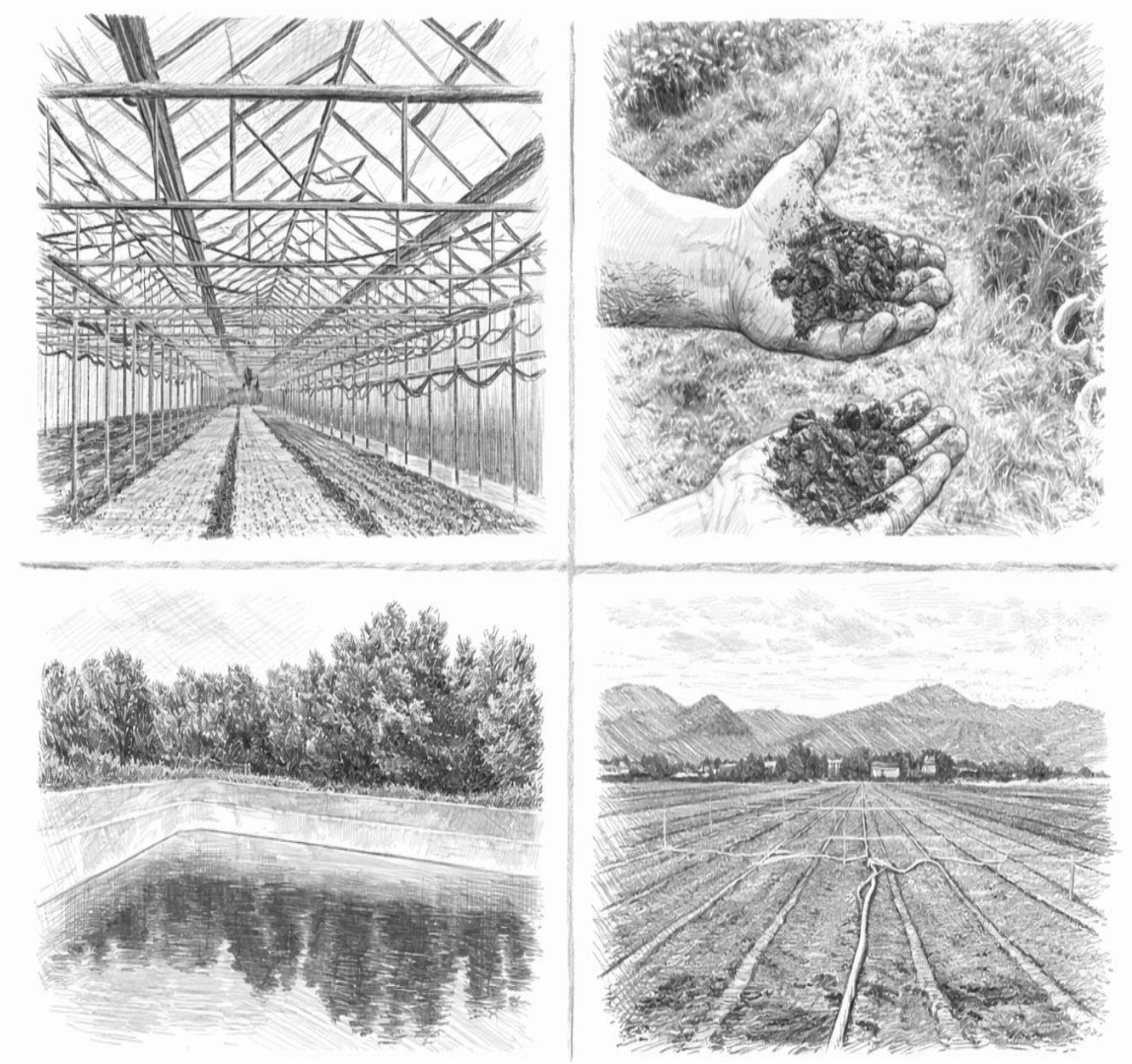


How Uncertainty Shapes Climate (In)action: Behavioral Dynamics of Farmers' Adaptation Decisions

Christine Heinzel and Britta Höllermann
Osnabrück University, Germany

cheinzel@uni-osnabrueck.de

05 May 2026

Abstract

Sharing not permitted

Research Setting

PROBLEM

Behavioral responses to **uncertainties** remain poorly understood.

CASE STUDY AREA

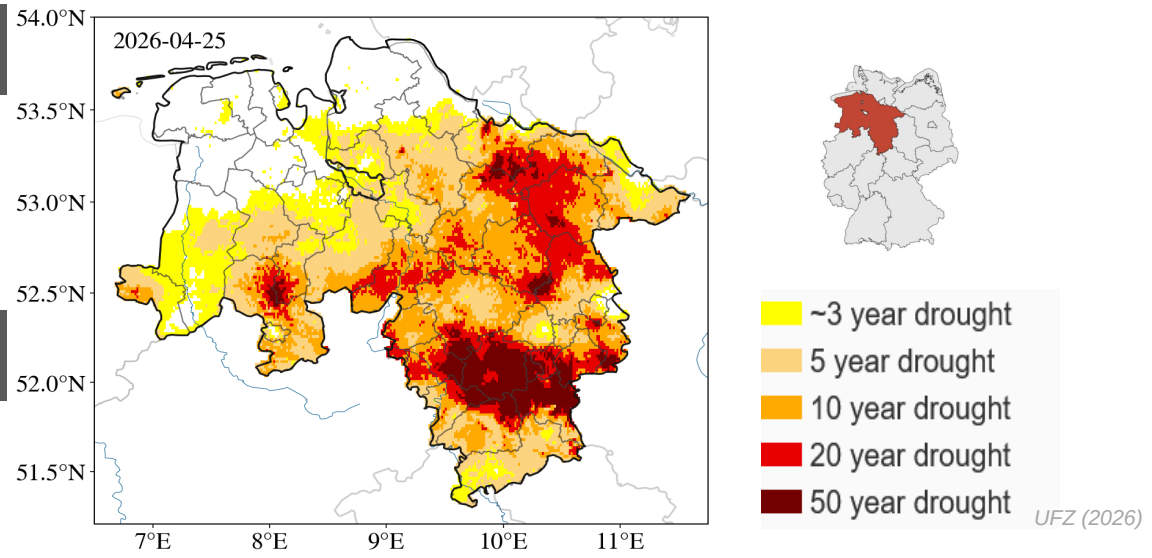
Lower Saxony, Germany.

RESEARCH QUESTION

How do **farmers** perceive and interpret **uncertainties**, evaluate their response options, and develop strategies for **adaptive behavior**?

METHODS

Development of a **novel framework,** combining **uncertainty research** with a **behavioral model.**



UFZ (2026)

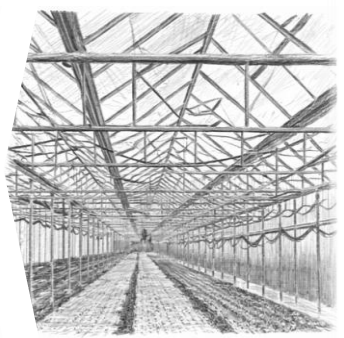


NLWKN (2025)

Key Results

What SHAPES uncertainty perception?

Forecast use and **drought experience** are associated with **higher perceived uncertainty**.



