# To Adapt or not to Adapt: How Swiss Fruit Farmers respond to Climate Change

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**Abstract:** Climate change poses a substantial threat to global agricultural livelihoods, with particular challenges for the perennial crop sector due to path dependencies. This study utilizes survey data from Swiss fruit farmers to analyze grower behavior, climate perception, and adaptation strategies. We investigate the differential impacts of frost and drought on farmers' livelihoods, providing an extensive overview of Swiss farmers' perspectives on climate change. Our examination encompasses climate perceptions and the assessment of willingness to adapt to various paths, exploring factors influencing adaptation choices. Preliminary findings highlight significant harvest losses from frost compared to drought. Farmers with irrigation systems demonstrate enhanced abilities in identifying temporal shifts in precipitation. Moreover, farmers acknowledging both climate change and its human causes exhibit more accurate climate perceptions than those denying climate change. Additional results reveal a U-shaped relationship between farmers' losses and their willingness to adapt, with a tendency for climate change believers to exhibit greater adaptability to future climatic shifts. This study contributes scientific insights into the complex dynamics of climate change impacts on Swiss fruit growers, offering a basis for informed decision-making and adaptive strategies in evolving climatic conditions.

**Keywords:** climate change, climate impacts, agriculture, adaptation strategies, perceptions, beliefs

# 1 Introduction

In agricultural landscapes, anthropogenic climate change manifests in extreme weather events, posing severe challenges to farmers. Documented consequences in Switzerland highlight the profound effects of warming (MeteoSchweiz, 2018) and anticipated alterations in the frequency and intensity of extreme weather events heighten agriculture's vulnerability (CH2018, 2018). Past severe heat waves and droughts in Europe underscore the need for proactive adaptations involving stakeholders like farmers and policymakers (Büntgen et al., 2021). Effective adaptation and mitigation require an understanding of the causes and impacts of climate change, coupled with a willingness to alter behavior (Niles and Mueller, 2016). The decision-making process thereto involves intricate factors like farmers' beliefs, knowledge, and economic considerations (Chatrchyan et al., 2017).

Hence, understanding farmers' behavior is crucial for sustaining food production amidst multifaceted pressures in local agricultural systems. This comprehension is vital for identifying instances requiring intervention and shaping effective policies that facilitate socio-technical change and innovation (Feola et al., 2015). For example in response to these risks, cropping system changes have demonstrated substantial adaptation benefits, including increased net farm income in the United States (Prato et al., 2010).

This research project investigates the relationship between climate perceptions and adaptation behaviors of Swiss fruit farmers as well as explores climate impacts on perennial crops, focusing on frost and drought events. Farmers, as key stakeholders, face these challenges, necessitating adaptive strategies. Emphasis is on the long-term perspective of farmers dealing with perennial crops, recognizing the intricate nature of their decision-making and addressing a current gap in evidence related to factors influencing adaptation choices for perennials (Gunathilaka et al., 2018). To bridge this gap, a comprehensive survey was conducted to explore farmers' perceptions and expectations concerning climate change.

The paper's structure is organized as follows: In Chapter 2, a comprehensive exposition of the survey's content and structure will be provided. This will be followed by a summarization of both the characteristics related to farms and farmers. Furthermore, an examination of the impact of drought and frost on agricultural yield, along with a synthesis of the associated adaptation behaviors and climate beliefs and perceptions, will be presented. A subsequent analytical step will involve the construction of a belief typology and the formulation of an index to measure the willingness to adapt (WTA).

# 2 Survey

An essential approach to extract otherwise invisible factors, such as perceptions and beliefs are surveys (Stantcheva, 2022). Hence, to elicit farmers' individual characteristics, infrastructure on the farm, climate perceptions and beliefs, we conducted an online survey using the platform Qualtrics[1]. As farmers in Switzerland are required to fill out administrative documents received by e-mail, the coverage error[2] will be minimal. Online surveys have many advantages such as the flexibility of the target group to complete the survey at their convenience.

Kruse et al. (2015) conducted a survey of fruit growers in northeastern and northwestern Switzerland in 2013 to examine the past impacts of drought and the adaptation measures taken, as well as readiness for future measures in response to increasing extreme events. Results show that drought damage has been limited over the past decade. Nevertheless, most respondents believe they will be affected by drought more frequently and intensively in the future. However, the effects of other extreme events, such as frost, are not considered.

The creation of the survey was implemented in several feedback loops. A first draft of the survey was created where some questions were based on the survey conducted by Kruse et al. (2015) to achieve longitudinal data. Feedback in multiple rounds was gathered by local producers, employees of the Swiss Fruit Association SOV, Agroscope, the Swiss Confederation's center of excellence for agricultural research and Agridea, the centre for Agricultural Advisory and Extension Services. After completion, the survey was translated in to french and sent to around 1800 fruit farmers, i.e. all fruit farmers in Switzerland, cultivating more than 20 acres of orchards and took place from May to December 2022. Participation was incentivised by the opportunity to win a Landi voucher.

The content of the survey consists of 5 different question blocks A-E (see Table 1).

[1] The survey is still ongoing and responses will be collected until end of December 2022

[2] The *coverage error* is the difference between the potential pool of respondents and the target population (Stantcheva, 2022). Hence, an online survey can only be filled out by people having a phone/computer and internet access.

Table 1: Survey: Content and Structure

| | Thematic block | Questions aimed at |
|---|---|---|
| A | Questions about the farm | Type of fruit, acreage, distribution, irrigation system and amount of irrigation, source of water |
| B | Questions about the effects of drought on fruit growing | Impact due to drought in the last 10 years (+ and −), financial loss, adaptation measures, effect of years 2015 and 2018, willingness to adapt new measures if extreme years occur more often |
| C | Questions about the effects of frost on fruit growing | Impact due to frost in the last 10 years (+ and −), financial loss, adaptation measures, effect of years 2015 and 2018, willingness to adapt new measures if extreme years occur more often |
| D | Questions about their assessment (climate perception, beliefs) | Agreement/disagreement ( agree \| somewhat agree \| somewhat disagree \| disagree \| don't know) with several statements regarding drought, frost and climate change, perception of weather change over time, concern about several climate-related risks and future impacts, general opinion about the government, public policy and agriculture, risk averse/taking |
| E | Closing questions (individual characteristics) | Gender, age, experience, education, category of farm (full-time farm, etc.), membership of SOV |

## 2.1 Results

The survey was sent out to 1887 fruit farmers via mail. In total we received 547 responses, which equals a response rate of 28.9%. From those, 127 responses were dropped due to insufficient data, leaving 420 responses (22.2%)

### 2.1.1 Farms' and farmers' characteristics

From the 420 responses, 27% originated from the canton Thurgau, which is a clear majority. 10% of the respondents are located in the canton Aargau and around 9% each came from the cantons Basel and Zurich (see Figure 13). The mean year of birth of the person responsible for the farm is 1972, where the oldest respondent having a birth year of 1922 and the youngest

1998, with the first quartile being at 1964 and the third 1978. Years of experience range from 1 to 97 years, with a mean experience of 28 years. q(25) is at 18 years and q(75) at 37 years. 95% of the farmers are male. Most of the farmers grew up in agriculture and then proceeded by either doing an apprenticeship, going to farmer manager school and doing a master, or a combination of the ones mentioned before. Almost half of the respondents went on to get further qualification in fruit growing, such as taking a tree pruning course, courses in organic farming or speciality courses for stone fruit and pomes. Additionally, as can be seen in Figure 15, farmers have a tendency to be more risk loving than risk averse.

Regarding the farm category, 81% of farmers run a full-time farm, meaning that the non-farm income of the farm manager is less than 10% non-agricultural. About 10 % run a part-time farm with 10%-50% non-agricultural income and 8% with non-agricultural income more than 50%. Only 1% operate a 'recreational farm' where the farm income is insignificant as part of total income. Of the respondents, 86% are members of the Swiss Fruit Association (SOV).

