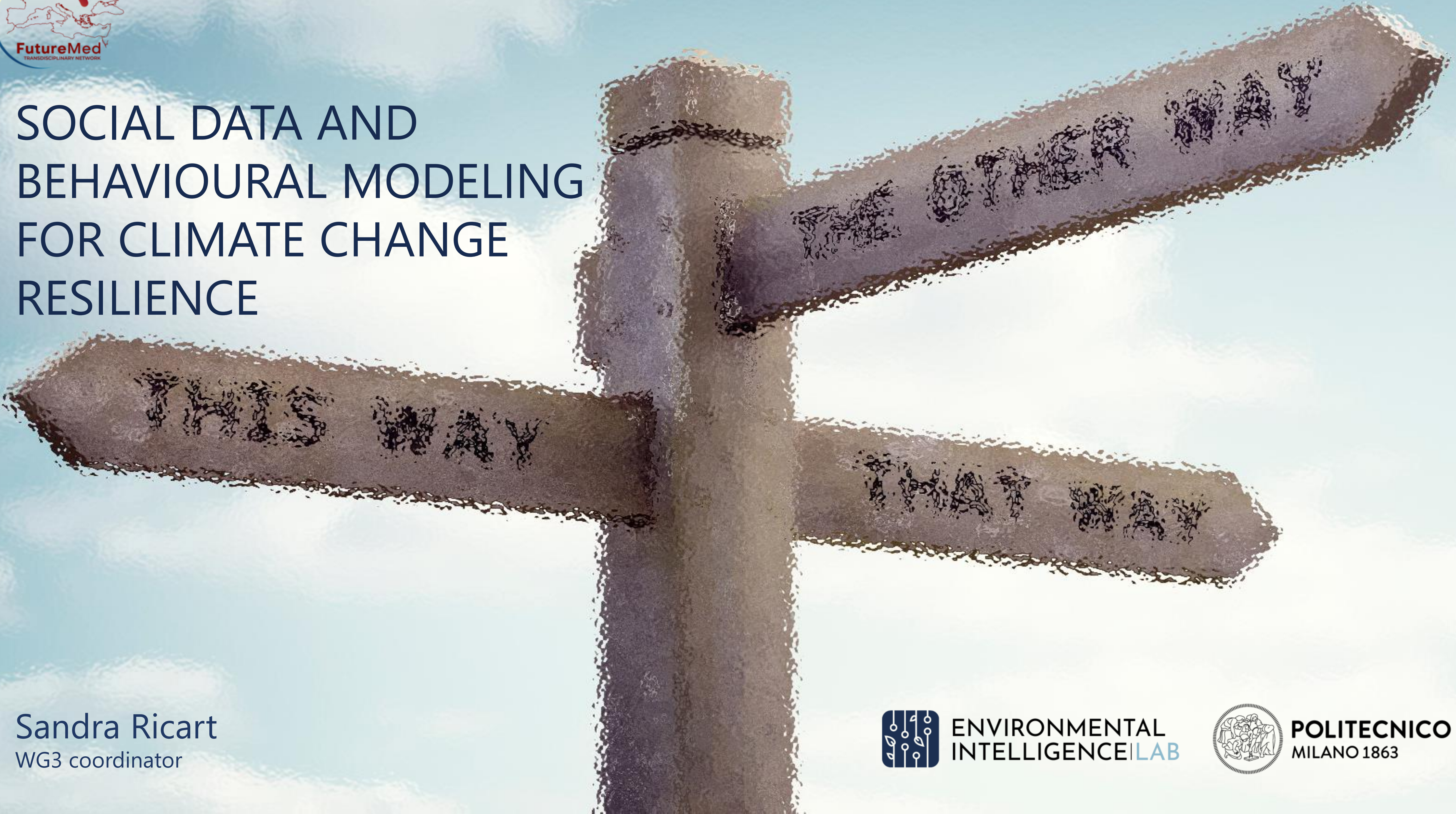
SOCIAL DATA AND BEHAVIOURAL MODELING FOR CLIMATE CHANGE RESILIENCE



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ENVIRONMENTAL INTELLIGENCE LAB

