Agronomy rules: A case study on the mismatch between farm-scale measures and policy instruments for drought adaptation in Seewinkel, Austria

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Working Paper No. 3 from the Build Back Better research project

August 2024

available at https://buildbackbetter.joanneum.at/

Abstract

Farms all around the world need to enter Climate Resilient Development Pathways (CRDPs) that account for increasing pressure from rising temperatures and changing precipitation patterns because of climate change, navigate structural change in the agricultural sector, and prepare for future drought hazards. The semi-arid Seewinkel region in Eastern Austria faces a history of drought, flooding and irrigation, a falling groundwater table, tightening water resource conflicts and cross-border dependencies. Farmers in this region already adapt to drought risk, and will increasingly need to do so. Consequently, policymakers initiated regulations and subsidy programmes in line with European agricultural policy, and issued regional water management strategies. However, mismatch between farmers' capacities and the current policy instruments fails to encourage CRDPs. Based on 20 semi-structured interviews with farmers in the Seewinkel region, the present paper describes the personal, social, policy, economic and agronomic factors why specific drought adaptation measures are implemented at farm scale. Farmers state high risk awareness and self-efficacy. Social factors are limited to informal peer learning on drought adaptation. Economically, farmers struggle to balance the demands of a competitive market situation with the costs and effort of technical irrigation or the cultivation of drought-adapted crops. Agronomic considerations such as production practices, timing of management steps, pest control and fertilising, play a central role. Since they consider agronomic flexibility as essential, farmers take out subsidies only if they are compatible with their production strategy. For example, subsidies for greening measures are foregone due to restrictive requirements, even though these measures are nevertheless implemented to some extent. Thus, current policy instruments have only marginal effects on local drought adaptation; they provide add-on funding but have hardly any incentivising effect. Revised policy instruments should include seasonal and regional gradations, simplification and flexibilisation, as well as incentives for regional transformative adaptation towards CRDPs.

1. Introduction

Climate change already is and will increasingly be affecting agriculture all over the world, through increasing temperatures, changing precipitation patterns, and greater frequency of extreme events (IPCC, 2019). According to climate models, central Europe will undergo widespread drying and bear the risk for consecutive drought, especially in +2°C scenarios (Lehner et al., 2017). Higher temperatures will influence phenology and plant growth, and higher transpiration and evapotranspiration rates, changing precipitation patterns and the increasing risk for heavy precipitation will lead to substantial restrictions of water supply and water balance in agriculture (Eitzinger, 2007; Karner et al., 2019).

Temperature rise, changing precipitation patterns and an increase of extreme weather events are expected to largely affect agriculture also in Austria, beyond the already occurring level (Chimani et al., 2016; Eitzinger, 2007; Smit and Skinner, 2022). In the last years, besides high damages related to hail, frost, heavy precipitation or flooding (€ 365 Mio. between 2018 and 2022), considerable economic loss also occurred due to drought events (€ 565 Mio. between 2018 and 2022) (Österreichische Hagelversicherung, 2024). Especially in the south-east of Austria, an increase in summer days and heat days is already observed. At the same time, winter days and frost days are decreasing (Chimani et al., 2016).

Interviews with farmers in Austria showed that farmers themselves recognize climate change as temperature increase, disappearance of transition periods, warmer winters, hotter summers and heavy rainfall events (Mitter et al., 2019). Besides negative effects, climate change can also open up new opportunities in agriculture, such as better growing conditions for crops due to higher atmospheric carbon concentration resulting in increased activity in photosynthesis and higher water efficacy (Fischer et al., 2002; Howden et al., 2007).

These developments influence agronomic decisions on farm-level. Agronomy is understood as the science of cultivation of land, crop production and soil management (Collins Dictionary, 2024). Also, non-biological factors such as technical aspects of farm machinery or access to energy sources may inform agronomic considerations. Mills et al. (2018) allocates aspects as soil conditions, weather, crop rotation or pest control to agronomic motivation. Aspects of agronomy are mentioned in in the context of barriers of practice (Fleming and Vanclay, 2009), ecological (IPCC, 2014) and dispositional factors (Kreft et al., 2023). In the following, we use the terms agronomy and agronomic for the farmers' holistic perspective on agricultural practices; referring for instance to biological factors as climate, soil, physiology and phenology of crops, control of weeds and pests (American Society of Agronomy, 2024).

There are several possibilities for adaptation to drought and thus enhanced resilience, such as landscape designing, crop rotation, land cover, efficient irrigation systems, drought-resistant cultivars and increasing the water storage potential of soil (Adger et al., 2007; Eitzinger, 2007).

While being affected by climate change and challenged to adapt to changing conditions, agriculture is also a relevant player regarding climate change mitigation (Alig et al., 2015; Anderl et al., 2024; IPCC, 2022a). As integrated policy instruments may encourage the transformation towards decarbonisation and climate change adaptation (Madsen et al., 2022), policy instruments for agriculture may evoke change in procedures and functionality and thus help to achieve mitigation and adaption to climate change, using a set of possible activities: mandatory regulations, paid voluntary agri-environmental programmes, or unpaid voluntary actions based on social approval. Farmers' decision making regarding adaptation and mitigation highly depends on the practicality and financial effort of measures, as they often do not have the capacities to adapt and are pressured by changing markets (Hyland et al., 2015; Pröbstl-Haider et al., 2016). In general, measures are most likely to be pursued if there is a beneficial impact on income (Mills et al., 2018; Mitter and Schmid, 2020). On the other hand, there is also non-monetary motivation to peruse adaptation and mitigation, such as environmental responsibility or longing to contribute (Gabel et al., 2018; Greiner, 2015). However, the connection of climate change adaptation, disaster risk reduction and sustainable development in agriculture is not yet explicitly implemented in Austria (Leitner et al., 2020).

In this study, we investigate the individual reactions of farmers on repeated drought, why they choose specific adaptation measures and how these choices are influenced by existing policy instruments and funding programmes. We analyse as a case study the Austrian Seewinkel region, which can be regarded as an interesting example for other regions due to its specific circumstances, including a history of drought and irrigation as well as flooding, a falling groundwater table, tightening restrictions and regulations to reduce water consumption, resource conflicts as well as cross border dependencies with the neighbouring state of Hungary.

Farmers in the Seewinkel region already adapt to drought risk, and will increasingly need to do so in the light of climate change. The present paper illustrates the mismatch between current policy instruments (that are, funding programmes and water management regulations) and the farmers' considerations and capacities. We show that this mismatch is most pronounced regarding agronomic factors. Consequently, current policy instruments have only marginal effects on local drought adaptation. We conclude with suggestions how policy instruments could be revised.

2. Theoretical background

2.1 Factors for adaptation measures

Climate resilient development pathways

Climate resilient development pathways (CRDPs) are trajectories for integrating climate change adaptation and mitigation in pursuing sustainable development, taking into account the complex interactions between climate, social and ecological systems. Natural hazards events, such as drought, might disrupt these pathways (IPCC, 2022b, 2014).

Implemented adaptation measures on farm scale

The IPCC defines resilience as the capacity of social, economic and ecological systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure as well as biodiversity in case of ecosystems while also maintaining the capacity for adaptation, learning and transformation (IPCC, 2022c). According to Lankford et al. (2022) resilience against drought can happen accordingly to four categories: **absorptive capacity**, which are considered short-term responses to buffer the impact of the shock. **adaptive capacity**, which includes learning, adjusting and adapting to the shocks happening; **anticipative capacity**, which stands for the preparation and planning that is made against unexpected changes in water supply; **transformative capacity**, which stands for fundamental changes to social and economic processes which result in deep structural changes. These categories differ in importance over space and time. Measures to increase the resilience against drought would contain farm planning at an individual scale, improving the monitoring of water and land, support with advice during and between droughts and include multi-sector stakeholders in decision making (Lankford et al., 2022). In the remainder of the paper, we use these four dimensions to understand and classify the farmers' individual reactions for implementing adaptation measures. In addition, we focus on possible **maladaptation**, describing short-sighted measures, which may reduce damage in the short term but do not lead to long-term sustainable adaptation, but lead higher vulnerability (IPCC, 2022c). Approaches which comprise climate change **mitigation** (IPCC, 2022a) are also specifically highlighted.