Decision competences and positive **attitudes** are linked with **lower perceived uncertainty**.



Uncertainty perception SHAPES behavior!



Perceived uncertainties are linked to more **passive behavior**.



Lower process uncertainty is associated with more **active responses**.

I am looking forward to further exchange at **PICO spot 2.8.**

Sharing not permitted

ECO RISK

PICO Navigation

Click for detailed information

Go back and forth

Go back to main menu

For more information, please contact **cheinzel@uni-osnabrueck.de**

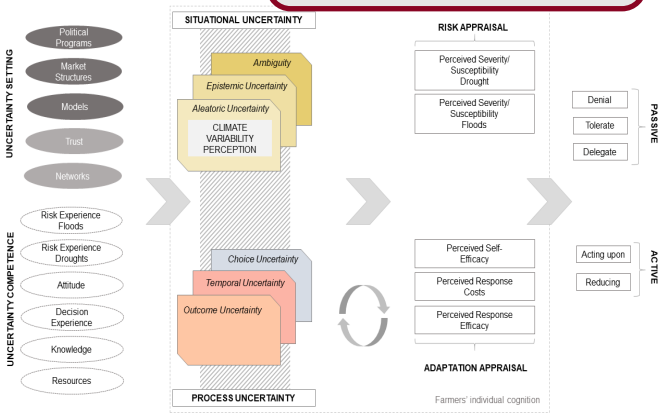




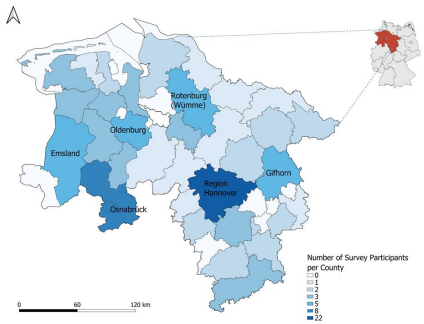
Main Menu

Study Area

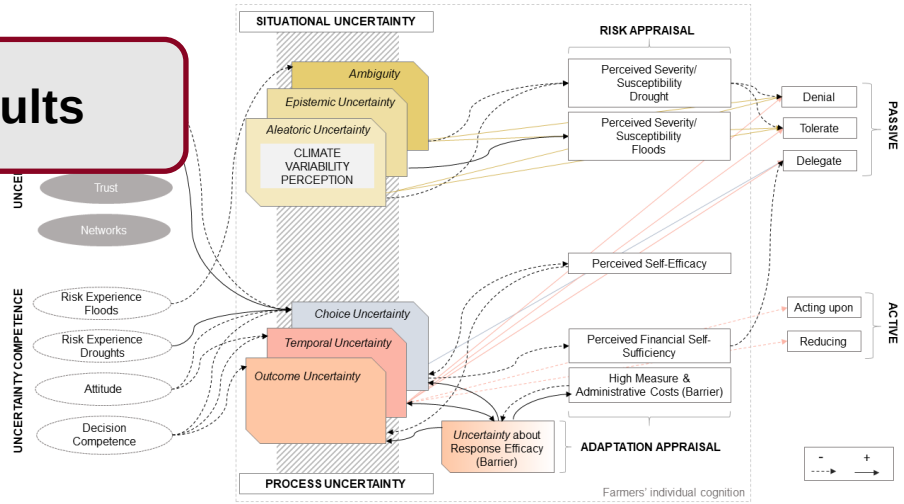
Theoretical Framework



Data Collection and Analysis



Results



Practical Implications

Case Study Area 1/3

Sharing not permitted

Lower Saxony and its Agriculture



Lower Saxony

- Germany's second-largest federal state
- Around **58% of the state's land area is used for agriculture**
- 2.3% of the approximately 4.1 million people in employment work in agriculture

Agriculture in Lower Saxony

- 33,320 farms with an average of 76 hectares
- **Dominated by arable farming** (1.9 million ha) and grassland (689,500 ha); High livestock densities
- **Highest share of irrigated agricultural land in Germany** (~12%)



Sources: LSN (n.d.); LSN (2023); MU (2022)

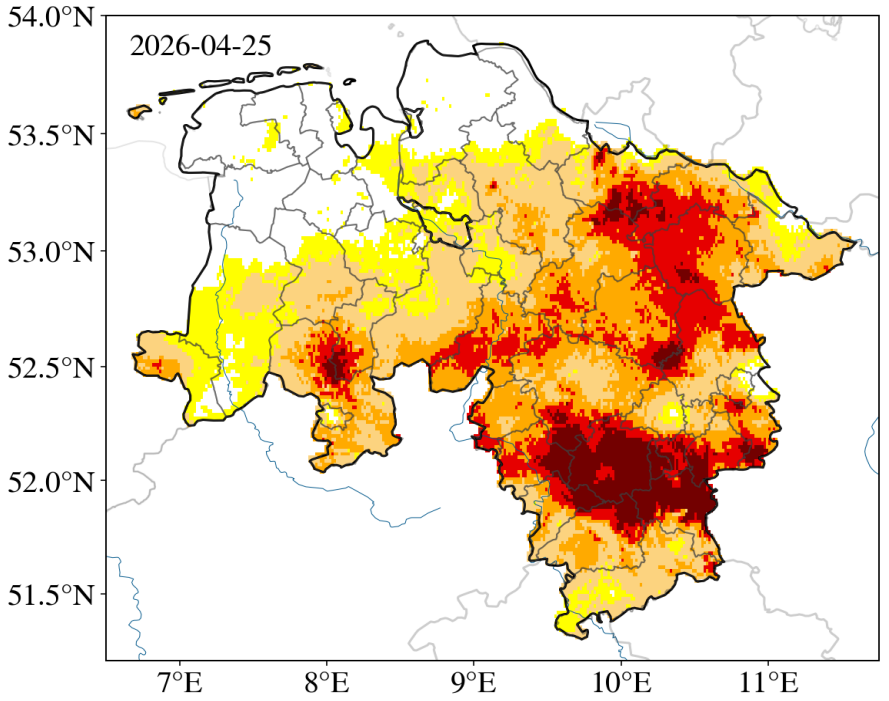
Case Study Area 2/3

Sharing not permitted

Droughts in Lower Saxony

Lower Saxony has experienced pronounced **hydro-climatic variability** in recent decades, with an increasing **occurrence** of both extreme **wet and dry conditions**.