The average size of farms is 1572 ares, which corresponds to 157200 $m^2$, and ranges from 24 to 120000 ares, with 75% of all respondents have farms below 665 ares. 43% through wholesalers such as fenaco and Tobi and 34% distribute their products through direct sales, farm stores, market stalls or the like. About 5% of the farmers sell through wholesalers such as Migros, Aldi, Lidl or similar. 9% use a local or regional distributor such as Landi and the remaining 5% use other distribution logistics.

Of the 420 respondents, 312 grow stone fruit, 343 pome fruit, 88 berries, 34 nuts and 22 other fruits. The majority of fruit growers grow not only one crop, but several. It follows that both pome and stone fruit are the crops that produce the greatest economic yield for the farmers.

In terms of potential measures, the literature shows that there is a wide range of potential on-farm mitigation strategies (e.g. increasing productivity and efficiency, specific technology, adapting farm management (Kreft et al., 2021)). Regarding fruit production, irrigation infrastructure is arguably the most important measure that farmers use to protect against climate impacts, as it is used to address both frost and drought.

Of 418 respondents, 140 do not irrigate their fruit crops, 220 irrigate with a fixed infrastructure, of which less than half irrigate all of their fruit crops. Those who irrigate part of their crops with a fixed infrastructure irrigate on average 55% of the crops. 78 growers irrigate with a mobile device or by hand and do not have a permanently installed irrigation system. We still need to investigate how irrigation infrastructure differs among crops, cantons and other determinants.

In theory, irrigation can be divided in two broad groups, total surface irrigation and local irrigation, which in turn can be divided into two groups, see Figure 1. Whole surface irrigation can be either overcrown irrigation or undercrown irrigation, while local irrigation is either microjet irrigation or drip irrigation (Monney and Bravine, 2011). Information on the usefulness of the various irrigation systems in terms of drought and frost protection can be found in SECTION 2.1.2.

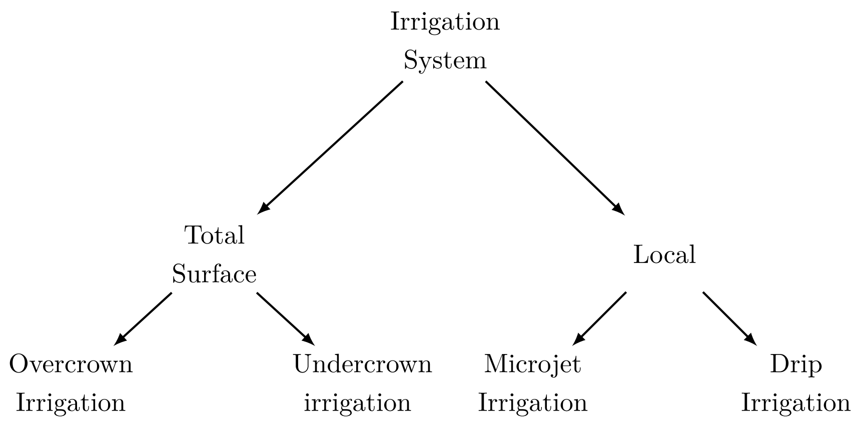



Figure 1: Different irrigation systems.

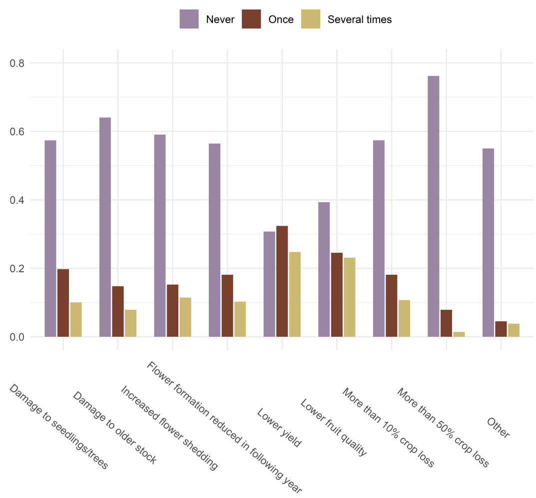
From our survey data, the majority (188) of participants with fixed installed irrigation systems irrigate their crops with drip irrigation. 43 participants use a microjet irrigation system, 41 rely on an overcrown irrigation infrastructure and 41 use sprinklers to irrigate. Some participants rely on more than one system. Most participants get water from either groundwater or water reservoirs. Fewer rely on water supply from lakes or rivers. Almost 90% of the respondents don't have contracts with the municipality to secure water supplies from the drinking water network. The minority who has a contract is spread over most of the cantons and not concentrated in one canton.

When planting crops, the vast majority of 65% of the respondents take site-specific characteristics into account, like soil conditions, topography, geographic targeting. Those who consider site-specific characteristics mostly evaluate soil conditions, frost vulnerability and in general resistance of crop, closeness of water source and topography (often gradient and geographical targeting).

### 2.1.2 Effect of drought and frost on agricultural yield

When examining the impact of drought and frost on orchards over the past decade, it becomes evident that frost has inflicted more significant damage. Figure 2 illustrates the harm caused by both dry spells and frost. Across all damage categories, a larger proportion of farmers have reported damage attributed to frost compared to damage caused by dry spells.

Consequently, the financial losses over the period of the last 10 years are larger because of frost than because of drought. Where the mean loss as percentage of the average agricultural income from the fruit-growing branch of the business over the last 10 years is 7.5% from drought and 20.7% from frost. Potential measures against drought are irrigation, soil cultivation (e.g. hoeing, loosening), ground cover (e.g., mulching, overgrowth), shading, cultivation of drought-resistant fruit crops, whereby in Switzerland mainly irrigation and ground cover are used (Kruse et al., 2015). We see in our sample, the majority (64%) uses irrigation as measure against drought. Around 42% use ground cover to protect against drought, 15% use tillage and 8% use shading. These countermeasures were able to prevent on average 20% of the losses that would've have been endured without measures.



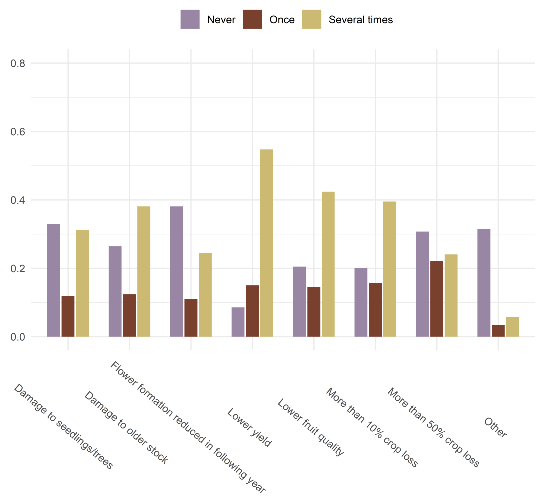




Figure 2: Has there been any damage caused by dry spells (left)/frost (right) on your orchard in the last 10 years?

As response to late spring frost, potential measures are overhead irrigation[3], heating (frost

[3] Water releases heat to its surroundings when it freezes. As water freezes directly on the plants, the heat benefits the plant parts. The system must be switched on before the wet bulb temperature falls below the critical plant temperature. For example, for emerging apple blossoms, which suffer first damage from -0.5°C, the over-crown irrigation must be switched on at a relative humidity of 85% at the dry temperature

candles)[4] and air circulation (wind and blower machines)[5]. Out of the chosen answers, most farmers respond to frost by using frost candles (39%). Only 13% of respondents use irrigation as frost protection and about the same percentage have insurance against frost damage. In addition, many farmers use foil coverage of the crops to prevent frost damage. Irrigation as response to drought is seen far more often, than in response to frost. On average, farmers irrigate 30 days because of drought, 90% of all values lying below 82 irrigation days, but only one day because of frost, where 90% of all values lie below 5 irrigation days. The measures against frost were effective in at least a third of the cases and were able to prevent on average 30% of the financial losses.