Factors for adaptation measures and transformation

Multiple factors for adaptation measures and transformation are elaborated by former research (see literature overview in Annex I). We identify five major categories, which we use in the remainder of the paper to understand and classify the farmers' decisive factors behind their individual reaction: personal factors, social factors, policy factors, economic factors, and agronomic factors. While the five categories help to structure the data, they overlap to some degree, such as that financial issues are sometimes included in other categories then economic, e.g. policy factors.

Cognitive and personal factors play an important role for adaptation measures and transformation. Without knowledge about climate change causes and impacts, the individual risk appraisal of climate change may differ (Fleming and Vanclay, 2009), while personal opinions influence risk perception towards climate change (Adger et al., 2007). Reasons for implementing adaptation measures can be the subjective perception of risks, knowledge as well as emotions. The stronger farmers are affected by climate change, the more pressure they feel to implement certain adaptation measures. Which measures are chosen, depends on the kind and amount of damage they have to deal with (Kropf and Mitter, 2022a). Grothmann and Patt (2005) argue that decision making for private people associated with climate change depends on risk perception and subjective ability to adapt. Thereby, risk perception is a process of considering the probability of a risk, the risk experience in the past and the severity of the risk in the future.

Social factors influence the probability of taking action. Positive impacts of peer relationships are likely to influence each other, share information and talk about economic network effects, agricultural training and mutual exchange of experiences improves the knowledge about measures and their advantages and advice can help gathering information about technical issues (Schaub et al., 2023). For our analysis we include also interactions between farmers such as cooperation, lack of cooperation, and multiplier effects as social factors.

Policy factors imply the interaction between farmers and different governance levels, including funding programmes, statutory regulations and water management plans. These factors are outside farmer's control and go beyond mere economic aspects. Besides legislation, regulations and water management plans, funding programmes are the most dominant expression of policy strategies (Kreft et al., 2023). Policy factors include the trust in public policies, which also influences mitigation and adaptation to climate change (Grothmann and Patt, 2005).

Economic factors include financial considerations in connection with or without reference to external support or subsidies. Financial issues are sometimes included in other categories (e.g. policy factors), sometimes aspects as cost and benefit are mentioned separately (Barghusen et al., 2021; Hamann et al., 2016; Mills et al., 2018).

Agronomic factors address the question, how to grow crops efficiently and therefore comprise considerations regarding timing of management steps, climate, soil, control of weed or pests. For the purpose of this paper, we also include technical or structural barriers directly related to agricultural production; economic factors are considered separately. Agronomic motivation in the context of adaptation means, that farmers implement certain actions without explicitly thinking of mitigation or climate change (Mills et al., 2018), depending also on the underlying farm structures and processes (Kreft et al., 2023).

2.2 Strategies and instruments related to water management on national and regional scale

There are several strategies on national and regional scale displaying a direct or indirect effect on water management on farm-level and subsequently on drought. At EU level, the Common Agricultural Policy (CAP) shapes the agricultural sector. The CAP is currently based on the CAP 2023-27 legal framework and the CAP Strategic Plans, designed to contribute to the ambitions of the European Green Deal, including Farm to Fork Strategy and Biodiversity Strategy (European Commission, 2024). At national level, the CAP is translated into national operational programmes, which enable national funding, taking into consideration national characteristics and needs. For Austria, the Austrian agri-environmental programme ("ÖPUL") and the rural development programme ("Ländliche Entwicklung") are the most important national instruments besides the conditionality and legal framework.

Table 1: Overview of current main instruments on national and regional scale with direct or indirect effect on water management on farm level in the Seewinkel region (status in August 2024). Sources: (AMA, 2024a, 2024b, 2024c, 2023a, 2023b, 2022; Kropf et al., 2021; Republik Österreich, 1996b, 1955a; Sailer, 2022)

Instrument	Description of principal regulations and requirements
Legal framework and conditionality	
Subsidised drought insurance	Based on the Disaster Fund Law 1996 and the Law on Hail Insurance Subsidies, insurance premiums for drought insurances are subsidies with 55% by federal government (disaster fund) and states; basic financial hedging
GAEC 6: minimum soil cover	Conditionality within the CAP; requirement for minimum soil cover of at least 80% of arable land or 50% of permanent crops during winter (from 1^{th} November to 15^{th} February); minimum soil cover is fulfilled with a) catch crop b) leaving harvest residues or c) non-rotational tillage (e.g. using a cultivator or disc harrow); certain field vegetables are excluded
Funding programmes	
Austrian agri-environmental programme "ÖPUL"	
Intercropping for arable crops	Actively sown green cover between two main crops or for undersown crops in oilseed rape; 7 different greening options (different greening periods/requirements regarding number of mixture partners and of species); restriction of plant protection, fertilising and soil cultivation measures during greening period
Permanent greening for arable crops	At least 85% of the arable land must be greened with main or catch crops at all times of the year; restriction of plant protection, fertilising and soil cultivation measures during greening period with catch crops; requirements regarding due dates for sowing, minimal time periods for greening, maximal periods between main and catch crops
Groundwater protection arable crops	Combination with the funding option intercropping or permanent greening for arable crops is mandatory; restriction of plant protection, fertilising; obligation for training, soil analysis and documentation (partly mandatory due to legal framework)
Erosion protection for arable crops	Implementation of soil conservation systems for crops at risk of erosion (field beans, potatoes, pumpkins, maize, beetroot, soya beans, sunflowers, sorghum), e.g. mulch sowing, no-till or strip-till methods; for some crops undersowing (field beans, pumpkins, soya beans and sunflowers) or dams (potatoes) are eligible
Erosion protection for vineyards and orchards	Only year-round greening is eligible; disturbance of cover crops without soil cultivation allowed; sowing within 8 weeks mandatory after soil cultivation; seeding mixture must contain at least 3 perennials; possible top-up: use of pheromones
Rural development programme	
Funding for irrigation infrastructure	Funding for irrigation infrastructure; funding of power units, sprinkler systems, pipes; only new devices are eligible; no funding of fossil fuel powered pumps or units; funding rate: 40%; minimum eligible project costs: 15.000 €; retention period: 5 years
Regional water management strategies	
Ground water regional programme	Regionally defined regulations based on national strategy (Austrian National Water Management Plan); targeting water quality
Technical water strategy	Monitoring of ground water tables; consensus on groundwater withdrawal to avoid overuse of the regional groundwater body; definition of warning levels and corresponding restrictions (e.g. only drip irrigation allowed / irrigation bans regulations regarding the operation of the wells

Regional strategies and instruments mainly address the ground water table and water quality. The groundwater regional programme comprises guidelines and control systems to improve water quality, e.g. by the restriction of the use of fertilizer and pesticides. The water management plan provides the regulations for the monitoring of ground water tables at several measuring points and the definition of restrictions when tables fall under certain levels. A slight revision of the strategy took place in 2023, when the actual implementation of the restrictions was adjusted.

Since the beginning of the 20th century, external water supply has been an issue in the Seewinkel region. The dotation of water from another region (e.g. surface water from Hungarian Danube (Moson-Danube) is recently upcoming again. The current planning has the primary objective of contributing to raising the groundwater level. Several studies investigated the different options for the dotation, the impact on ecology and water quality. In any case, the implementation would require high costs and effort and the coordination with Hungary.

2.3 Case study region Seewinkel

The Seewinkel region in the east of Austria covers about 450 km^2 and is characterized by its semi-arid pannonian climate with annual average precipitation of just 500-600 mm (Kropf et al., 2021). Due to almost 300 sun days per year and frequent winds the transpiration rate is relatively high (Blaschke and Gschöpf, 2011). A special natural phenomenon are the shallow saline lakes that emerge through rainwater. Due to the high salt concentration of the water, these wetlands provide a special habitat for flora and fauna (Blaschke and Gschöpf, 2011). After the Second World War, wetlands were drained to create more agricultural land. Since then, the groundwater table fluctuates with the current precipitation level (Blaschke and Gschöpf, 2011). The water balance of Lake Neusiedl, the main surface water body to the west of the Seewinkel region, depends on precipitation and evaporation and is therefore highly sensitive to climate change. The lake already dried up more than 10 times (Soja et al., 2012). Due to climate change the annual and seasonal patterns of precipitation and drought in the Seewinkel region hugely vary and are expected to increasingly do so in the future (Karner et al., 2019). The groundwater body "Seewinkel", which delimits the case study area, is located in the following municipalities: Andau, Apetlon, Frauenkirchen, Gols, Halbturn, Illmitz, Mönchhof, Neusiedl am See, Pamhagen, Podersdorf am See, St. Andrä am Zicksee, Tadten, Wallern im Bgld, Weiden am See.