- **Groundwater levels have declined** since the 1960s
- Risk of **more frequent and prolonged agricultural droughts** increases, with implications for crop yields, fodder availability, and farm income
- Areas with sandy soils in the northeast are especially vulnerable to drought, driving **increased irrigation needs**



German Drought Monitor April 2026, Total Soil (1.8m) (UFZ)

Sources: NLWKN (2019); Wilhite et al. (2014); Riediger et al. (2014)

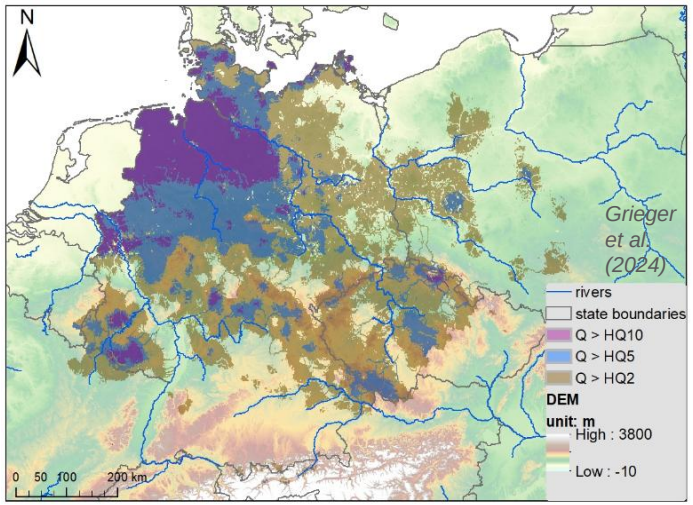
Case Study Area 3/3

Floods in Lower Saxony

Lower Saxony has experienced pronounced **hydro-climatic variability** in recent decades, with an increasing **occurrence** of both extreme **wet and dry conditions**.

- **Extreme rainfall events have intensified** since the 1960s
- Simulations indicate that **future floods are likely to become more severe**, potentially exceeding the design thresholds of flood protection infrastructure

Christmas Floods 2023/24





During the Christmas floods of winter 2023/24, severe inundation (purple areas in the left figure) affected large areas of farmland, resulting in high yield losses.

Sources: NLWKN, (2021); NLWKN (2025)

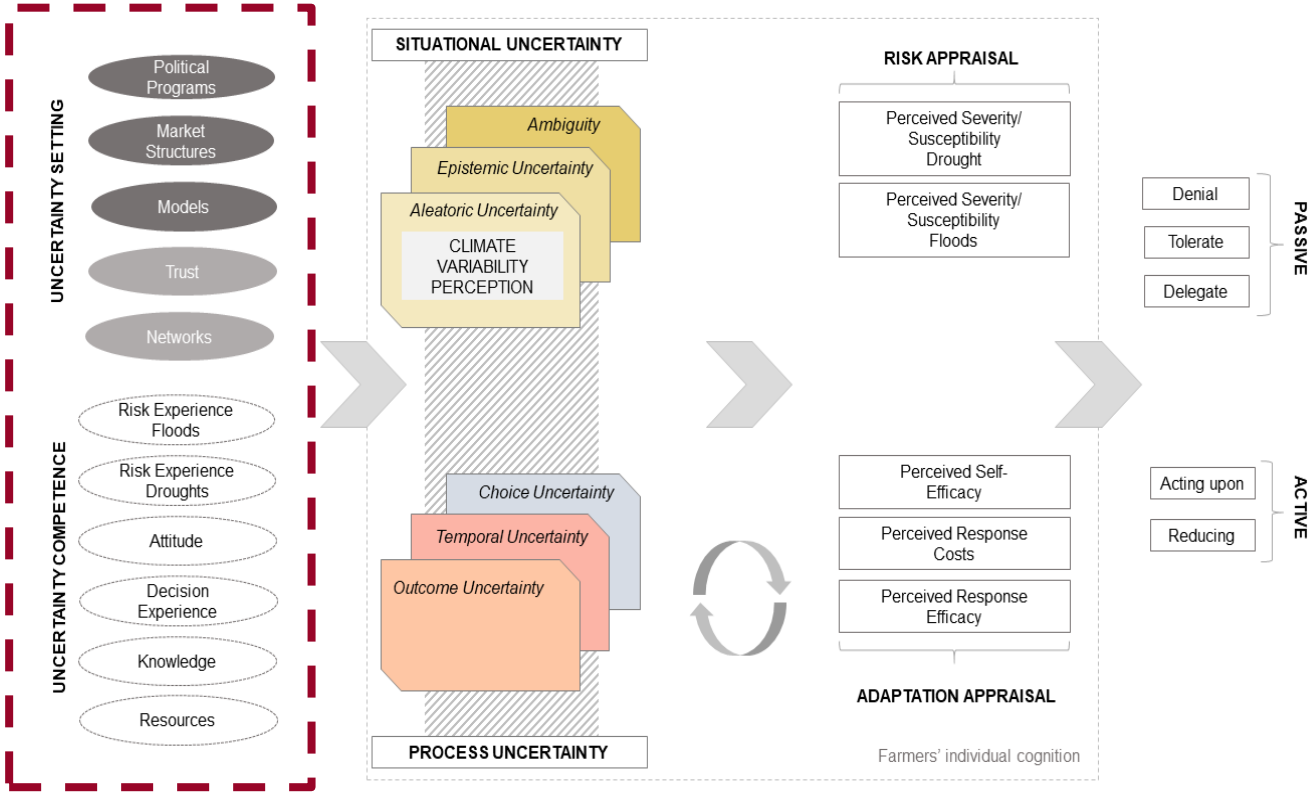
Framework 1/4

Sharing not permitted

Uncertainty Setting and Uncertainty Competences

How actors perceive and respond to uncertainty depends on:

- **Uncertainty settings:** formal governance rules and informal structures
- **Uncertainty competencies:** ability to understand and address uncertainty



Framework for Farmers' Adaptation Response under Uncertainty Perception (Heinzel & Höllermann, in submission).

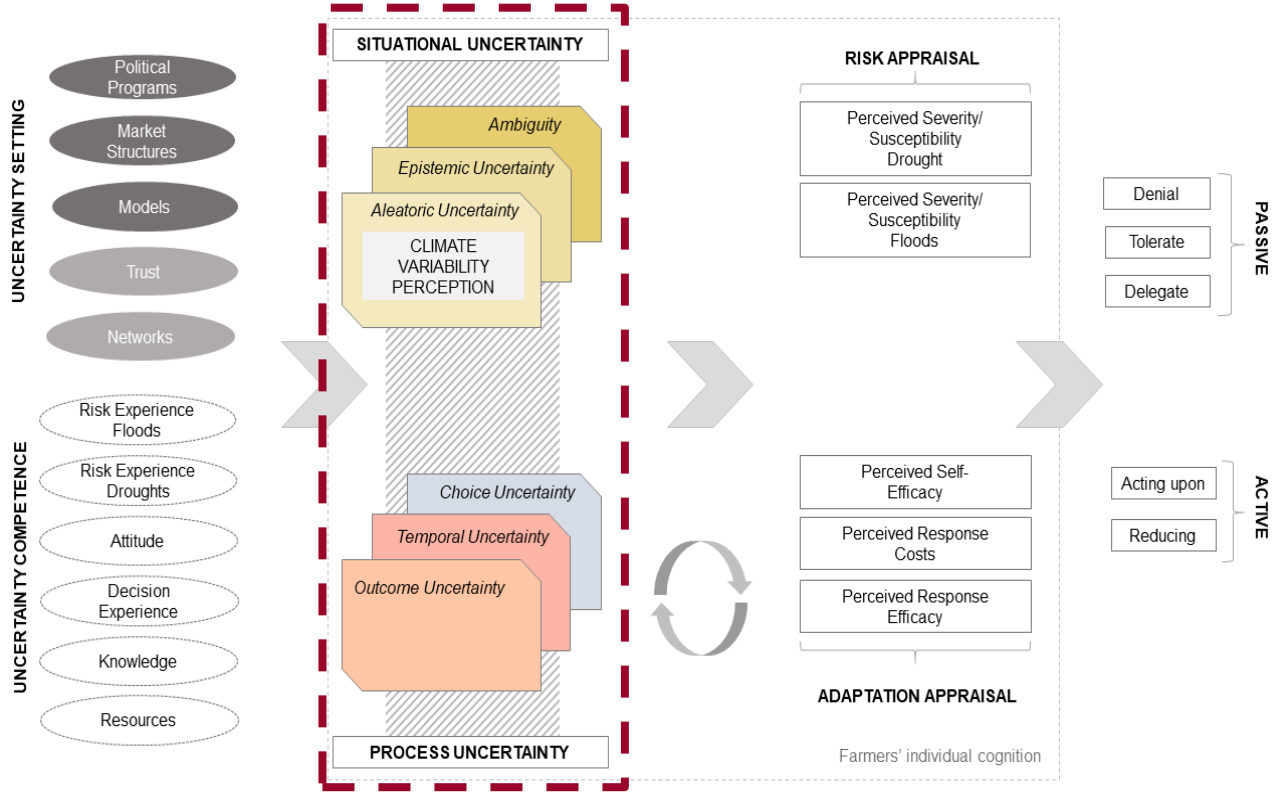
Sources: Akse (2024); Dewulf & Biesbroek (2018); Ayres (2017); Sorvali et al. (2021)