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ROADMAP

Social Data

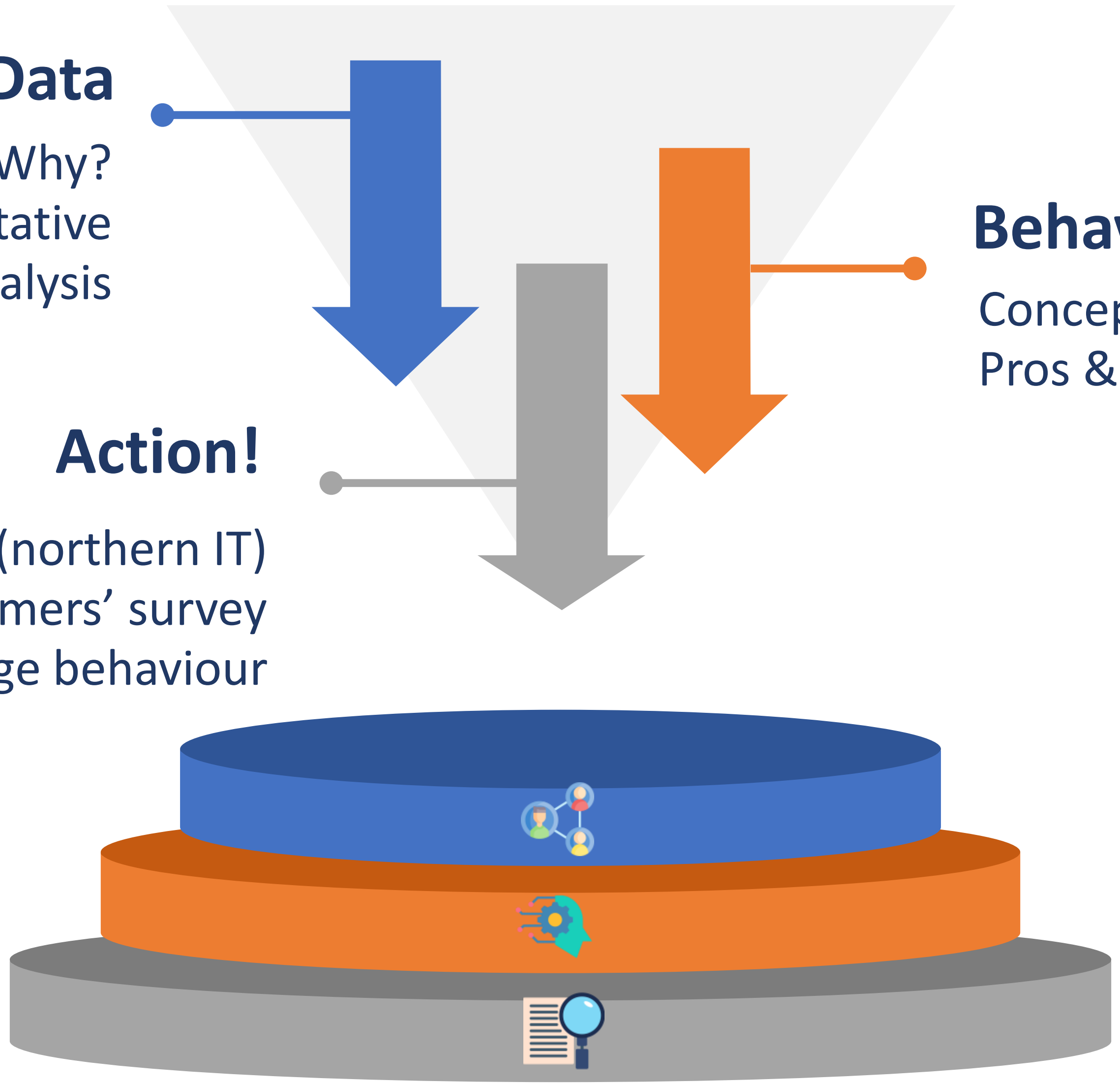
Why?
Qualitative vs Quantitative
Data Sources & Analysis

Behaviour modelling

Concept
Pros & Cons

Action!