Agriculture is an important economic sector in the region: 56% of the total area is used for arable farming, 10% for viticulture and 6% for permanent grassland. About 1.000 farms cultivate an area of ca. 33.000 ha (GeDaBa – BAB, 2024; Karner et al., 2019). The most frequent drought adaptation measures are drought-tolerant crops and cultivars, soil conserving tillage practices, irrigation, changes in irrigation strategies (irrigation during night to reduce evaporation) and technique (drip irrigation), and drought insurance (Kropf et al., 2022). Irrigation for agriculture in the Seewinkel region relies on groundwater (Valencia Cotera et al., 2023). Irrigation pumps are mainly fossil fuel powered, but some farmers consider switching to renewable energy due to rising fuel prices (Kropf et al., 2022). Further approaches discussed are improved waste water treatment (percolation, backwatering) and flexible groundwater pricing. The latter would lead to an increase in costs for agricultural production, but would incentivise reduced groundwater use (Mitter and Schmid, 2020).

Main policy actors at the regional level are the water authorities of the federal state of Burgenland, the Chamber of Agriculture Burgenland, and the authorities of the national park at Lake Neusiedl. On the local level, co-operatives manage irrigation and access of individual farms to groundwater wells. The co-operatives are supervised and regulated by the district authority, i.e. the Water Management Department which is also responsible for the technical water strategy. Kropf et al. (2021) suggest that a cross-sectoral institution could help in aligning the different stakeholder interests in land and water use. Some formats for actor cooperation are already established: The national park and the federal government of Burgenland (especially the water department) cooperate for the successful implementation of projects. Furthermore, the regional government of Burgenland has recently appointed a 'task force' for the Seewinkel region in order to mediate between different interests and ensure the preservation of Lake Neusiedl in the long-term. Cross-border panels, such as the Austrian-Hungarian Cross-border Water Commission, also affect policy instruments.

The Seewinkel region is an interesting case study for the purpose of the present paper, because water shortages from a mix of changing precipitation patterns, higher average temperatures, land use and water management put increasing pressure on farms' revenues and viability, but the combination of predominant land use (e.g. cultivation of water-demanding crops) and currently implemented drought adaptation measures (especially irrigation) seems insufficient to enter a long-term climate resilient development pathway.

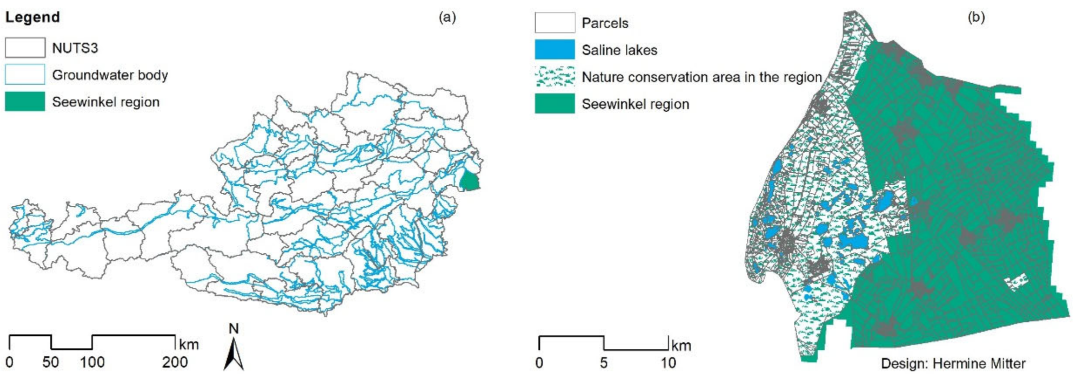

Figure 1: Location of the Seewinkel region in Austria (a) and overview of the Seewinkel region (b). Note: The Lake Neusiedl National Park is part of the nature reserve. Figure: Hermine Mitter, in (Kropf et al., 2021), based on (Amt der Burgenländischen Landesregierung, 2021; BMLFUW, 2017; Nationalpark Neusiedler See-Seewinkel, 2021; Statistik Austria, 2019).

3. Methods

Based on a framework literature study, twenty semi-structured interviews (for interview guideline see Annex II) were conducted with farmers as affected individuals, to understand their perception of as well as their reactions to drought as climate change induced hazard. With this number of interviews, the point of theoretical saturation could be reached (Mayring, 2022). The interviews were conducted with the farmer, sometimes together with the spouse or other family members. However, data on individual views of several people engaged is too fragmentary to allow for intra-farm comparisons. Interviewees were instructed to refer to the most recent drought event when describing impacts and reactions. Since the statements of the interviewees were from their point of view and thus possibly biased, statements of different persons on the same topic were contrasted and factual information was verified based on the document analysis.

Farmers were purposefully selected to cover a broad scope of typical agricultural activities of the region (arable crops, vegetables, viticulture and fruit production), to gain a comprehensive picture (see Annex III). Farms with livestock were excluded to focus the research question and avoid dissipation regarding adaptation measures and funding programmes. Unfortunately, some farm types could not be covered, for example farms with viticulture and high irrigation intensity due to high reluctance to participate in interviews. 13 of the farms are run organically, which is not specified in Annex III due to data protection reasons. 17 of the interviewed farmers use irrigation systems, while 3 do not use irrigation.

To approach potential interviewees, farmers were contacted by advocacy, advisory representatives and colleagues from another institution involved in the underlying research project. Interviewed farmers were asked to recommend further affected farmsteads they knew in the region. The face-to-face interviews were conducted between January and March 2023 and lasted 60-90 minutes each. Interview audio recordings were transcribed for analysis. We employed qualitative content analysis (Döring and Bortz, 2016; Mayring, 2022), using MAXQDA software for coding the interview transcripts. Responses were structured in a category system, carried out deductively from the main interview topics. The paper uses translations from verbatim German interview quotes for explicit examples.

To analyse the farmer’s individual reactions we investigate for the decisive factors behind the individual reaction, connected to the existing policy instruments, classifying them by the five categories drawn from the literature.

4. Results

The results are structured as follows: 4.1 und 4.2. present general views on the current climatic and policy situation in the entire Seewinkel region. Subsection 4.3 focuses on implemented measures and experiences on farm level. Finally, subsection 4.4 analyses the factors underlying adaptation measures according to section 2.1.

4.1 Farmer perspectives on climatic situation

In principle, dry conditions are mentioned as normal for the region *("We were never a wetland in that sense in the area anyway.")* and the deterioration due to climate change is considered by several farmers as foreseeable *("…it's all connected and it was foreseeable for a long time."*. Farmers describe an increasing water deficit and falling groundwater tables caused by lack of precipitation (especially missing winter precipitation) and rising evapotranspiration rate due to higher temperature. As a consequence, the discrepancy between water supply and water consumption increases, groundwater buffer is depleting and falling levels in groundwater wells are observed. For the last decade, the years 2013, 2021, 2022 and 2023 are repeatedly mentioned as especially dry and hot years with corresponding damages. On the other hand, years with high precipitation and flooding are mentioned (e.g. in 2004 and 2014). Weather extremes are perceived as cumulating and not only drought, but also heavy rainfalls and a shift of precipitation pattern as aggravating the situation. Furthermore, precipitation differs on a very low spatial resolution and the evolvement/history of the drying-up of the Lake Neusiedl and the brines (e.g. "Zicksee", "Lange Lacke") is described. Some farmers presume a linkage between microclimate and precipitation in the region and the water level of the Lake Neusiedl.