Framework 2/4

Uncertainty Perception

Actors can perceive situational and process uncertainties:

- **Situational uncertainty:** aleatoric (random variability), epistemic (knowledge gaps), and ambiguity (conflicting interpretations)
- **Process uncertainty**: what to do (choice), what will happen (outcome), and when to act (temporal)



Framework for Farmers' Adaptation Response under Uncertainty Perception (Heinzel & Höllermann, in submission).

Sources: Lipshitz & Strauss (1997), Moure et al. (2023); Hüllermeier & Waegeman (2021); Singh et al. (2020); Bevan (2022); Luce & Raiffa (1957)

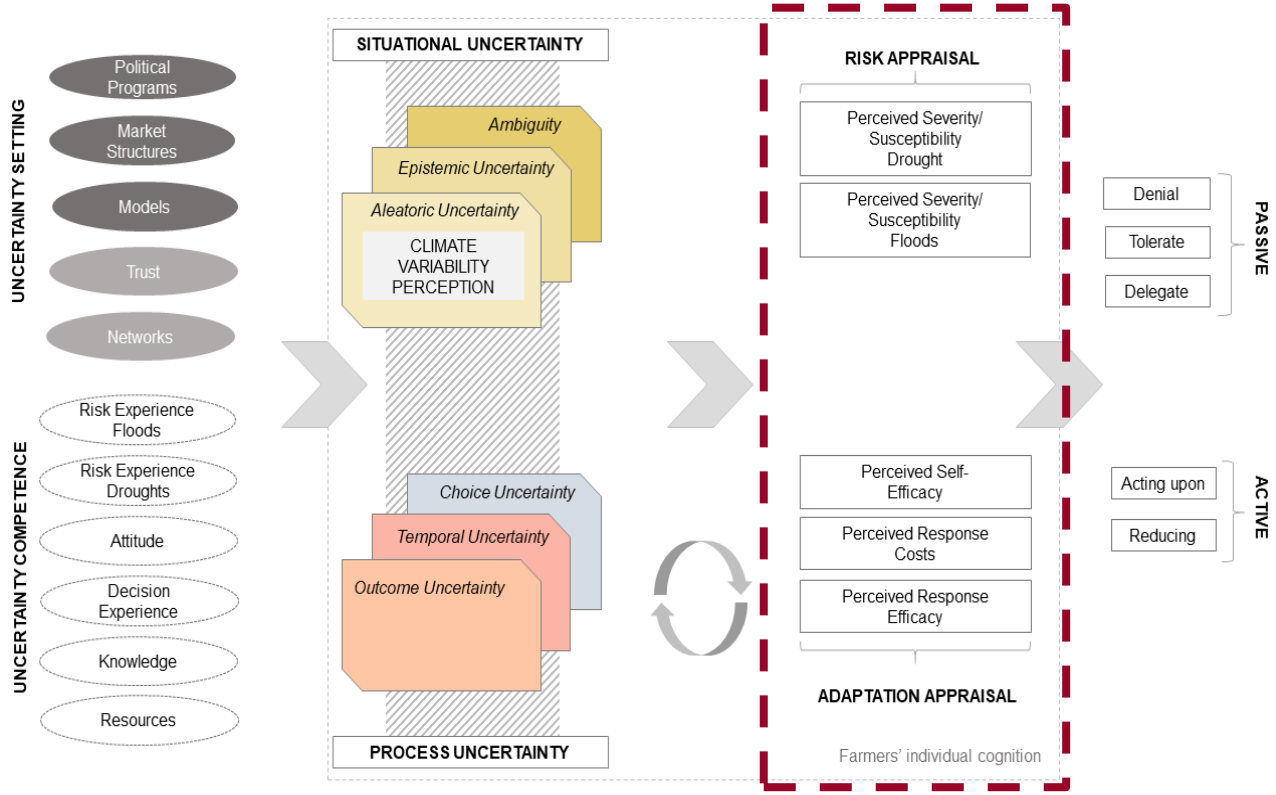
Framework 3/4

Sharing not permitted

Perceptual and Cognitive Processes for Climate Change Adaptation

Uncertainty perception is underrepresented in behavioral models; integrating it with the Protection Motivation Theory (PMT) helps explain responses

- The **Model of Private Proactive Adaptation to Climate Change** (MPPACC) builds on PMT by adding contextual factors
- Two key processes: **risk appraisal** and **adaptation appraisal**
- High appraisals can lead to adaptive behavior; low appraisals can result in maladaptation



Framework for Farmers' Adaptation Response under Uncertainty Perception (Heinzel & Höllermann, in submission).

