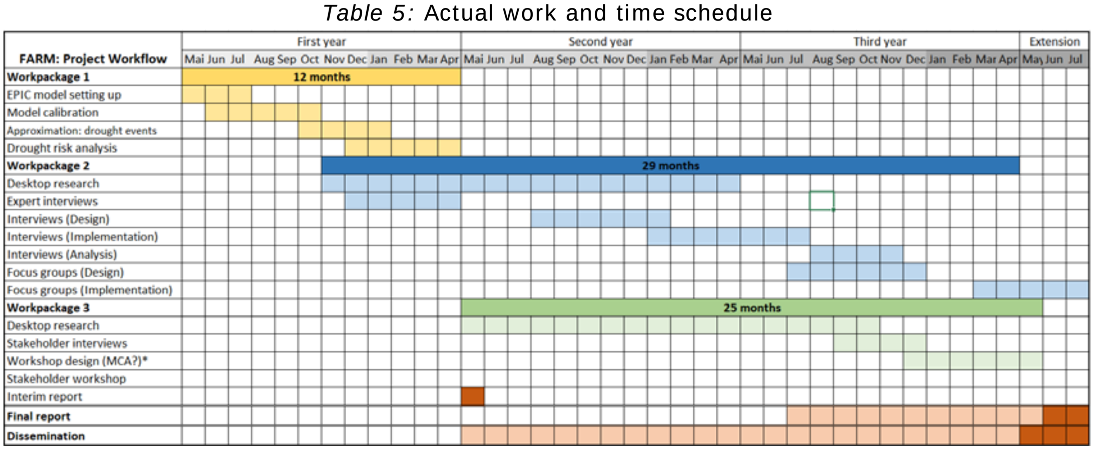


Table 5: Actual work and time schedule



8 Publikationen und Disseminierungsaktivitäten

Publications in scientific journals

- Hochrainer-Stigler, S. and Hanger-Kopp, S. (2017). Subsidized Drought Insurance in Austria: Recent Reforms and Future Challenges. Wirtschaftspolitische Blätter, no. 4: 599–614.
- Hochrainer-Stigler S., Balkovic J., Silm K. and Timonina-Farkas A. (2018). Large scale extreme risk assessment using copulas: an application to drought events under climate change for Austria. Computational Management Science, doi:10.1007/s10287-018-0339-4.
- Gaupp, F., Hochrainer-Stigler, S. and Hall, J. (2019). Changing risks of simultaneous global breadbasket failure (accepted). Nature Climate Change letter.
- Ajsad, N, Gaupp, F. and Hochrainer-Stigler, S. (2019). Large-scale drought and Migration (second revision). OR Spectrum.

Book chapters

- Hanger-Kopp, S. and M. Palka. (2019). "Exploring Drought Resilience through a Drought Risk Management Lens in Austria." In: Disaster Risk Reduction and Resilience, edited by Y. Muneta and S. Hochrainer-Stigler. Disaster and Risk Research: GADRI Book Series. Springer.

IIASA working papers

- Hanger-Kopp, S. and M. Palka. (2019). "An Expert Workshop on Integrated Drought Risk Management (DRM): Identifying Synergies and Trade-Offs for the Austrian Agricultural Sector." IIASA Working Paper. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Other publications

- Hochrainer-Stigler, S., Hanger-Kopp, S. and Palka, M. (2018). „FARM Farmers and Risk Management: Examining subsidized drought insurance and its alternatives." In: Berichte zur Klimaforschung. Klima- und Energiefonds, Wien.
- Palka, M. (2019). „Cooperation needed! The case of drought management in Austria". Nexus blog post. At: https://blog.iiasa.ac.at/2019/09/04/cooperation-needed-the-case-of-drought-management-in-austria/

Fact sheets and policy briefs

- Palka. M. and Hanger-Kopp, S. (2019). „Agricultural crop insurance in Switzerland, focusing on drought". International Institute for Applied Systems Analysis
- Palka. M. and Hanger-Kopp, S. (2019). „Agricultural drought risk management in Germany: Insurance solutions and other public support measures". International Institute for Applied Systems Analysis
- Hanger-Kopp, S. and Hochrainer-Stigler, S. (2017). „Agricultural drought insurance: Austria as a case study". International Institute for Applied Systems Analysis

- Hanger-Kopp, S., Palka, M., Stangl, M., Tasser, M., Birschitzky, J., Mitter, H., Oberforster, M. and Pammer, R. (2019). „Dürrerisikomanagement im österreichischen Ackerbau: Synergien und Trade-offs“. International Institute for Applied Systems Analysis.

<u>Presentations and external workshops</u>

- Klimatag 2018: Hanger-Kopp, S. and M. Palka. (2018). „Agricultural drought risk management in Austria: A farm level study”. In: 19. Österreichischer Klimatag, 23 –25 April 2018, Salzburg, Austria.
- Klimatag 2019: Hanger-Kopp, S. and M. Palka. (2019). „Dürrerisikomanagement im österreichischen Ackerbau”. In: 20. Österreichischer Klimatag, 24 –26 April 2018, Vienna, Austria.
- ECCA 2019: Palka, M. and Hanger-Kopp, S. (2019). „Integrated agricultural risk management to increase drought resilience: a farm level study in Austria”. In: 4th European Climate Change Adaptation conference, 28-31 May 2018, Lisbon, Portugal.
- Hanger, S. (2017). Landwirtschaftliches Risikomanagement in den USA und Kanada. 3. Sitzung zum Thema „GAP nach 2020 und Risikomanagement“. Ministry of Agriculture, Forestry, Water Management and the Environment. 29 June 2017.

<u>Participation in workshops</u>

- Symposium Risikomanagement in der Land- und Forstwirtschaft, 23. May 2018, Steiermarkhof, Graz.
- Diskussionsveranstaltung Klimawandelanpassung am Betrieb - wie umgehen mit zunehmenden Hitze- und Trockenperioden?, 1. June 2018 in Wolkersdorf im Weinviertel.

<u>Planned, but not yet released publications:</u>

- Corina, B., Pflug, G. and Hochrainer-Stigler, S. (submitted). “Risk Layering under ambiguity: an application to farmers exposed to drought risk”. Risk Analysis.
- Hanger-Kopp, S. and M. Palka. (submitted). “Decision Spaces in Agricultural Drought Risk Management: A Mental Model Study of Austrian Crop-Farmers.” Local Environment.
- Hochrainer-Stigler, S., Hanger-Kopp, S. and Palka, M. (in preparation). Insurance and Risk Perception. Sozialwissenschaftliche Blätter.
- Hanger-Kopp, S. and M. Palka. (in preparation). “Drought risk and drought risk management strategies among Austrian crop farmers - A standardized survey”. IIASA Working Paper. Laxenburg, Austria: International Institute for Applied Systems Analysis.

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