Referring to the whole region, the quantification of damages (yield/quality) vary widely from total to marginal losses; the valuation is mainly depending on year, cultivated crops and extent of irrigation. The interviewed farmers mention many colleagues who rely on irrigation alone and that it will be fatal for them if irrigation were restricted. The need of every crop – also of extensive crops – for a certain amount of water in critical phenological stages to ensure yield and/or quality is emphasised once. As a consequence of the prevailing situation, farmers see the economic viability of agricultural production in the Seewinkel region jeopardised.

> *"How can you manage to keep any farm going despite a lack of water and, above all, the crops that are irrigated, are actually the crops that keep a farm going and that generate the greatest turnover and the greatest profit. Without these crops it would be very difficult to maintain a farm business."*

However, also positive effects of drought and higher temperatures are observed: less problems with some diseases or weeds (good conditions for organic farming), higher wine quality (especially for red wine) or the possibility to cultivate new crops. Saflor, sweet potato, sorghum, peanuts, spices and herbs were mentioned as crops with potential in the region.

4.2 Farmer perspective on drought risk and policy instruments

Besides the given climatic conditions and their changes due to climate change, mistakes in the past and self-inflicted sources for regional drought risk are considered as relevant. The main reasons given are the drainage of the "Hanság" wetlands, the outflow of surface water via channels (e.g. via "Einserkanal") and the discharge of wastewater via the sewerage system. The historical drainage to gain arable land are partly viewed critically today; the designation of building land and construction of buildings in flood zones is coincidentally identified as a conflict of interest. Some farmers think, it would be better to have recurrent floods, devastating some fields but gaining groundwater reserves for future years. Additionally, there is a dependence on Hungary due to the cross-border connection of the canals and the corresponding impact of decisions on water management (e.g. damming of the "Einserkanal", opening of the floodgates).

Further factors that increase regional drought risk are the encouragement and increased cultivation of crops with high water demand (e.g. vegetables, potatoes, maize for seed production), ignorance of the necessary changes and the lack of windbreaks.

> *"And then we have the many self-inflicted things in the region, such as drainage, wrong crops. No windbreaks and so on. So there are many reasons why this is so dramatic in our region."*

With regard to the policy instruments, mainly the funding programmes and the statutory regulations (including the water management plan) are known; there is less awareness of overarching strategies at province, national or EU-level. However, a strongly top-down influence of these strategies is recognised, which do not take into account the situation of small-scale agriculture and the differences between growing regions with divergent conditions.

> *"They always claim to help and support small businesses, but actually, with every new CAP program everything becomes a little more difficult."*

The importance of the national park for the development of the region is repeatedly emphasised. Several strategies trigger controversial opinions and are mentioned either as helpful or unhelpful. The water management plan is mentioned as instrument to define the framework or avoid extreme activities; in contrast, lack of coordination or missing regional perspective is presumed. The opinions on the irrigation ban during day within the regional water management plan range from "reasonable regulation" (reduces vaporisation of water, manageable restriction, was done like this before) over "irrelevant" regarding evaporation to "counterproductive". The restriction of the time period is mentioned to collide with frost irrigation and consequently endangers the protection of fruit crops against spring frost. On a mid-term perspective, farmers expect that the irrigation ban will lead to the elimination of certain crops and consequently to economic problems and abandonment of agriculture / farms.

Funding of irrigation infrastructure is generally seen as helpful for regional agriculture, but there are farmers expressing the opinion, that irrigation should not be funded any more, if water is scarce. Especially the funding and promotion of drip irrigation is discussed controversial: most of the interviewees consider it to be unsustainable and not suitable for arable crops and that water consumption will not be reduced. Others see it as a water saving method; but mainly for viticulture or fruit production.

Several aspects of funding requirements within the rural development programme are considered to be hindering factors for regional drought adaptation. Firstly, internal labour is not funded. Secondly, used machinery and some machinery components are not eligible. Thirdly, the upper limits of funding are mentioned: for investments in water-saving and thus more expensive infrastructure, capping has a proportionally greater impact.

The current national agri-environmental programme is perceived as providing little support for adaptation to drought as no specific measures are subsidised. The funding of greening measures (as "Erosion protection for vineyards and orchards") or the conditionality on greening in winter (GAEC 6) were mentioned as neutral, unhelpful or detrimental to agronomic practice. Some greening measures which are funded are even considered to have a detrimental effect on drought (e.g. undersown crops) or negative effects on other agricultural sectors (bees). Requirements regarding the planting or later removal of trees are cited as an obstacle to the planting of trees. Missing funding opportunities for windbreaks or agroforestry systems is mentioned as gap. However, some statements show that current funding requirements have not yet been recognised.

The drought insurance is considered as a useful option for financial hedging, on the other hand the system of drought index is regarded as unfair with regard to the relationship between weather data, spatial differentiation and loss estimates.

The recently (again) upcoming strategy of external dotation of water is provoking diverging opinions, reflections range from "only possibility for the region", "helpful and simple strategy" or "opportunity to replenish the groundwater reservoir" to "threat to the ecosystems in the lake". However, most farmers do not have the confidence to assess the external dotation from other water bodies because they lack the knowledge to do so.

The farmers' predominant narratives refer to missing (regional) strategies or coordination and lacking trust in (political) actors, although the extent and the allocation to specific stakeholders or decision makers varies. Main aspects mentioned in this context are the lack of technical background and the missing consideration of divergent conditions in different regions – a dry region needs other regulations or funding requirements than a wet region. Regarding the regional water management, the drainage and outflow of surface water instead of water logging in the region is being criticised. Damming on local level are occasionally mentioned as best practice. The procedure of the groundwater level monitoring is questioned in terms of the placement of measuring points; the assessment of ground water levels appears too small-scale.

Institutions such as the Chamber of Agriculture or public authorities are closely linked to policy instruments due to their role. The interviewees perceive the focus of these actors to be primarily on optimisation of irrigation, technical measures or water procurement. Consequently, the expansion of more efficient irrigation is more strongly propagated than, for example, the cultivation of water-saving crops or integrated strategies. The local irrigation co-operatives are mentioned with their central role in the implementation of the water management plan, but the intensity of internal communication on changing regulations or critical situations diverges. In this context, the control of irrigation bans and the legal situation with regard to liability and penalties is considered problematic. Several further actors –

mediating or catalysing policy instruments – are mentioned as relevant, such as hail insurance, food retailer, companies or press. The dominant role of food retailers and companies regarding prices and market opportunities is emphasised repeatedly. Another narrative is the blaming of farmers for the depletion of the groundwater body.

4.3 Implemented adaptation measures on farm scale

The interviewed farmers usually implement multiple measures, no complete inaction can be observed. Main measures are irrigation, cultivation of drought adapted crops and cultivars as well as adapted soil cultivation and greening. Reported measures on farms (Annex III) are grouped in the following according the categories proposed by (Lankford et al., 2022).

A**bsorptive capacity**, mainly manifests in functional adaptation: irrigation and its optimisation in terms of timing or infrastructure (e.g. irrigation by night, drip irrigation) which is not necessarily combined with other measures. Further investments in irrigation infrastructure are often not envisaged, due to planning insecurity or financial reasons. Another response which can be allocated to absorptive capacity is contracting a drought insurance to reduce the financial impact.

Regarding **adaptive capacity**, measures to reduce water losses as limited adjustments to soil cultivation or adjustments of production technique such as modifications in timing, plant protection or fertilisation can be mentioned. However, these adjustments are mainly motivated by other factors than drought. For soil cultivation a wide range of approaches, varying intensity and different reasons are reported.

Anticipative capacity is expressed for example by adaption of crops, crop rotation, cultivars or rootstocks. Measures to retain water on different scales (soil, site, and region) are occasionally reported.