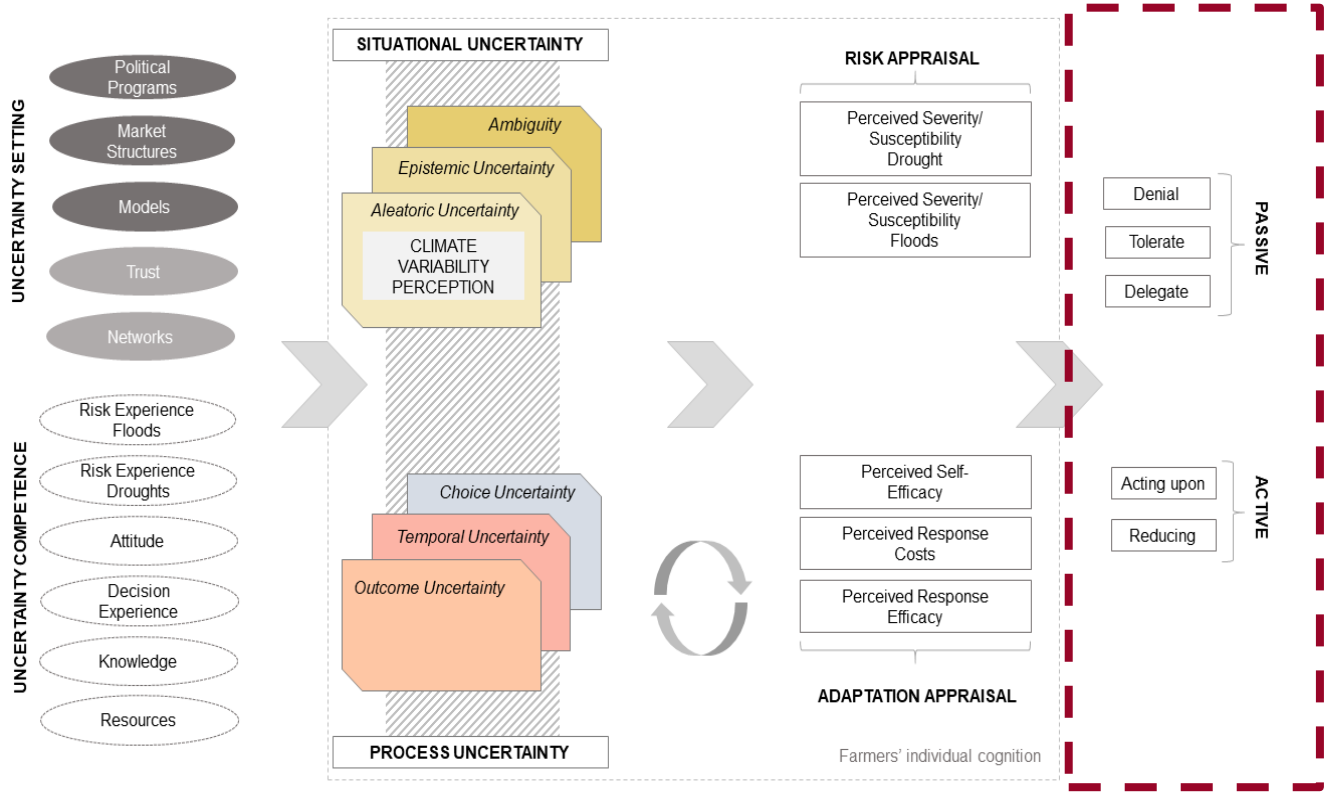
Sources: Höllermann & Heidenreich (2025); Grothmann & Patt (2005); Kothe et al. (2019); Villamor et al. (2023); Zobeidi et al. (2022)

Framework 4/4

Sharing not permitted

Passive and Active Response to Uncertainty

- **Passive responses:** denial (ignoring uncertainty), tolerance (accepting it), and delegation (shifting responsibility)
- **Active responses:** acting upon uncertainty (taking precautionary, flexible measures) and reducing uncertainty (seeking information)



Framework for Farmers' Adaptation Response under Uncertainty Perception (Heinzel & Höllermann, in submission).

Sources: Moure et al. (2023); Van 't Klooster & Veenman (2021)

Data Collection and Analysis

Sharing not permitted

Data Collection

GOAL: to test the applicability of the framework for understanding farmers' decision-making and responses to uncertainties arising from extreme weather events.

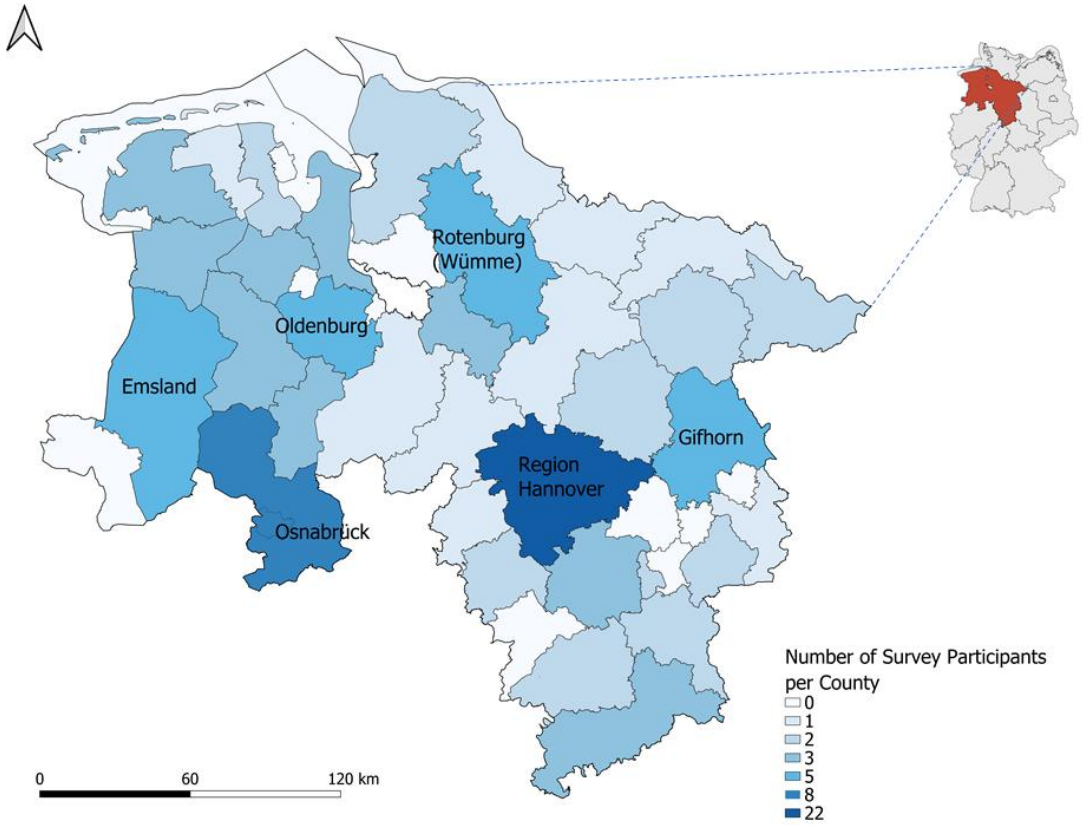
- Online survey (Feb-Mar 2025) of **farmers in Lower Saxony, Germany**, distributed via regional networks, farmers' associations, direct e-mail invitations and snowball sampling
- **102 responses** analyzed

Data Analysis

- **Descriptive analysis** was conducted to characterize the distribution of variables
- Reliability tests (Cronbach's $\alpha > 0.5$) were used to refine variables and prevent multicollinearity
- **Multiple linear regressions** (with bootstrapping, 2,000 samples) and **logistic regressions** were applied