Regarding positive effects, the majority of farmers (57%) expressed the view that drought periods have had a beneficial impact on fruit-growing. This positive effect is primarily attributed to reduced fungal infestations, diminished requirements for pest management, and lowered disease pressure.

When comparing the impact of extensive drought over two years (2015 vs. 2018), 2018 had a more substantial influence. Approximately two-thirds of respondents reported experiencing greater losses in 2018. Nonetheless, the majority of them still incurred no more than a 10% reduction in their harvest. Regarding frost, 2017 was a more challenging year for over two-thirds of all farmers, with nearly 50% of them losing more than half of their yield. However, only 20% of the farmers got compensation payments as a result of that frost. We don't know whether the other farmers didn't apply for these payments or if they were not eligible. The average total payment (not per ha) in 2017 was just short of 60'000 Swiss francs, where in 2021 it was around 25'000 Swiss francs.

### 2.1.3 Adaptation behaviour

The farmers were inquired about their responses to events like droughts in 2015 and 2018, and frost events in 2017 and 2021, occurring at varying intervals: every 2 years, every 5 years, and every 10 years.

There were several adaptation answer possibilities as well as two answer possibilities with exit strategies (give up orchard, give up farm). What is striking, is that there seem to be different preference pattern regarding adaptation versus exit strategies.

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of 0°C. If the relative humidity is 65%, the system must be switched on already at 1°C dry temperature, because at lower relative humidity there is greater evaporative cooling.

[4] The air is heated by a heating source (fire). White tin buckets with 6l of kerosene are distributed in the plant before the frost night and lit with a burner before the temperature falls below the critical temperature. At -4°C 300-350 candles/ha are needed. According to the manufacturer, the burning time is about 8 hours. However, new kerosene candles often burn shorter (6-7 hours) under practical conditions.

[5] Circulation of the air layers. By circulating the air layers, warm air from higher layers enters the system.

We expect to see linear patterns, meaning, that as the frequency of the drought/frost event increases more farmers would choose adaptation options and fewer farmers would just want to write off their losses. The same pattern was expected when looking at exit options. We expected with increasing frequency of events, that more farmers would be willing to either give up their orchards or give up their farm. The effects were expected to be more pronounced for frost, as frost impacts are larger and harder to adapt to.


Figure 3: Suppose a year like 2015/2018 (2017/2021) occurs more frequently in the future: What measures would you take to combat drought (frost)?

What we can see in Figure 3, however is that farmers are rational in their answers for when it comes to adaptation strategy. As the frequency of heavy drought events rises from 10 to 5 and then to 2 years, farmers consistently exhibit an increased likelihood of switching crops, seeking insurance, and installing fixed irrigation infrastructure. Concurrently, the proportion of farmers opting to write off losses without implementing measures decreases. Similarly, with the escalating frequency of frost events, farmers show a linear preference for switching crops, investing in wind blowers, fixed irrigation infrastructure, insurance, and candles, while the inclination to write off losses diminishes. These are all very linear and rational patterns. However, this linearity does not carry over to exit strategies. In contrast to the expected linear pattern in exit strategies, a U-shaped preference emerges. Farmers express a higher likelihood of considering exit strategies (giving up orchard or farm) when faced with frost or drought events occurring at 2-year or 10-year intervals. This unexpected outcome is particularly pronounced when examining frost events. These are preliminary results and will be investigated in a next step. We do see that frequency seems to matter. One hypothesis is that it is influenced by the perennial nature of the crop.

### 2.1.4 Climate perceptions and beliefs

As depicted in Figure 10 in the Appendix, respondents were asked to share their views on statements related to drought and frost. The analysis indicates a widespread agreement among farmers regarding the expectation that "Drought will occur more often in Switzerland in the future compared to the past." However, when it comes to a similar statement about frost, there is a somewhat agreeable sentiment. Furthermore, a significant number of farmers believe that future drought periods will be longer, and they anticipate adverse effects on their farms due to drought. Despite this, farmers show hesitancy in securing investment loans for irrigation systems or investing in facilities for waste water reuse or irrigation ponds, especially in the context of both drought and, to a greater extent, frost. Notably, their readiness to invest is more evident in fixed irrigation systems, particularly in response to an expected increase in drought occurrences. Additionally, farmers express a willingness to educate themselves on appropriate management options in the event of increased occurrences of either frost or drought in the future.

Regarding climate perceptions, most farmers firmly believe that there has been a consistent rise in both the annual accumulation of heat degree days and summer temperatures. Although to a lesser extent, a significant majority also observes an increase in winter temperatures, the frequency of heavy precipitation, and instances of pest infestations over time. Water availability and annual precipitation are generally perceived as stable factors. These findings are visually depicted in Figure 11 in the Appendix.

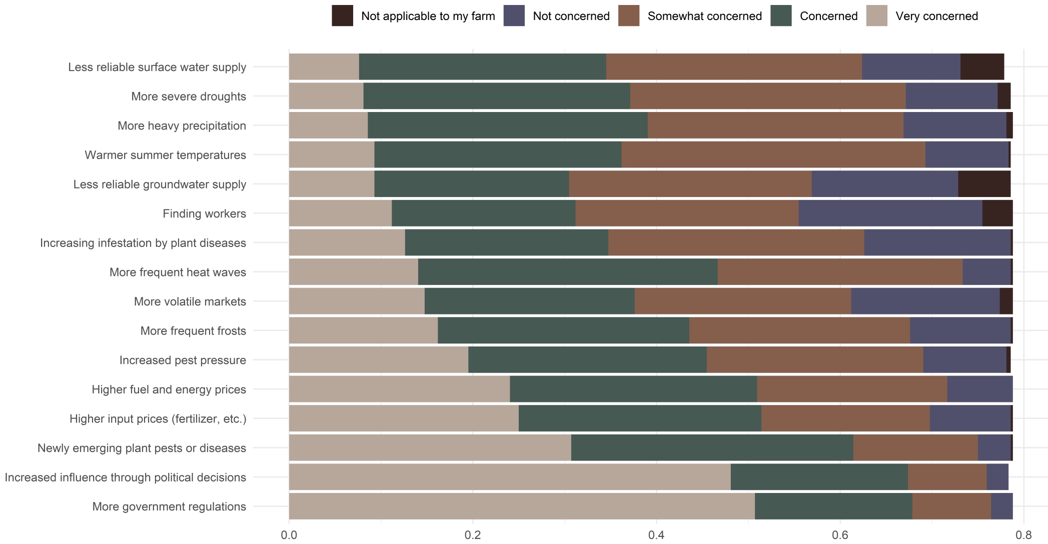



Figure 4: Q: How concerned are you about the following climate-related risks and the future impact they could have on your farming operation during your career? Indicate the level of your concern.

Referring to Figure 12, a notable majority of respondents express apprehensions about climate change, recognizing the increase in global average temperatures and the evolving global climate. They often perceive climate change as a potential threat to agriculture. However, their concerns are more focused on heightened government regulations and increased political influence, rather than the potential aggravation of severe droughts or more frequent frosts. Figure 4 provides a visual representation of a ranking that reflects respondents' levels of concern regarding climate-related risks and future impacts.

In line with these findings, a majority of farmers either agree or partially agree with the statement that environmental regulations present challenges to the efficient and profitable operation of their farms. Additionally, there is strong agreement among farmers regarding the ethical responsibility to protect the health of the soil (refer to Figure 5).