Measures as intensive greening or mulching strategies, substantial changes in soil cultivation, establishment of windbreaks as well as the implementation of agroforestry can be considered as **transformative capacity**, as production systems or agricultural landscape undergo substantial changes. For greening strategies, different degrees of implementation and varying assessment is reported; consequently, in some cases it can rather be considered as adaptive capacity. With focus on short term effects, greening is usually assessed to have a detrimental effect on water balance, compete for water or increase weed occurrence and are implemented with restraint. On the other hand, farmers with longstanding experience report positive effects of reduced/shallow soil cultivation and fostering of humus accumulation by greening strategies or organic fertilizers. Especially if the implementation has been going on for many years, farmers are convinced of the positive effects on water holding capacity and soil quality, regardless of the crops cultivated. The use of drought resistant greening plants, local seed or spontaneous greening is emphasised. Mulching with foil (conventional / biodegradable) or straw is seen as an effective method to reduce water consumption; aspects as the deposition of (micro)plastic or high effort are hindering aspects, respectively. Occasionally,

transformative approaches are expressed by purposeful inaction: no irrigation to force vine roots to expand in deeper soil layers and accepting the consequences regarding yield level.
It is extremely important for farmers to see the positive effect on their fields, especially when it comes to the implementation of new measures.

> *"But practice has confirmed what the younger generation may have been thinking. And it has already become clear that a rethink is definitely necessary."*

In few cases, measures that are more likely to be considered as **maladaptation** are reported; i.e. cultivation of crops with higher water consumption, intensified irrigation (combined with high consumption of fossil fuel) or frequent soil cultivation. However, such behaviour is often reported at a regional level, beyond the interviewed farmers. Climate change **mitigation** aspects are particularly evident with regard to the conversion of the power unit of irrigation infrastructure. Several farmers already changed to electricity or intend to switch from fossil fuel to electricity/photovoltaics.

4.4 Factors for adaptation measures and transformation

4.4.1 Personal factors

Referring to their own properties, farmers show high awareness regarding climate change, yet there is a wide range between a very high and a rather low risk perception ("all is getting worse" vs. "changing weather conditions are normal"). Farmers make their assessment based on scientific as well as historical data, but also – to a large extent – based on their own experience. Mostly, drought events were anticipated and their adaptation process is already ongoing for a longer time span. The distinction of actions mainly driven by recent drought events versus measures which were already in place or driven by other reasons is not clear-cut. Some measures are recently being intensified or complemented with further measures (e.g. more greening).
A high degree of self-efficacy is present. Most farmers assess their implemented measures as sufficient and as the best they can do, expressing little worries about their estate. At the same time, they expect the future of whole sector to be very challenging, especially for those farms without sufficient measures in place. Some farmers downplay the future risk of drought, as fluctuations have repeatedly occurred. Statements and media reports on evaporation during irrigation or drying out of the Lake Neusiedl are occasionally considered as exaggerated.
Drought is perceived as uncontrollable natural phenomenon, which belongs to the region and is subjected to self-regulation and coincidence. Farmers express fatalism and feel powerless; however, this does not imply inaction, but effectiveness of measures is considered limited. Inconsistency between high degree of self-efficacy and response efficacy and the reported feeling of helplessness against (changing) climate is reported (being powerless, nature cannot be controlled).
In addition to social and economic goals (see following sections), personal goals comprise ecological aims and considerations such as avoiding unsustainable/inefficient irrigation regarding ecological

footprint; switch to renewable energy sources; causing only low input of resources; saving water; focus on healthy soil, biodiversity and nature conservation; avoid (micro)plastic input.
In this context, trade-offs between economic and ecologic aspects are mentioned, as well as the importance of local food production instead of imports.

4.4.2 Social factors

Social aims mentioned are related to the own person (such as leading a good, meaningful life, mirrored by sustainable farming) but are also seen in a larger context; sometimes failing due to the lack of capacity (e.g. manpower). Sustainable farming is regarded as contributing to a more sustainable society and leading by good example. Furthermore, the responsibility for employees and the wish of being a good employer are stated.
Farmers report a comprehensive exchange in the sector and mutual learning. This exchange with peers is of great importance and often enfolds an inspiring effect. Indeed, many farmers see themselves as being the frontrunners and examples for others; decisions are taken primarily on their own assessment and experience. The role of important actors is emphasised several times. However, farmers often refer to individual persons or experts, less to the respective institution.
Beyond the exchange of information, there are various forms of cooperation between farmers, such as land swap either to reduce water losses and optimise irrigation infrastructure or to optimise crop rotation by the collaboration of different farm types. The cooperation is not only driven by drought, but also by production-related reasons.
Several conflicts of interests are reported: between affected individuals or groups (e.g. arable crops vs. viticulture) or different interests (agriculture vs. nature preservation). One area of conflicting interests relates to the flooding of cellars of private households which would intensify, if backwatering is implemented. Farmers perceive repeated negative portrayal or blaming of agriculture – partly supported by the press and political representatives. This is presumed to shape the public opinion and reported to burden or annoy farmers:

> *"All the psychological stress. You have to justify yourself."*

4.4.3 Policy factors

Policy instruments at different levels have an effect on farmers' behaviour. The stated effects are grouped following the structure in section 2.2.

Legal framework and conditionality

Farmers cultivating arable crops often refer to the greening conditionality GAEC 6 as affecting their production processes; not always directly related to drought, but as a general limitation. Depending on cultivated crops and the previous farming strategies, farmers consider it as easy to integrate, notice problems for following crops or perceive it as not compatible with their production (see section 4.4.5).

Funding programmes

In the following, the statements of the interviewees are structured in four categories according to the triggered effects: non-effect, where funding is not taken up; add-on effect, where funding provides a windfall benefit to already planned reactions; steering effect, where funding influences the design of already planned reactions and trigger effect, where funding directly causes the realisation of reactions that would not have been considered otherwise.

A **non-effect** can be repeatedly taken from the statements. Farmers report to implement measures primary regardless of funding opportunities or to choose only funding options, which correspond to their initial plans and to ignore other options. Funding is mainly foregone due to restrictive funding requirements, sometimes even though the subsidised measures are implemented on the farm.

> *"You'd rather do without and be more flexible and independent than have to stick a timing that doesn't suit you."*

For certain funding options, the reasons for the non-effect are explicitly named: For "Groundwater protection for arable crops" more non-uptake or opt out reactions are reported for new funding period, due to reduced funding amount, more bureaucracy and restrictions of production , e.g. for plant protection. "Erosion protection for vineyards and orchards" is less uptaken in the new funding period due to the new requirement of year-round greening. For "Strip till" the higher weed pressure and limited possibilities to manage weed in some crops are mentioned as reasons for reluctance to implementation.

Some **add-on effects** are reported, especially for investments in irrigation infrastructure. The funding of irrigation infrastructure is mainly considered as helpful, though not as decisive for the implementation itself. Regarding the components of irrigation infrastructure as drip irrigation tubes – that are used for only one year – for some farmers the guidelines seems unclear, for others it is clear (and problematic), that there is no funding (as the retention period of 5 years cannot be fulfilled). In the light of the ban of certain irrigation systems, some farmers express their wish for subsidies for new irrigation systems. The fact, that only electric power units are eligible in the new rural development program unfolds little steering effect, as structural and technical barriers prevail (see section 3.4.5).

A **steering effect** is rarely mentioned, and mainly in connection with an add-on effect. Examples are slight adjustments to fulfil funding requirements as the choice of cultivars, small modifications of already planned or implemented greening strategies or a more extensive implementation of investments than originally planned. Considered over a longer period of time, the subsidies for greening are cited as the decisive factor for its current implementation in practice.

Trigger effects are reported only occasionally for some specific measures: planting or rebuilding of windbreaks, the establishment of biodiversity areas, the switch to electric irrigation drive and the damming on local level.

The farm advisory services are used as sources of information and are sometimes perceived as supportive, e.g. for funding applications. However, there is little perceptible effect on the individual reactions.

Regional water management strategies

Some of the interviewees were directly affected by the irrigation bans recently put into practice in 2022 and 2023; for others, their irrigation periods, irrigation technique or fields were outside the scope of the bans. Via the restrictions of irrigation, the water management plan shows a direct effect on farmers' decisions and strategy driven reactions as changes in irrigation technique (drip irrigation), selection of crops or timing of irrigation (only at night).