Results 1/7

Descriptive Statistics: Respondents



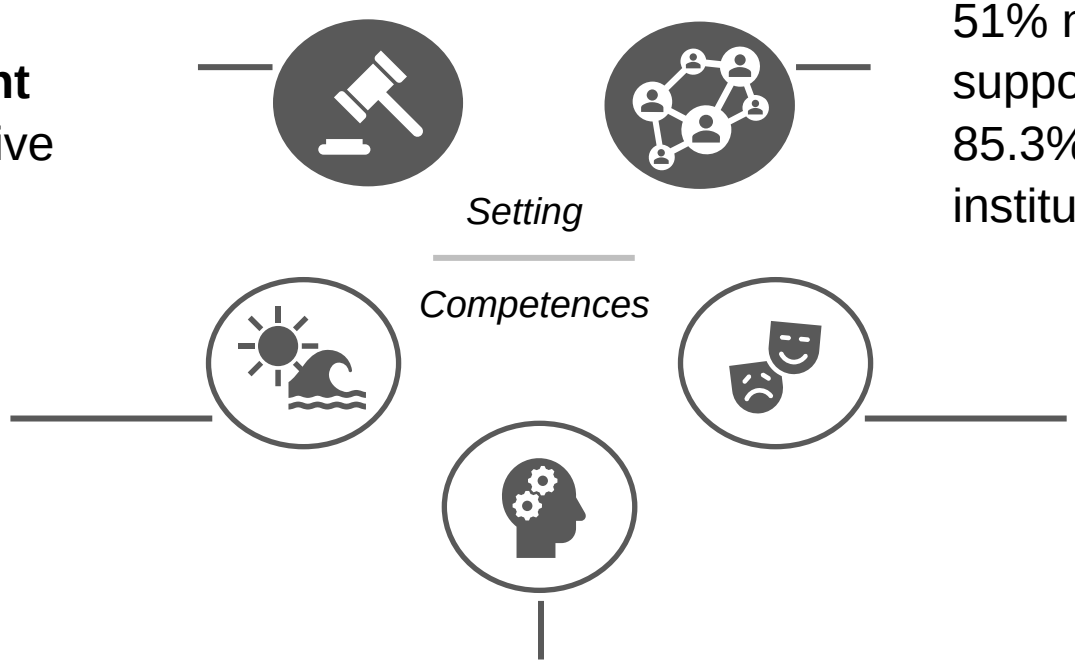
Distribution of Survey Participants in the Case Study Area.

- **Sample**: 102 farmers, mostly male (67.6%), older (majority 45+), and highly experienced in agriculture (>20 years)
- Farms were predominantly **large-scale** (39.2% with 101-200 hectares and 21.6% exceeding 200 hectares)
- Focused on **arable farming** (36.3%) and forage crop production and pasture-based livestock farming (17.6%)

Results 2/7

Descriptive Statistics: Uncertainty Setting and Competences

95.1% use **weather forecasts**; 17.6% engage with **government programs;** 12.7% with alternative **market structures**



51% never or rarely use **networks** for support in extreme weather preparation; 85.3% have (very) low **trust** in political institutions

96.1% experienced **drought;** 65.7% experienced **flooding** (in the past 5 years)

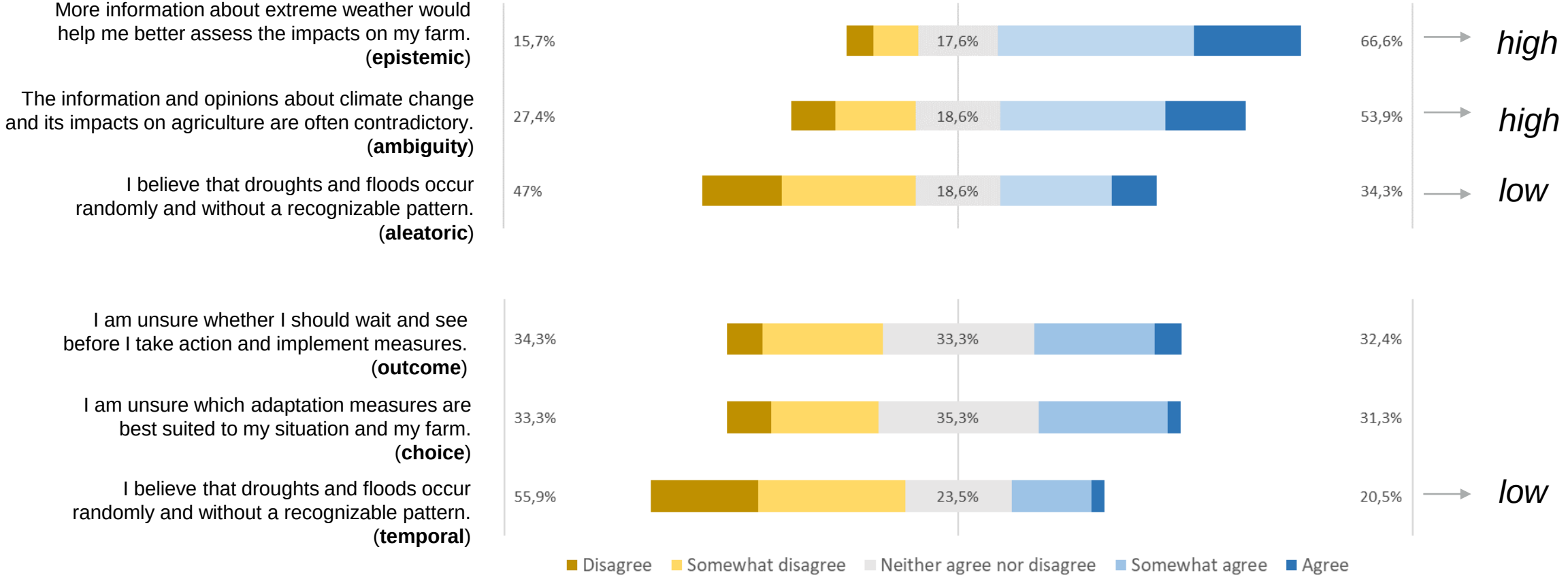
Attitudes: 58.8% view extreme weather purely as a burden; 41.4% see it as an opportunity for adaptation

Decision-making experience, **knowledge** about extreme weather events and **resource availability** were generally moderate to high

Results 3/7

Sharing not permitted

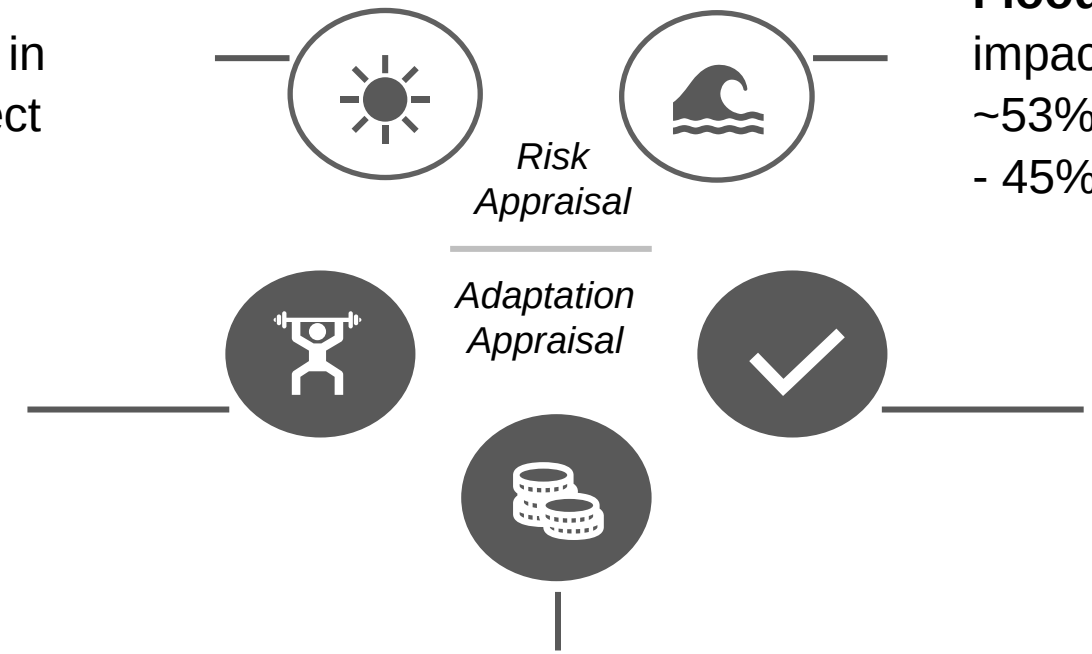
Descriptive Statistics: Uncertainty Perception