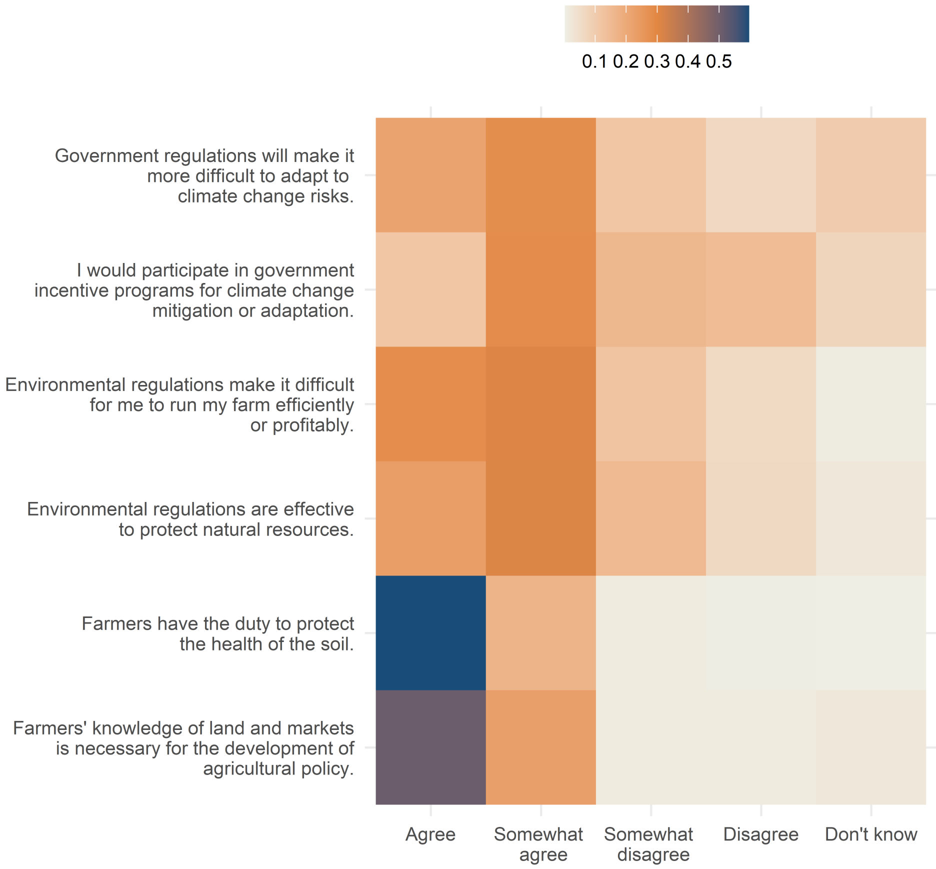



Figure 5: Q: Indicate how much you agree with the following statements.

Examining the ability of farmers in identifying temporal shifts in precipitation relative to their employed irrigation systems, we find that farmers employing a fixed, installed irrigation system are significantly more proficient in detecting the mostly adverse trend in yearly precipitation. We categorize farmers into three cohorts based on their irrigation methodologies: fixed irrigation, mobile irrigation, and absence of any irrigation system. We cluster the group that uses fixed irrigation systems on all or on part of their crops. We match these groups with the logical variable of their precipitation trend estimation (TRUE/FALSE). Combining these two TRUE/FALSE logical variables, we get the TRUE/FALSE count of each group and see how many farmers per group were right in their estimation. Subsequently, a statistical comparison is performed, employing a Chi-squared to test the existence of significant distinctions among these three different groups (p-value $= 8.396e^{-07}$). The group with no irrigation infrastructure performed better than the group with a mobile or hand irrigation infrastructure. This result becomes notably more pronounced when restricting the analysis to full-time farmers, the demographic constituting the vast majority of survey participants. Ongoing investigations are being conducted to ensure the robustness.

In order to evaluate the accuracy of climate perceptions, historical weather data is compared to farmers perception of changes in summer temperature, winter temperature, annual precipitation, number of heat days per year, number of frost days per year, frequency of drought and frequency of heavy precipitation events.

### Historical weather trends

MeteoSchweiz[6], the federal office of Meteorology and Climatology provides weather parameters, e.g. precipitation and temperature (daily average, daily minimum, daily maximum) for ground monitoring stations all over Switzerland. Based on the daily ground stations, daily cantonal data was built, creating the daily mean of the stations in the respective cantons. Figure 6 shows the distribution of the respondents location as well as the weather station. In a next step, we want to precise farmers climate perception with individual station data as opposed to cantonal weather data.

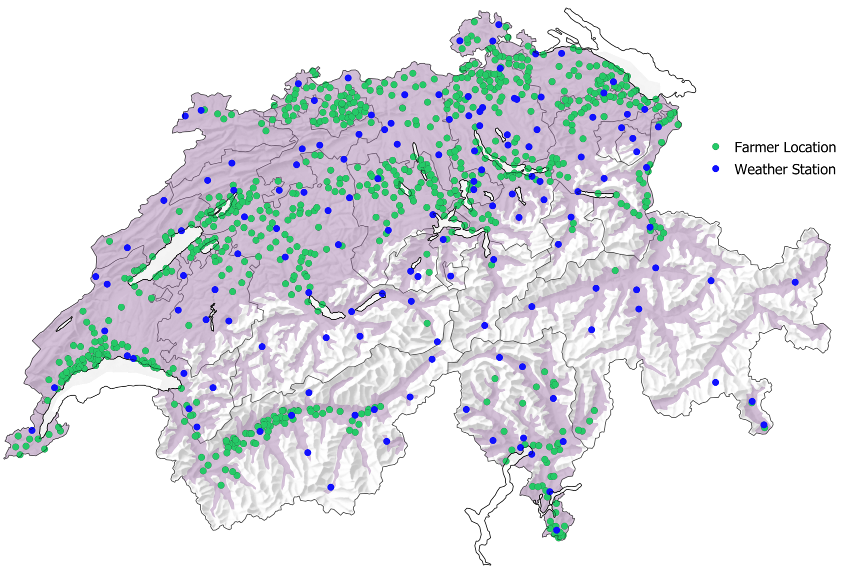



Figure 6: Farmers' location (green), weather monitoring station (blue)

[6] 'Die Dienstleistungen wurden von MeteoSchweiz, dem Bundesamt für Meteorologie und Klimatologie, zur Verfügung gestellt'.

Table 4 in the Appendix illustrates the linear trends in winter temperatures (DJF), summer temperatures (JJA), precipitation, spring frost days ($\leq -1°C$ in MAM), and heat degree days (number of days above 30°C) over the past three decades. These trends were then combined with farmers' perceptions of the corresponding changes. Farmers were asked about the observed trends in the timespan of their agricultural careers, ranging from summer temperature, winter temperature, yearly precipitation, heat days, to frost days, and more. Their responses could indicate whether these variables increased over time, remained constant, decreased over time, or if they were uncertain. By aligning the weather trends with farmers' perceptions in each canton, we derived true and false values. The distribution of these perceptions is presented in Figure 7.

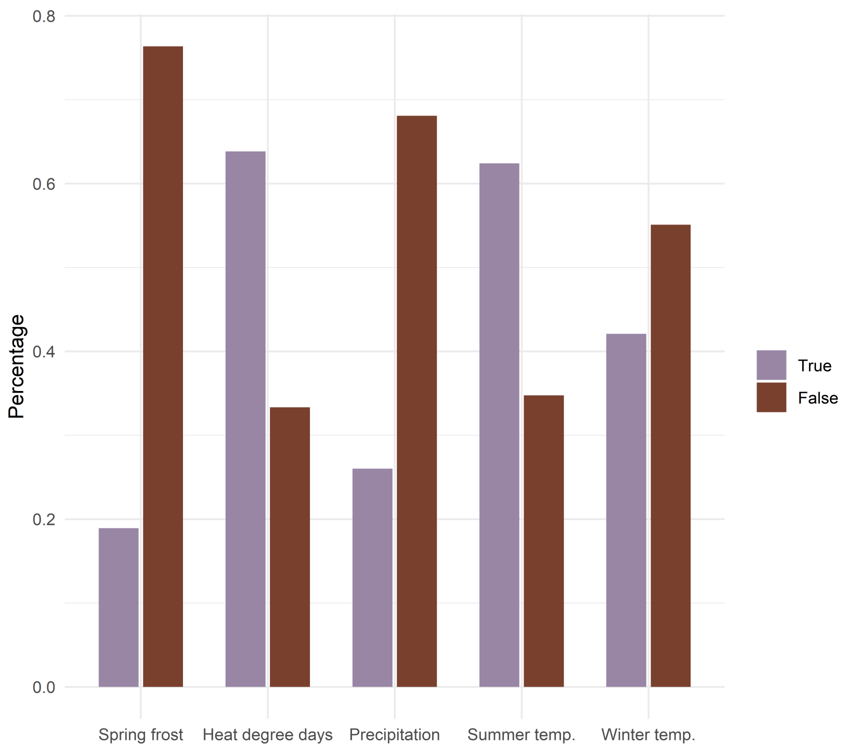



Figure 7: How well do farmers percieve weather trends?