4.4.4 Economic factors

For personal economic goals, the main topic is financial stability and economic independence. An important factor for profitability is the cultivation of irrigation-intensive cultures, as market prices are high. Moreover, funding is considered as a relevant part of income and a certain dependency of subsidies is stated. This is occasionally also entitled as "keeping artificial things alive" and cost-covering selling prices would be favoured. Nevertheless, financial consideration besides funding programs are dominant. Higher effort regarding workload and costs for certain measures is mentioned repeatedly and farmers seek to reduce costs and effort, e.g. by avoiding too much irrigation technique (especially drip irrigation). Expansion goals cannot be realised due to limitations in budget and staff (not enough labourers, too expensive). Economic considerations as specifications from the buyers, market situation and market price play a major role for the selection of crops and cultivars. For example, certain crops (e.g. sorghum) or batches from mixed cropping are not marketable or the cultivars are specified by the buyer (e.g. the seed company). As the cultivation of crops without market perspective is not feasible, adaptation options are limited and the call for the cultivation of alternative, drought resistant crops is thwarted.

> *"There are a lot of restrictions in the downstream industry, which have a very inhibiting effect on agriculture."*

Furthermore, uncertainty about expected revenues, pricing pressure and market power of the buyers are mentioned. The conversion to organic farming was partly related to financial considerations, as for some crops higher market prices can be achieved with the same effort. In some cases, the conversion was driven by drought, but also further motivations – often personal reasons – were reported.

4.4.5 Agronomic factors

Flexibility regarding their agronomic production is crucial for farmers. For short- and medium-term decisions in production and timing of management the (actual/expected) weather and soil conditions in general play a major role. Organic farming also requires a different timing. Similarly, for modifications of plant protection, drought is a subordinate motivation, but farmers report less infestations of some pests due to drought. There is little awareness regarding the linkage of drought and fertilisation and consequently, only few of the interviewees modify their fertilising strategies due to drought. All farmers implementing greening measures state – regardless of the crops – that their main motivation is the positive effect on the soil.

For mid- and long-term decisions, further aspects are considered. For example, the motivations for the selection of crops and cultivars are multifaceted: besides drought resistance, factors as resistance against pests, quality characteristics, and economic aspects play an important role.

Furthermore, the existing infrastructure (such as irrigation devices or machinery), the cultivated crops, occurrence of weed and the general availability of machinery and technical solutions are important factors. For the timing and choice of irrigation measures, farmers consider aspects as wind, effects on plant health, and capacity of irrigation infrastructure.

Technical and structural limitations are mentioned repeatedly, e.g. regarding irrigation with electric power units: mostly, the fields do not have a power connection and development is disproportionately expensive. For solutions with photovoltaics, batteries would be needed, as otherwise irrigation is only possible at daytime (which might be banned). In addition, the performance of electric power units is limited to certain irrigation techniques or applications. With regard to the limitation of irrigation to the night, the narrower time window for irrigation is mentioned. This might lead to irrigation under windy conditions or problems with technical capacity; consequently, farmers might be forced to invest in more irrigation infrastructure.

Partly, farmers do not see – for various reasons – any possibilities regarding further reductions of water consumption or adoption of water saving irrigation technique. On the contrary, the need for earlier and more frequent irrigation is reported and no water saving effect is expected by changed irrigation technique. Some farmers mention advantages of drip irrigation as low water consumption as well as targeted application, lower labour input for operating and higher technical clout.

Possible or already observed subsequent negative effects of different measures play a crucial role for farmer’s decisions. Especially drip irrigation for arable crops is considered to be not practicable and causes numerous concerns: high amount of plastic waste, deposition of (micro)plastic in the environment, damages by animals (mice, martens, wireworms, crows), salinisation, high costs (material, labour) and negative phytosanitary effects.

> *“No, not for anything in the world. Because I've already watched them cursing as they knelt in the mud in the wet field. Because the drip irrigation isn't technically mature yet.”*

For arable crops and measures as reduced soil cultivation, mulching, longer greening periods or biodiversity stripes, farmers mention increased emergence of weeds or invasive neophytes such as thorn apple or ragweed. Furthermore, seed beds resulting from reduced soil cultivation are not suitable for some crops. These problems are assessed differently depending on the crop and production method. For example in organic farming or for vegetable production, the implementation is mostly reported to be more challenging. In viticulture and fruit production, the permanent greening of vineyards is mostly seen critical due to the reducing effect on vigour and substantial competition for water and nitrogen.

Climate change affects the agronomic production in various further aspects, i.e. weed is not freezing off, heat waves coincide with drought phases, damages due to sunburn on some crops (apple, grapevine) and the occurrence of spring frost.

5. Discussion and Conclusions

In the light of climate change and diminishing water availability, business-as-usual of overusing water resources for water-demanding forms of agriculture cannot continue in the Seewinkel region. However, introducing stricter water management (including possible irrigation bans) to preserve groundwater implies a strong trade-off as farmers would face losses in quality and yield of profitable but water-demanding crops which would make the future economic viability of their farms uncertain. The interviewed farmers voice strong discontent with the current strategies and criticise the lack of an overarching strategy and of differentiated regional approaches that would allow them to develop a mid-term planning perspective. Missing trust in institutions and actors is found as crucial shortcoming. Furthermore, we observed a distinct discrepancy between the call for a top-down solution versus the desire for less intervention of policy instruments or actors and more individual responsibility and autonomy of farmers.

In the following, we summarise our three main findings as a basis for the further development of policy instruments in order to foster Climate Resilient Development Pathways (CRDPs).

5.1 Agronomic and economic factors predominant

All interviewed farmers do implement drought adaptation measures, typically rather as a bundle of interlocking activities than as stand-alone measures. Adaptation reactions are often already built up over a longer time span in order to prepare for drought phases. Farms with a high degree of diversification, adapted crops and favourable soil conditions cope better with dry phases as they are less dependent on the climatic needs of a specific crop. Farmers cope better if they are willing to experiment with alternative approaches, build experiential knowledge and upscale these approaches if they prove effective and feasible. However, while some measures are clearly motivated by drought concerns (e.g. irrigation, soil cultivation for higher water holding capacity), other are mainly taken for economic or agronomic reasons with drought adaptation as a side benefit (e.g. selection of crops or cultivars, timing of management).

Structuring in personal, social, policy, economic and agronomic factors shows a subordinate role of personal and social factors: Farmers show high self-efficacy and entrepreneurship. Our finding of high self-efficacy combined with low trust in policy actors corresponds to the results of literature (Grothmann and Patt, 2005).

Regarding policy factors, the uptake of funding critically depends on the compatibility of funding requirements with the prevailing production technique and timing. When deciding whether to apply for specific funding programmes, farmers prefer leeway in implementing certain production techniques over the funding amount. For several funding options, in particular intensive greening measures and rigid time constraints, a distinct mismatch between current policy instruments and the farmers' considerations and capacities is found. Consequently, most funding programmes achieve only add-on effects and hardly incentivise new or extended adaptation measures.

Economic factors play an important role as adaptation options are limited by the need to generate enough farm income. Drought-adapted crops or cultivars tend to provide less revenue on the agricultural market than water-intensive cash crops. Drought-adapted land use (lower shares of water demanding crops; adapted crop rotations; take some sites out of production) often implies less production output.

Agronomic factors are predominant and regulations or funding requirements are perceived as detrimental to agronomic considerations. Also expected subsequent negative effects and technical or structural limitations are crucial. Similar to Mills et al. (2018), we find a combination of extrinsic and intrinsic factors, with a more sustainable effect of intrinsic motivation. However, contrasting to Mills et al. (2018), agronomic motivation was predominant, regardless of whether the measure was subsidised or unsubsidised.

5.2 Suggestions to revise policy instruments

If the observed mismatch between farmers' capacities and the current policy instruments was reduced, public budgets could be deployed more effectively to reach policy goals. To achieve this, the design of policy instruments should take better account of the perspective, the different prerequisites and the approaches of the farms. Our finding corresponds to the results of Pröbstl-Haider et al. (2016), which state that policy strategies need to be adapted regionally and to the different strategies applied by different farmer segments. In the following section, we present concrete suggestions to revise policy instruments to better target and differentiate between farmers and subsequently foster absorptive, adaptive, anticipative and transformative capacity.