Results 4/7

Descriptive Statistics: Perceptual and Cognitive Processes for Climate Change Adaptation

Droughts: ~ 82% observed increased impacts/ frequency in the last 10 years; ~ 61% expect further worsening



Floods: ~50% observed increased impacts/ frequency, ~45% no change; ~53% - 59% expect no change/ ~40% - 45% expect worsening conditions

Self-efficacy: nearly evenly split, with 49.5% feeling able to take actions and 50.5% feeling unable

Response efficacy: 19.6% report doubts about the effectiveness of adaptation measures

Response costs: 43.1% can bear most costs, 56.9% rely at least partly on external support; 75.5% identify high costs/ administrative burdens as major obstacles

Results 5/7

Sharing not permitted

Descriptive Statistics: Passive and Active Response to Uncertainty

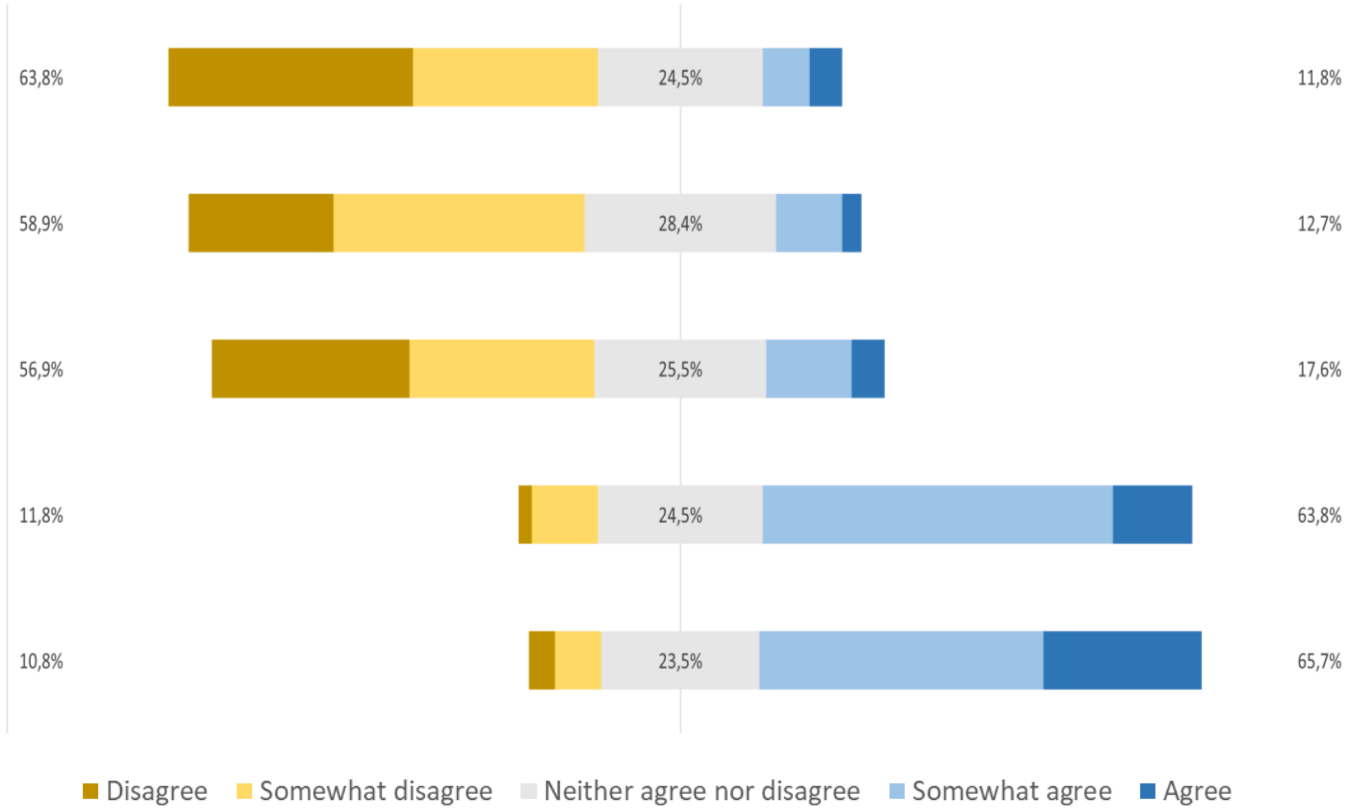
Current and future climatic changes don't cause me any uncertainty - I don't have to react to them. (Passive response - **denial**)

Extreme weather is part of farming, I don't take any special measures. (Passive response - **tolerance**)

I expect support measures to help me prepare for extreme weather - I don't see that as my job. (Passive response - **delegation**)

I prepare my farm for climate risks with flexible and versatile measures. (Active response - **acting upon**)

I obtain information (e.g. from weather forecasting platforms) to reduce possible uncertainties caused by extreme climatic events. (Active response - **reducing**)