Adda river (northern IT)
Farmers’ survey
Climate change behaviour

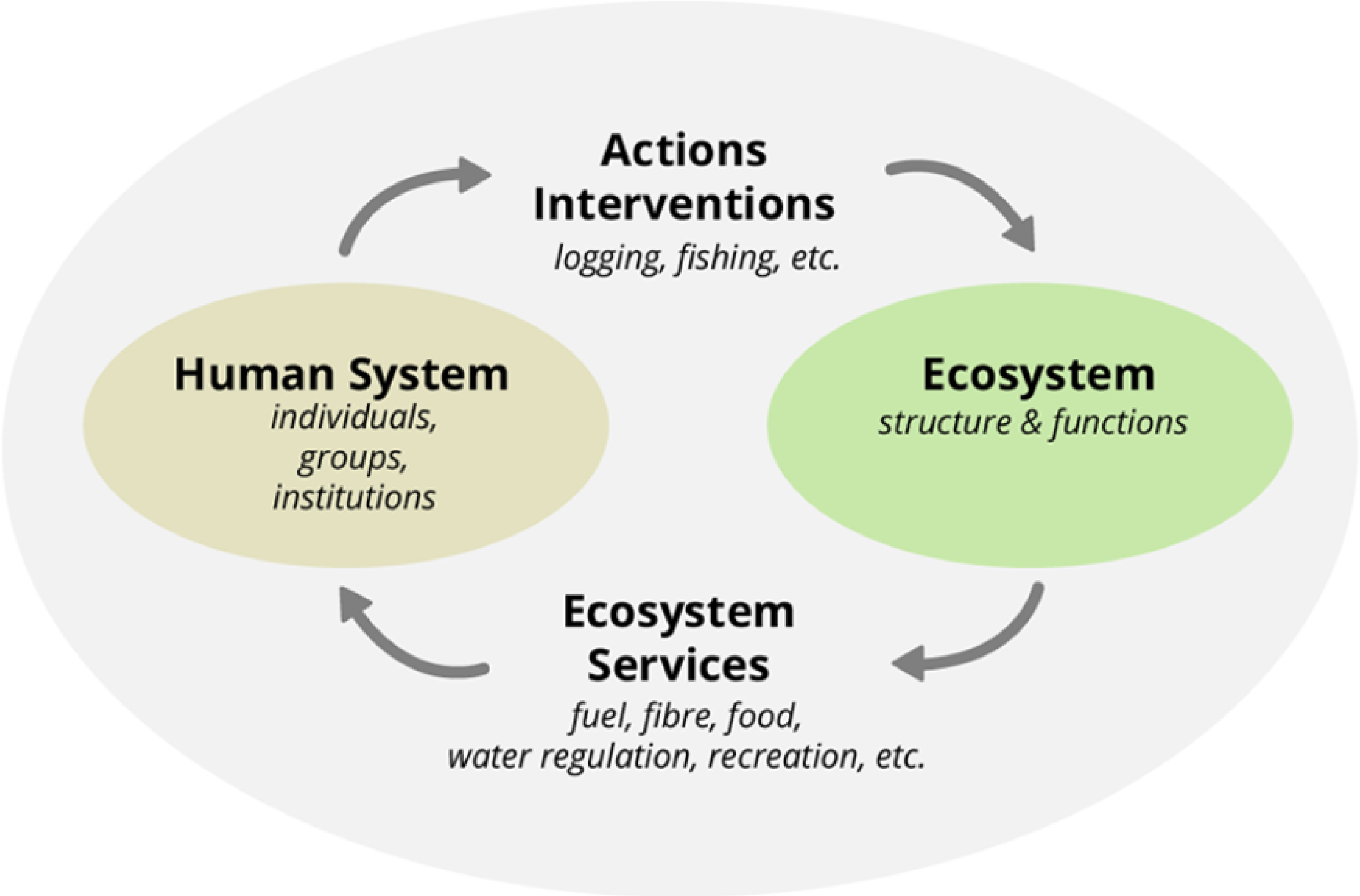


Social Data

Socio-Ecological Systems

Sense of Place

CONTEXT – MOTIVATION