Additional inquiry is needed to elaborate on the reasons behind the inaccuracies among farmers in perceiving spring frost occurrences. One plausible hypothesis is that the potentially large impact of spring frost on yield may contribute to an inflated perception of their frequency, whereas the comparatively easier adaptability to drought leads to an underestimation of its occurrence.

### Climate Change Beliefs

The following four farmers typologies have been created based on Niles and Mueller (2016): (1) the conviction that climate is not changing, with no human contribution; (2) the perspective that climate remains unaltered, yet humans play a role in climate change; (3) the belief that the climate is undergoing changes, but without human involvement; and (4) the acknowledgement that both climate change is occurring and humans are contributing to it.

For each of the specified perception variables (see Figure 7), we calculate a contingency table and perform a Fisher Exact Test, extracting the p-value, to see whether there exists a significant association between the two different categories.

Table 2: Fisher p-values for different variables

| **Variable** | **Fisher p-value** |
|---|---|
| Summer Temp | 0.0000185 |
| Winter Temp | 0.1889179 |
| Precipitation | 0.2362960 |
| Heat Days | 0.0009469 |
| Frost Days | 0.6290025 |

The table indicates that belief typology is significantly associated with perceptions of summer temperature and heat days, while perceptions of winter temperature, precipitation, and frost days do not show significant associations. It is imperative to investigate the specific directions and underlying reasons for these observed patterns. Belief type 2 was excluded from the analysis due to its limited representation with only two observations. Additionally, the "Uncategorized" category predominantly comprises missing values, with approximately 30 individuals indicating a lack of knowledge or uncertainty regarding their belief type.

Table 3: Correlation matrix

| | **Type 1** | **Type 3** | **Type 4** |
|---|---|---|---|
| Summer Temp [TRUE] | -0.192 | -0.178 | 0.245 |
| Winter Temp [TRUE] | -0.130 | -0.037 | 0.080 |
| Precipitation [TRUE] | -0.041 | -0.094 | 0.100 |
| Heat Days [TRUE] | -0.216 | -0.083 | 0.170 |
| Frost Days [TRUE] | 0.014 | 0.029 | -0.023 |

The correlation matrix reveals associations between belief typologies and weather perceptions. Notable findings include the moderate positive correlations between Type 4 beliefs and being right in their climate perception. Being of Type 4 and having a better climate perception seem to be associated more than with the other types. These results underscore potential patterns in how individuals' belief systems may be linked to their perceptions of specific weather conditions, providing insights into the interplay between cognitive frameworks and environmental interpretations. However, the correlational nature of the analysis cautions against inferring causation or complex dependencies.

Further inquiry is needed to explore additional underlying character traits that may influence in this context. Additionally, it is crucial to examine whether experiences with frost or drought have had an impact on the observed patterns.

#### Willingness to adapt

In the years 2017 and 2021, significant occurrences of frost were observed, and in the years 2015 and 2018, noteworthy instances of drought were recorded. In response to these climatic events, farmers were surveyed regarding their anticipated reactions if such incidents were to happen at intervals of two, five, or ten years. The respondents provided answers categorized as follows: a two-year interval corresponded to the numerical value one, a five-year interval to the value two, and a ten-year interval to the value three. The survey entails various adaptation measures, and an index reflecting the willingness to adapt (WTA) was derived from the respondents' answers. Figure 16 in Appendix displays the distribution over the individual WTA values as a response to both frost and drought.

The critical year for each individual was identified, signifying the specific temporal threshold (2, 5, or 10 years) beyond which the individual expressed readiness to implement adaptive measures. Subsequently, a mean was calculated across the potential adaptation measures, yielding a numerical value indicative of the individual's willingness to adapt, ranging between 1 and 3. A higher value on this scale suggests a lower willingness to adapt of the individual.

Figure 16 in the Appendix shows the distribution of WTAs over individuals for both frost and drought.

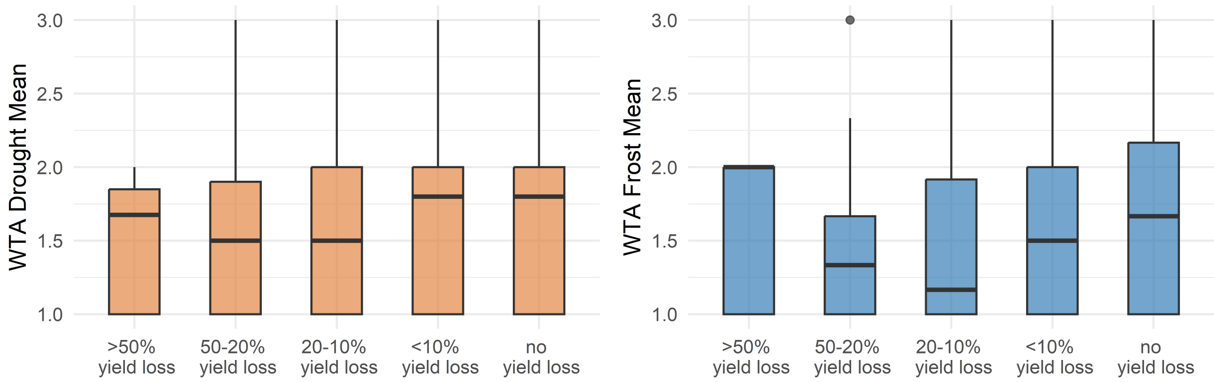



Figure 8: Willingness to adapt to drought and frost dependent on losses from drought and frost

Examining Figure 8, we can see that individuals' willingness to adapt (WTA) experiences an increase as losses decrease, followed by a subsequent decrease for exceedingly minimal to negligible losses. This trend is more pronounced in the context of frost. Nevertheless, the means across distinct groups do not exhibit statistically significant differences.

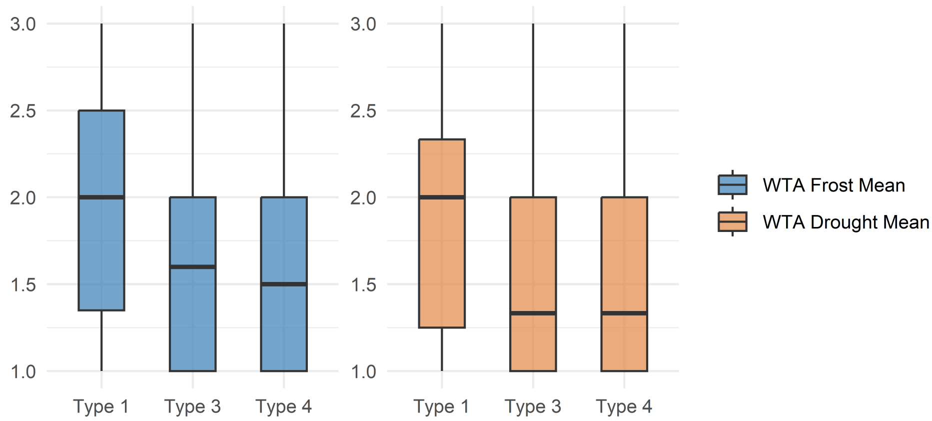



Figure 9: Willingness to adapt to drought and frost dependent on the belief typology noted above

If we compare the WTA values for the different belief typologies (Figure 9), we can clearly see that the mean WTA value is highest, meaning having the lowest willingness to adapt, for type 1. Type 1 is the group that was under the conviction that climate is not changing, with no human contribution. Respondents of both type 3 and type 4 are far more willing to adapt to future climate changes. Both type 3 and type 4 acknowledge climate change, diverging primarily in their assessments of human involvement in this phenomenon.