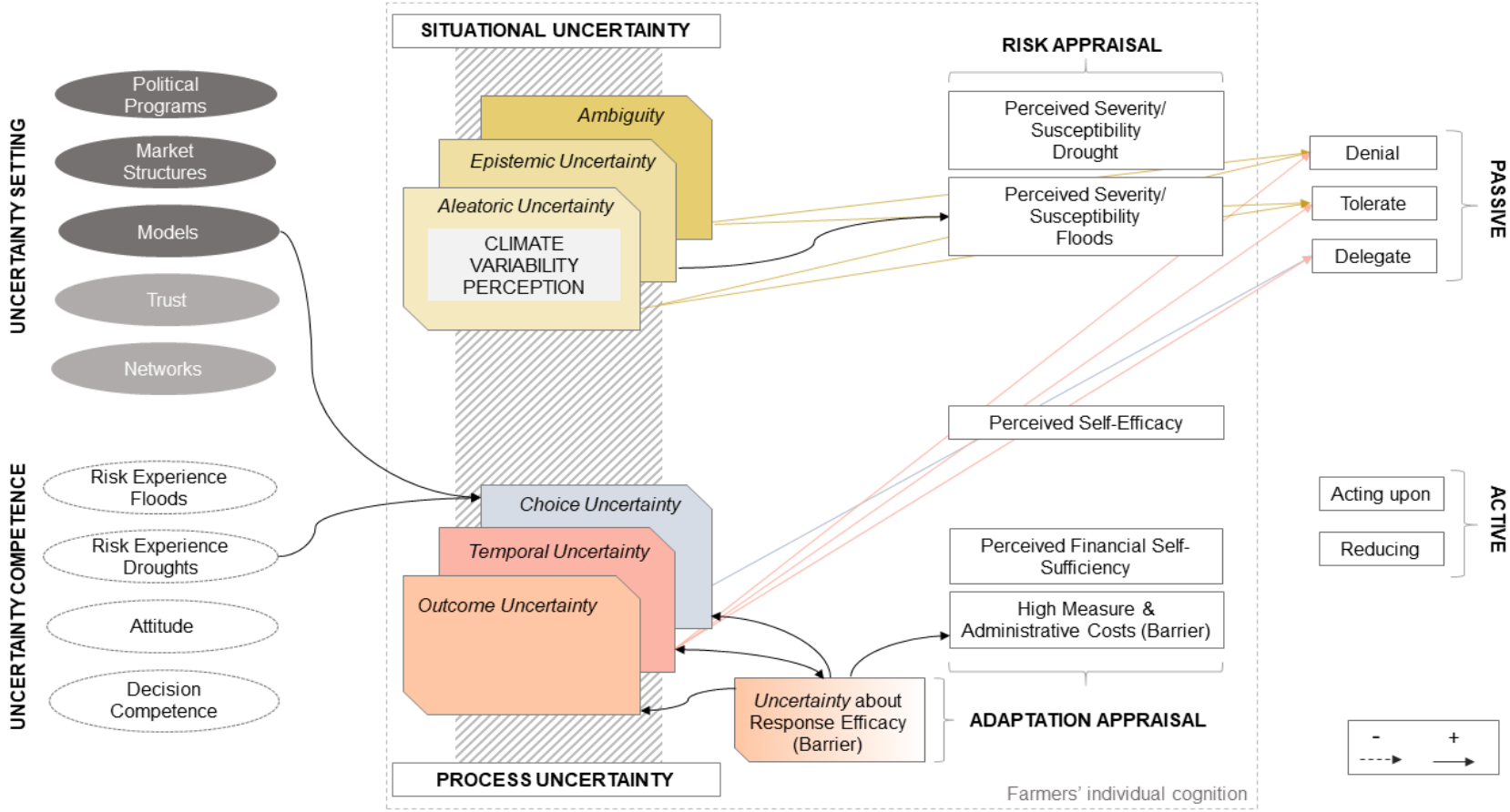


~ Two-thirds of the respondents indicate active response by agreeing to statements 4 and 5, and disagreeing on statements 1-3

Results 6/7

Regression Results – Positive Associations

Questioning the role of models and past experience

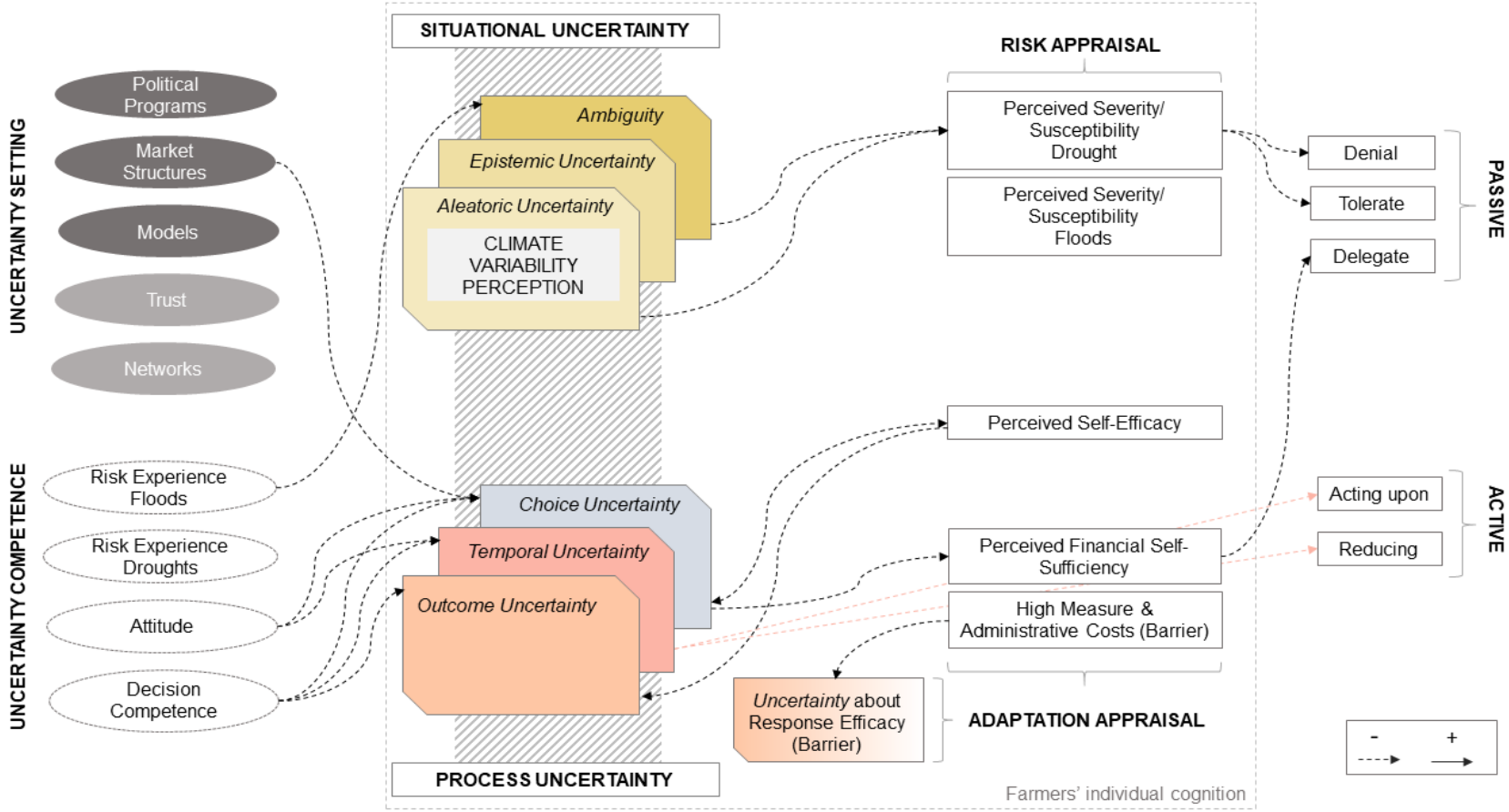


Uncertainty perception shapes climate inaction patterns

Continuous arrows represent positive associations; arrow colors differ only to increase readability (Heinzel & Höllermann, in submission).

Results 6/7

Regression Results – Negative Associations



Leverage points: Attitude and competences

Temporal uncertainty is linked to active responses

Dotted arrows represent negative associations; arrow colors differ only to increase readability (Heinzel & Höllermann, in submission).

Practical implications

Strengthening farmers' decision competence (knowledge, experience, resources) through capacity-building efforts can reduce uncertainty.

Decision-support tools can help clarify adaptation options, timing, and outcomes.

Improving uncertainty communication and clearer narratives can reduce ambiguity; **building trust** in institutions can increase farmers' openness to climate information.

Supporting farmers in cultivating more constructive **mindsets** may reduce the demotivating effects of uncertainty, with **communication strategies emphasizing manageable actions.**

Sources: Silici et al. (2021); Wenkel et al. (2013); Cooke (2015); Cologna & Siegrist (2020); O'Callaghan et al (2025)