Absorptive capacity, describing short-term responses to buffer the impact of the shock, is widely implemented by irrigation. To support this capacity, subsidies for investments in irrigation infrastructure should be aligned with regional conditions (e.g. water availability) and should offer higher subsidy rates if technologies are water-saving or powered with renewable energy sources. However, several structural and technical challenges were found to impede the transition to renewable energy sources: Electric irrigation pumps must fit to the structural conditions of the farms (e.g. required pumping power, electrical grid access in the open field) and irrigation at night is not possible with photovoltaics. In addition, for green electricity high costs arise and the defined lower and upper thresholds for funding limit the access to funding. Lower minimum eligible project costs would consider small farm structures better and funding caps should account for the higher investment costs of sustainable technologies that are not (yet) established mainstream products.

Adaptive capacity comprises limited adjustments to soil cultivation or adjustments of production technique. We conclude from our interviews, that adaptive measures may eventually lead to transformative capacity and hence to deep structural changes. If positive effects on production are recognisable, farmers may intensify measures due to agronomic motivation. A prototypical situation is observed for greening measures: here, the distinction between adaptive and transformative capacity is ambiguous, as there is a large variation in the degree of implementation. Funding requirements should be more flexible to cater to the different environmental conditions in Austria and to support the shift from adaptive to transformative. Concrete approaches can be firstly to differentiate subsidies by time or region by adapted requirements for greening conditionality, greening measures or specific support for dry areas with low productivity. Secondly, target values could be revised and flexible timeframes implemented. To select and design equitable result-orientated target values, it must be taken into account that farms are subjected to different conditions (e.g. location, soil characteristics) and therefore may have different potential of achieving a target value (e.g. humus content). Our results show, that flexible greening timeframes which include a compensation for longer timespans instead of penalties for deviations from due dates or funding limited to year-round greening would eliminate the main hindering reasons for the uptake of funding. The already existing tools for digital monitoring and reporting with the use of satellite data and an app solution can be used for simplification of reporting obligations. Disentangling funding options where unrelated aspects are funded within the same instrument would also support simplification; for instance, "use of pheromones" (instead of insecticides) is funded only as top-up for "erosion protection for vineyards and orchards". If farmers do not apply for the greening instrument, they also cannot receive subsidies for the use of pheromones, which undermines the policy goal to reduce insecticide use. Thirdly, to tackle the practical obstacles mentioned in the interviews, farm advisory services on seed mixtures and suitable techniques should be expanded and funding programmes should cover the high costs of intensive greening measures.

Adapted crop selection as a measure to enhance anticipative capacity and thus preparation and planning for future droughts is reported to fail due to economic limitations: drought adapted crops or mixed crops often lack marketability. Regional approaches (see section below) can be supportive here.

Our results show, that the actual policy instruments obviously fail to set clear accents or promote substantial changes, leading to transformative capacity. Clear incentives for comprehensive climate change adaptation and mitigation would be set with simplification of the legal framework and subsidies for new production systems, e.g. agroforestry systems, hedges, windbreaks and planting of trees. The focus should also be placed on regional approaches and intersections with other policy domains, such as tackling of biodiversity crisis, as emphasised by IPCC (2022b).

Several of the adjustments of the agri-environmental programme announced in 2024 (Bundesministerium Land- und Forstwirtschaft, Regionen und Wasserwirtschaft, 2024) are in line with some of the above-mentioned considerations. However, the specific design will be decisive for the meaningfulness and impact of these changes.

5.3 Potential of regional approaches

Farmers repeatedly call for measures to optimise local water management and to retain water in the region. However, these aspects lie beyond the scope of individual decisions or measures on farm scale and require regionally coordinated actions.

Expanding regional electrical grids and water pipe networks to better connect agricultural land would support absorptive capacity and reduce carbon emissions. In this context, already existing cooperation between affected farmers such as land swap to optimise irrigation can be mentioned as best practice example.

To enhance acceptance of irrigation restrictions within the technical water strategy and allow coping with other threats of climate change, exceptions for frost irrigation should be made.

Some water cooperatives have already installed facilities or reactivated former floodgates in order to retain or discharge water as needed. Large-scale backwatering instead of drainage, as repeatedly proposed in the interviews, could complement absorptive capacity and contribute to anticipative capacity. A regional implementation would require comprehensive cooperation across different institutions and stakeholders; possibly also with Hungarian authorities. Increased backwatering would imply negative side effects such as flooded area or cellars of private households. To avoid conflicts, compensation for flooded areas could be considered.

Promoting inter-company cooperation along the food value chain could foster anticipative capacity and reductions in carbon emissions from the agricultural sector. Enabling dialogue and new business models between farmers and downstream companies for processing, marketing and retail could provide market opportunities for drought-tolerant crops, could bypass intermediaries through direct marketing and thereby generate more farm income, and could reduce food waste through better coordination in harvest timing, produce transport and storage.

To achieve substantial transformative capacity, regional approaches seem essential. The joint implementation of hedges, windbreaks, landscape elements, fallows and biodiversity areas or stepping stone biotopes would need regional concepts and specific support for farmers and other land owners or actors (e.g. municipalities).

The need for a coherent long-term strategy supported by all actors is even more pressing when considering that the ongoing structural change is being accelerated by climate change and that the pressure on the economic situation of farms is increasing. Hence, we would like to emphasise that policy instruments as irrigation restrictions require subsequent strategies to maintain farms and agriculture in the Seewinkel region and to support the implementation of substantial and comprehensive adaptation measures.

5.4 Methodological limitations

Our small sample is not statistically representative for the entire agricultural sector of the Seewinkel region, but we are confident that our qualitative sampling process captured the main facets of drought adaptation. However, as large, irrigation-intensive farm types are underrepresented in our sample due to reluctance to participation, we would presume that among all farms in the Seewinkel region, economic factors play a stronger role and willingness to implement new drought adaptation approaches is lower than reported here. Even though the interviewees were asked to elaborate on their broader outlook, our cross-sectional study can only provide a momentary snapshot on a dynamic situation that shifts according to seasonal and yearly climatic conditions. Instead, longitudinal studies could track over a longer period how strategies and adaptation measures are developed, tried out, revised and eventually maintained or discarded. Finally, it remains a topic for future research whether the mismatch between agronomic considerations and policy instruments observed for the Seewinkel case similarly applies to other drought-affected regions that also operate under the umbrella of the European Common Agricultural Policy.

Declaration of interest statement

No potential conflict of interest was reported by the authors.

Acknowledgements

This study was conducted within the project 'Build Back Better: Leveraging systemic shocks for integrated climate change adaptation and mitigation' funded by the Austrian Climate and Energy Fund and was carried out within the Austrian Climate Research Program (grant number C163295). We thank all participants of our interviews; Hermine Mitter and Bernadette Kropf for cooperation and support of data collection; and Marlene Holzmann for scientific and technical assistance.