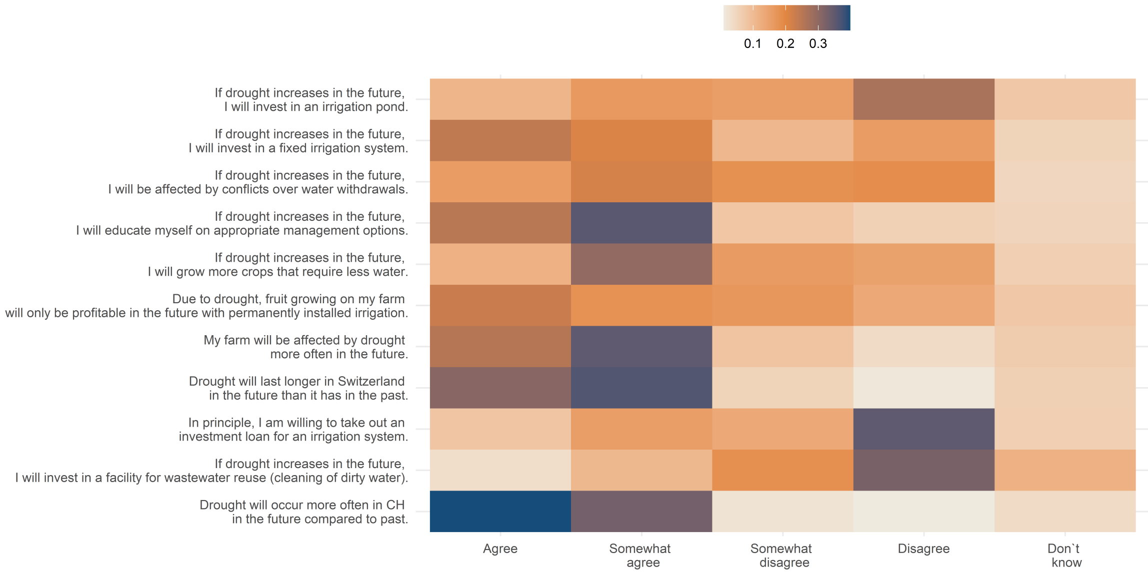
# 3 Conclusion

In summary, this study addresses the threats posed by climate change to global agricultural livelihoods, emphasizing challenges in the perennial crop sector due to path dependencies. Utilizing survey data from Swiss fruit farmers, we analyzed grower behavior, climate perception, and adaptation strategies, revealing a substantial mean harvest loss exceeding 20 percent due to frost over the last decade.

Our findings indicate farmers' current prioritization of concerns regarding government regulations over climate impacts. We also explored the relationship between farmers' willingness to adapt, yield losses, and belief typology. Farmers' climate beliefs significantly influence their inclination to adapt, with non-believers in climate change showing lower willingness to adapt to future climate impacts. These are preliminary results, indicating the need for further investigation as the survey offers extensive untapped information.

This study contributes to understanding farmers' adaptation mechanisms, perceptions, and beliefs, crucial for addressing future changes. The complex adaptation process requires ongoing research, supporting prior conclusions that there is no singular solution for enhancing agricultural resilience. Stakeholder involvement, collaboration among researchers and advisors, is essential for effective climate adaptation in agriculture. Our aim is to provide a foundation for informed decision-making and adaptive strategies in response to evolving climatic conditions.

# Appendix



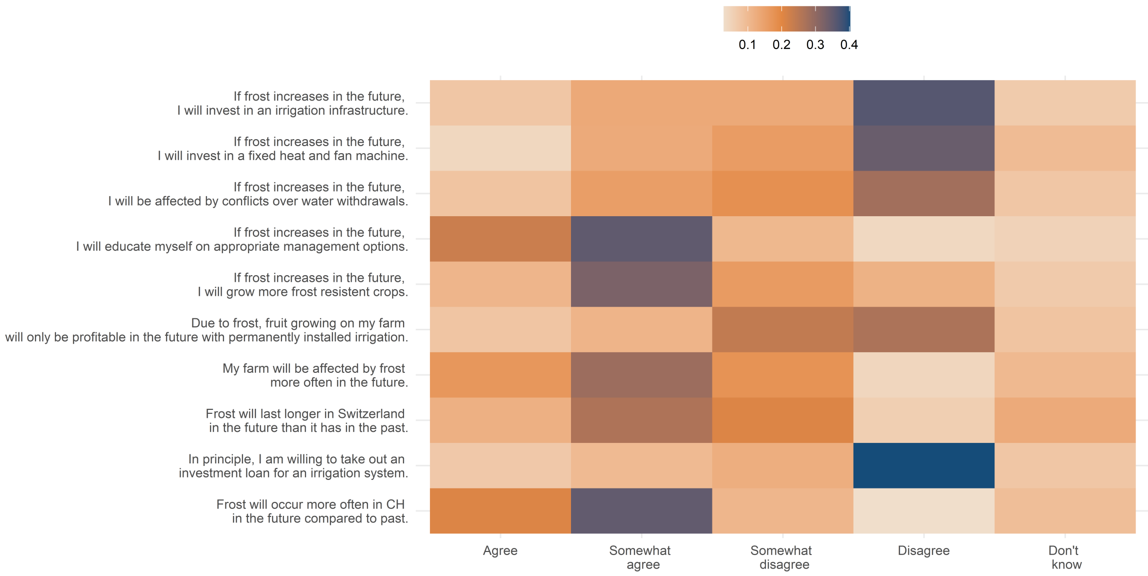




Figure 10: Q: How much do you agree with the following statements about drought/frost?

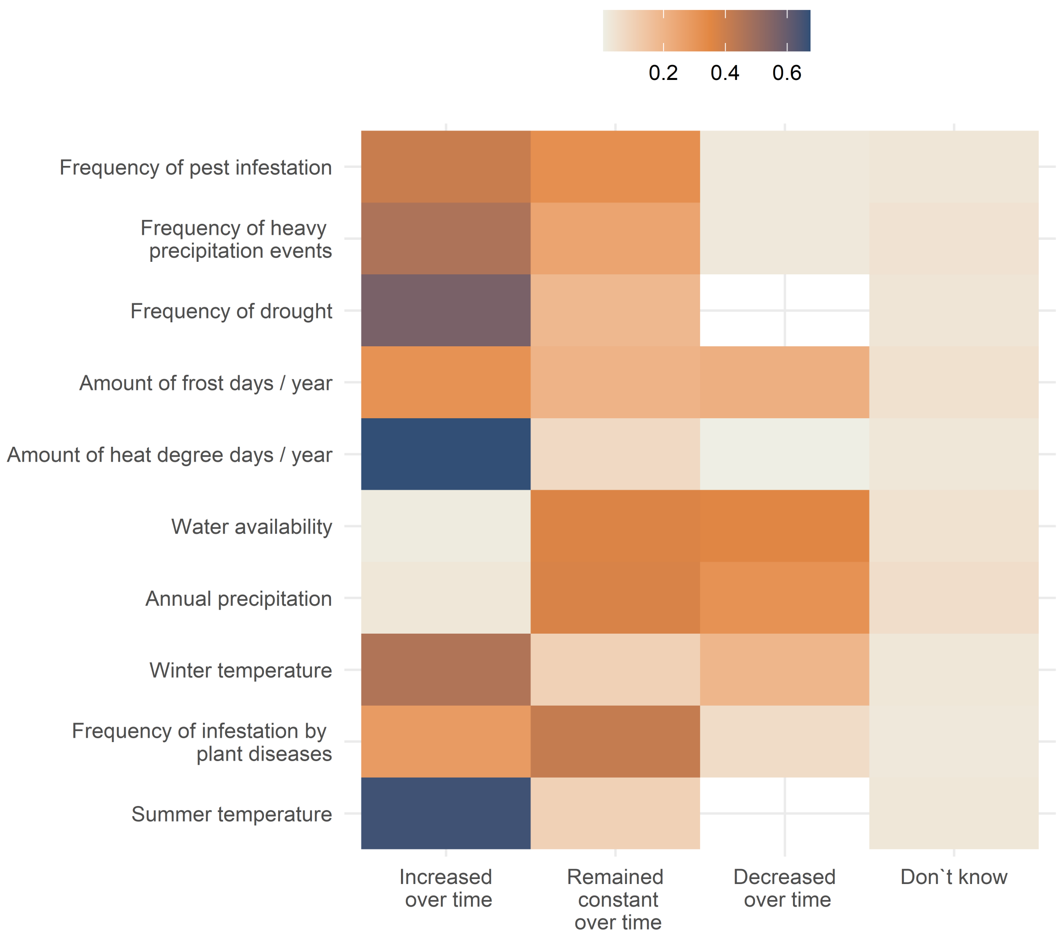



Figure 11: Q: Indicate which of the following trends (if any) you have observed during your agricultural career in your canton.