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7. Annex

Annex I

Table 2: Factors for farmers' decisions and the implementation of (adaptation) measures

Reference	Factors	Description/Details
Grothmann and Patt, 2005	Risk perception	Interplay between the probability to be affected by a risk and the existence of other difficulties; probability of a risk, the risk experience in the past and the severity of the risk in the future.
	Subjective ability to adapt	Perceived ability to adapt themselves, trust in policymakers
Adger et al., 2007	Cognitive	Personal opinions influence risk perception
	Technical	Technical development addressing climate change
	Financial	Financial investment often needed for adaptation measures
	Cultural/social	How groups experience climate change
	Physical/ecological	Some systems may not be able to change as quickly as climate change does
Fleming and Vanclay, 2009	Cognitive	Understanding the meaning of climate change
	Barrier of practice	Dependencies of available resources, like time and money
	Barrier of information	Lack of information and communication about climate change or the difficulty to find the right information
IPCC, 2014	Socio-economic	Economic constraints can impede especially mitigation
	Institutional	Adequate institutions are important, particularly for small-scale farmers
	Ecological	Include site-specific mitigation potential and limited land and water resources
	Technological	Difficulties to develop and apply relevant technologies; challenges in monitoring or reporting
Hamann et al., 2016	Personal norms	Problem-awareness, perceived responsibility and self-efficiency
	Cost and benefit	Decision making considers benefit, social and monetary effort
	Social norms	Address the unspoken rules and standards shared by most people
Mills et al., 2018	Agronomic motivation	Actions without explicitly thinking of mitigation or climate change
	Financial motivation	Whether measures are subsidized or unsubsidized affects implementation
	Environmental motivation	Farmers' intrinsic motivation. A personal interest in maintaining the wildlife and environment
	Outside farmers control	Regulations, legal requirements
Dessart et al., 2019	Dispositional	Personality, resistance to change, risk tolerance, moral concern, farming objectives
	Social	Descriptive norms, injunctive norms, signalling motives
	Cognitive	Knowledge, perceived control, perceived costs and efforts, perceives risks
Barghusen et al., 2021	Personal norms	Problem awareness, perceived responsibility and group efficacy
	Cost and benefit	Direct monetary rewards, indirect rewards and cost savings
	Social norms	Injunctive norms and descriptive norms
Kropf and Mitter, 2022b	Cognitive	Climate change beliefs, risk perception, adaptation efficiency, costs, self-efficiency, denial, wishful thinking, religious faith, fatalism
	Social	Descriptive and injunctive social norms, trust in advise and media
	Dispositional	General risk attitude, place attachment, personal responsibility, value systems
Kreft et al., 2023	Cognitive	Farmers might perceive the implementation of measures as risky or are simply resistant to change
	Social	The uptake decision is influenced by the farmers' social network and the adoption patterns of their peers
	Dispositional	The implementation of measures on the farm also depends on the underlying farm structures and processes
	Policy measures	Level of payment and how it changes the relation of costs and profits

Annex II

Table 3: Prinicipal questions for interviews with farmers

Topic	Principal questions
Farm structure	Personal information /Background / Details on farm
Perceived impacts of drought on farm	What impact has the repeated drought on your farm?
	What damage has been caused by drought on your farm in the last five years?
	How do you estimate the future risk of drought damage for your business?
	On what is your risk assessment based?
	How confident are you that your farm can cope with these damaging events?
Implemented measures	What measures have you implemented on your farm due to the drought?
	In your opinion, how effective are the measures implemented at your farm?
	What do the implemented measures cost you in terms of investment and labour?
	Which of the measures you have implemented are subsidised by public funds? Which (other) funding measures for agriculture does the farm participate in?
	If measures are funded: How important was the funding for the implementation of the measure(s)?
	Has the consulting service or the example of other companies supported you in the selection of measures and their concrete implementation?
	What role do laws or regulations play in the selection or implementation of the measure(s)?
	For farms with arable crops, fruit production or grassland: How important is the possibility of insuring against damage caused by drought for your farm?
	Have any measures been implemented on your farm in recent years that you consider less sensible from today's perspective?
	If no measures have been implemented: For what reasons have you not yet adapted cultivation to the drought?
Planned measures	What measures against drought are you planning for the future?
	Are there any measures against drought that you would like to implement but are unable to do so on your farm?
	What other measures against drought and funding opportunities do you know of?
	How would you rate the overall support offered to your farm in terms of adapting to the drought?
External water dotation and irrigation	How do you irrigate which crops on your farm?
	If irrigation is available: What adjustments do you plan to make to the irrigation on your farm?
	If no irrigation is implemented so far: Are you planning to install an irrigation system on your farm?
	In summer 2022, an irrigation ban was introduced for the first time in four sub-regions and a warning phase is in place in some sub-regions. How was your farm affected?
	If the farm is member of an irrigation co-operative: What is your experience of dealing with water shortages in the irrigation co-operative?
	The supply of external water is a much-discussed strategy for channeling water into the region. The water will also be used for agricultural irrigation. What do you think about the planned external water supply?
Opinion on agricultural policy	What is your opinion on the discussion about the development of agriculture in the Seewinkel region?

	In your opinion, what characterises the political discussion in the Seewinkel region?
Closure	Is there anything else you would like to add that we have not discussed?
	Can you recommend any other interviewees?

Annex III

Table 2: Overview on structural data and measures of interviewed farms. Source: own data

Nr	**Main Crop(s)***	**Farm size (range)****	**Characterisation of irrigation**	**Predominant measures** (based on (Kropf and Mitter, 2022b))		
				Soil cultivation, mulching, covering; production technique	**Adaption of crops and cultivars**	**Drought insurance**
1	Vineyards	Small	No irrigation / discarded	Greening and soil management measures, canopy management	No changes	None / not applicable
2	Arable crops	Small	10-20% of cultivated area irrigated; large area sprinkler; fossil fuel	Reduced soil cultivation, greening	Crops and cultivars	Yes
3	Orchards, vineyards	Small	100% of cultivated area irrigated; above crown sprinkling, drip irrigation; fossil fuel	Greening	Rootstocks	None
4	Arable crops	Middle	30% of cultivated area irrigated, small and large area sprinkler	Reduced soil cultivation, greening	Crops	None / planned
5	Vineyards	Small	100% of cultivated area irrigated; drip irrigation; fossil fuel	Greening, soil cultivation in case of drought	Cultivars	None / not applicable
6	Arable crops, vegetables	Middle	Ca. 50% of cultivated area irrigated, large area sprinkler, above crown sprinkling, drip irrigation, fossil fuel	Reduced soil cultivation, greening, mulching	Marginal changes	None
7	Arable crops	Large	Longer time period without irrigation, planned	Soil cultivation mainly adjusted to soil conditions, varying intensity	Diversification, cultivars	None / planned
8	Arable crops, vineyards	Middle	40-50% of cultivated area irrigated; large area sprinkler, drip irrigation (vineyards); fossil fuel	Adapted soil cultivation, greening	Marginal changes	None / discarded
9	Arable crops, vegetables	Small	100% of cultivated area irrigated	Reduced soil cultivation	Crops and cultivars	None / partly not applicable
10	Arable crops, vegetables	Middle	95% of cultivated area irrigated	Soil coverage, intensified soil cultivation / reduced soil cultivation (depending on crops), greening	Crops and cultivars	None
11	Arable crops	Large	No irrigation	Reduced soil cultivation, greening	Crops and cultivars	Yes

12	Arables crops	Middle	30-40% of cultivated area irrigated, large area sprinkler	Reduced soil cultivation (intensity, depth), greening	Crops and cultivars	None / discarded
13	Arable crops, orchards, vegetables	Middle	30-40% of cultivated area irrigated, small and large area sprinkler, drip irrigation, above crown sprinkling	Soil coverage, mulching, greening, few changes in soil cultivation	Crops	None
14	Arable crops, vegetables	Small	20% of cultivated area irrigated, drip irrigation	Reduced soil cultivation (depth), soil coverage	Crops	None
15	Arable crops, orchards, vineyards	Small	30% of cultivated area irrigated, above crown sprinkling, drip irrigation	Soil coverage, greening, reduced soil cultivation (depth)	Cultivars	Arable crops covered
16	Arable crops	Middle	30% of cultivated area irrigated, fossil fuel / electricity	Soil coverage, greening, reduced soil cultivation (partly implemented)	Crops and cultivars	None / considered
17	Arable crops, vegetables	Large	60% of cultivated area irrigated, small and large area sprinkler, drip irrigation planned	Reduced soil cultivation	Crops and cultivars	None
18	Arable crops, vegetables	Large	90% of cultivated area irrigated, fossil fuel	No specific measures, existing measures not intensified, standard procedures	No changes	Yes
19	Arable crops, vegetables	Middle	50% of cultivated area irrigated; small and large area sprinkler, drip irrigation; fossil fuel / electricity	Greening, reduced soil cultivation and soil coverage planned	Crops and cultivars	Yes
20	Vineyards	Middle	50% of cultivated area irrigated, drip irrigation, fossil fuel /electricity	Yield reduction, canopy management, greening, less soil cultivation	Rootstocks and cultivars	None / not applicable

*rarely cultivated crops or subordinated crops and fallows were omitted, due to data protection

**farm sizes are indicated in ranges due to data protection