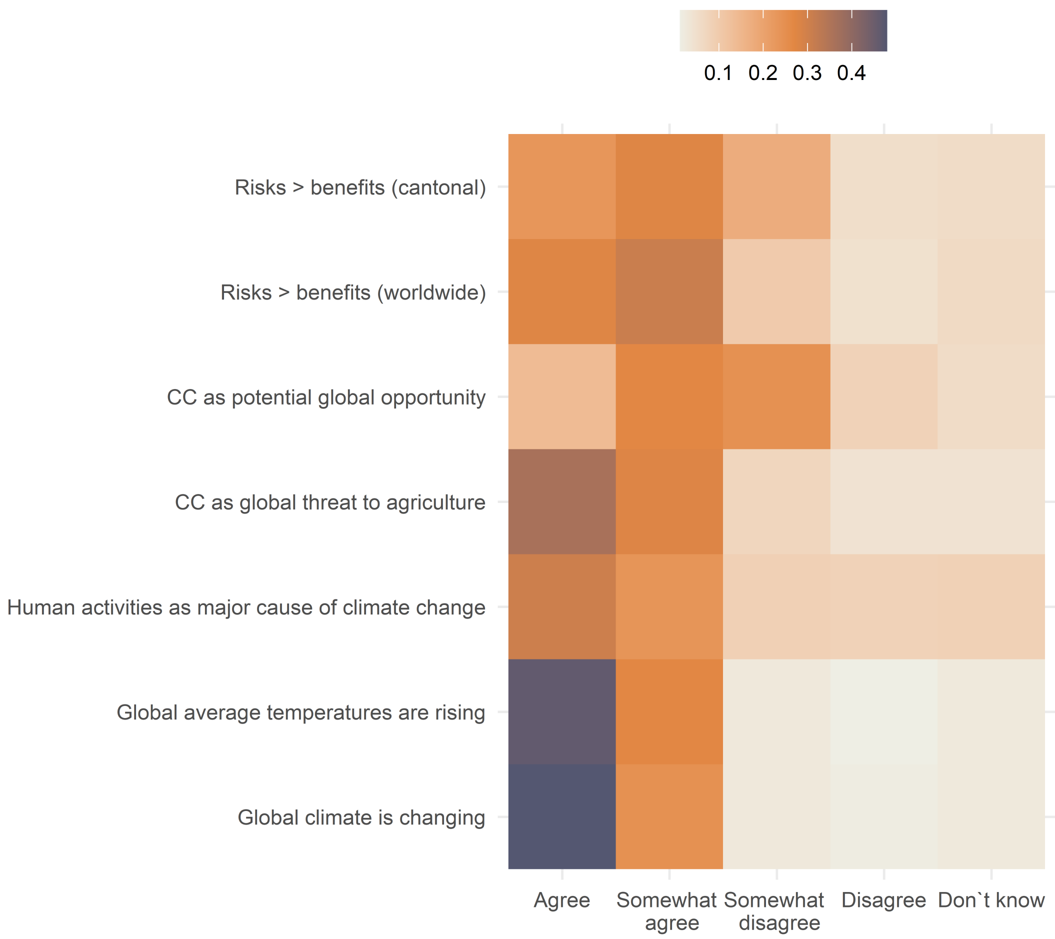



Figure 12: Q: Indicate how much you agree with the following statements.

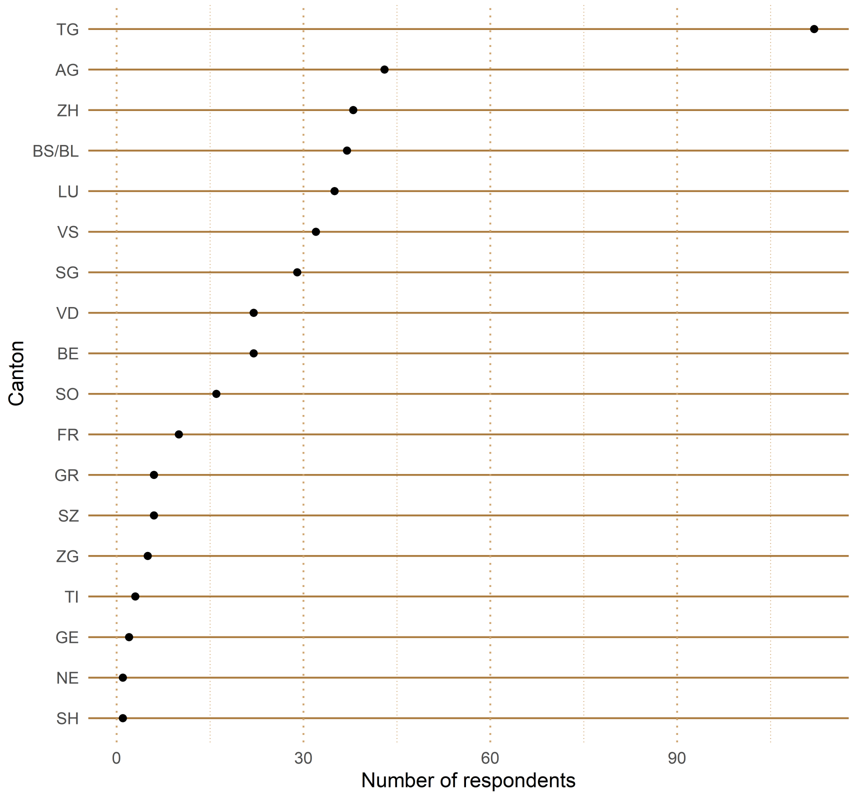



Figure 13: Cantonal distribution of survey respondents

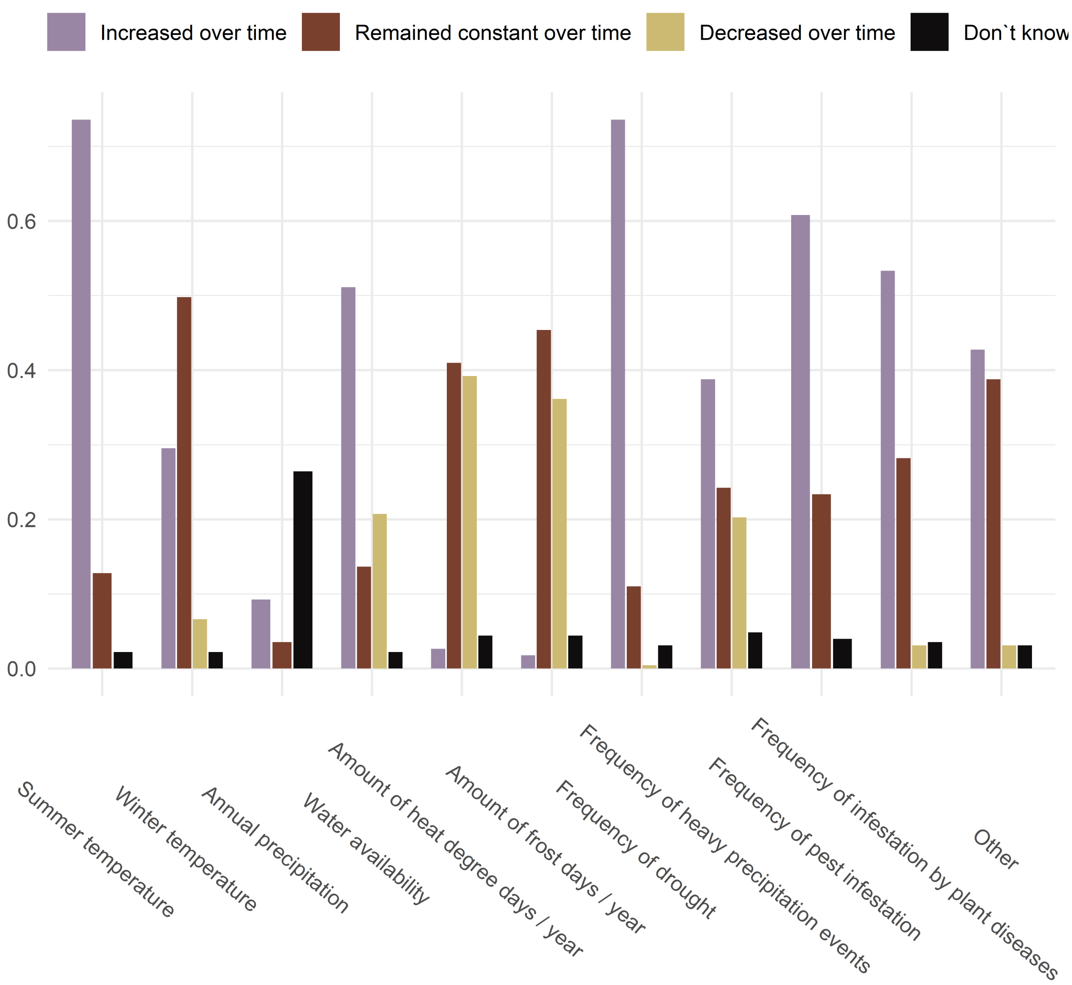



Figure 14: Q: Indicate which of the following trends (if any) you have observed during your agricultural career in your canton.

Table 4: Change of Climate Indicators (1981-2021)

| Canton | Δ Winter Temp. | Δ Summer Temp. | Δ Prec. | Δ Spring Frost Days | Δ Heat Days |
|---|---|---|---|---|---|
| AG | 0.038* | 0.042** | -0.013* | -0.038 | 0.220* |
| BE | 0.033 | 0.038** | -0.011 | 0.050 | 0.172* |
| BL | 0.042* | 0.055*** | -0.000 | 0.000 | 0.296** |
| FR | 0.026 | 0.034** | -0.018** | -0.055 | 0.084 |
| GE | 0.032 | 0.050*** | -0.003 | -0.174* | 0.217 |
| GL | 0.038* | 0.050*** | -0.001 | -0.103 | 0.195** |
| GR | 0.046* | 0.067*** | -0.001 | -0.130 | 0.409*** |
| JU | 0.041* | 0.046*** | -0.012 | -0.032 | 0.206** |
| LU | 0.034 | 0.046*** | 0.006 | -0.108 | 0.241** |
| NE | 0.031 | 0.038** | -0.004 | -0.075 | 0.198* |
| SG | 0.037 | 0.045*** | -0.000 | -0.044 | 0.123* |
| SH | 0.042* | 0.045*** | -0.007 | -0.020 | 0.250** |
| SZ | 0.033 | 0.047*** | -0.022** | -0.061 | 0.020 |
| TG | 0.045* | 0.054*** | -0.004 | -0.107 | 0.144* |
| TI | 0.032** | 0.048*** | -0.008 | -0.028 | 0.405** |
| UR | 0.034* | 0.039** | 0.001 | -0.010 | 0.098 |
| VD | 0.034* | 0.046*** | -0.006 | -0.071 | 0.208* |
| VS | 0.037* | 0.066*** | -0.003 | -0.141 | 0.523*** |
| ZH | 0.041* | 0.050*** | -0.002 | -0.021 | 0.273** |

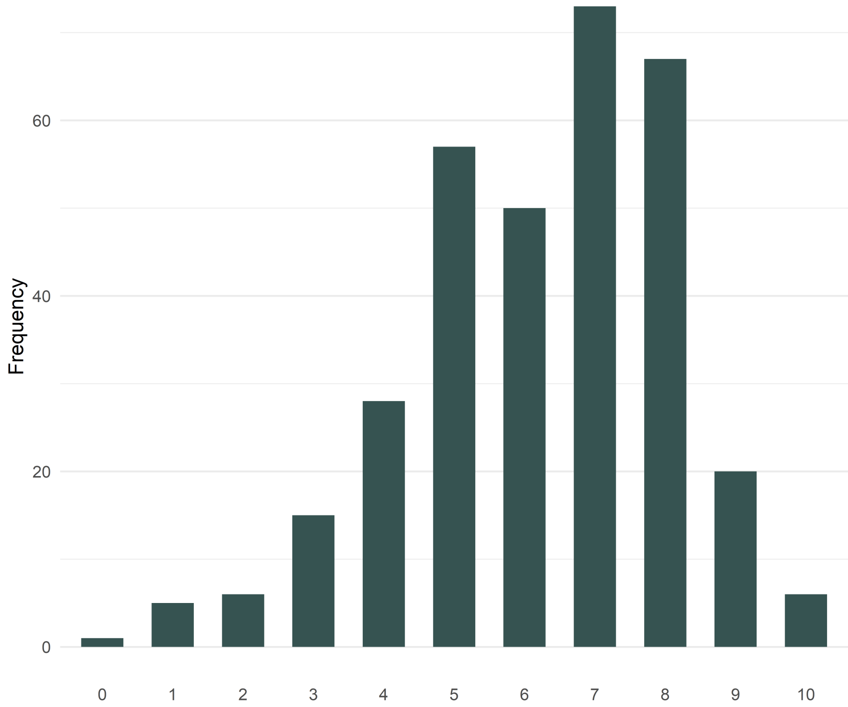



Figure 15: Q: On a scale of 0 to 10, where 0 means 'not at all willing to take risks' and 10 means 'very willing to take risks', how would you generally rate your personal willingness to take risks?

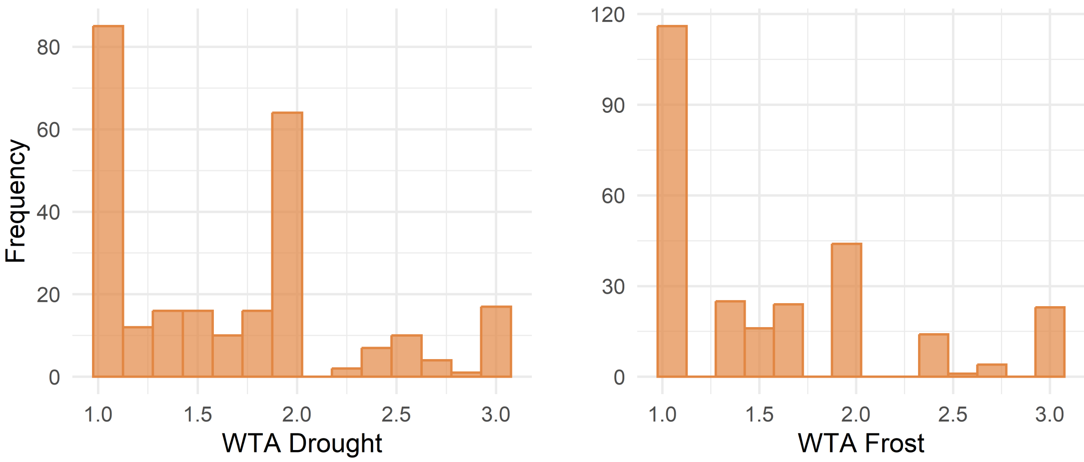



Figure 16: Willingness to adapt to drought and frost

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