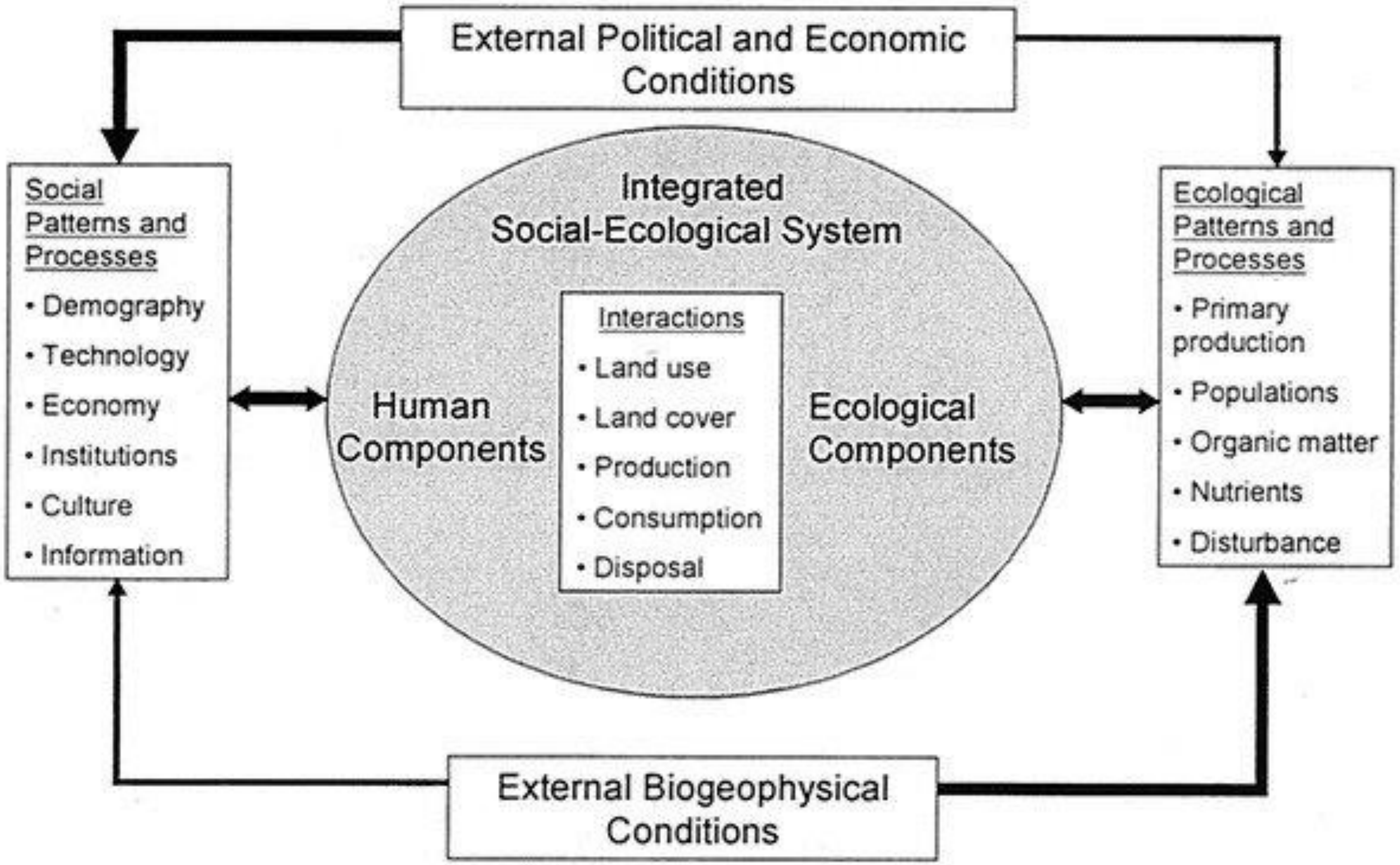


Socio-ecological systems emerge from this interaction in which its components interact and are conditioned in a dynamic and constant way.

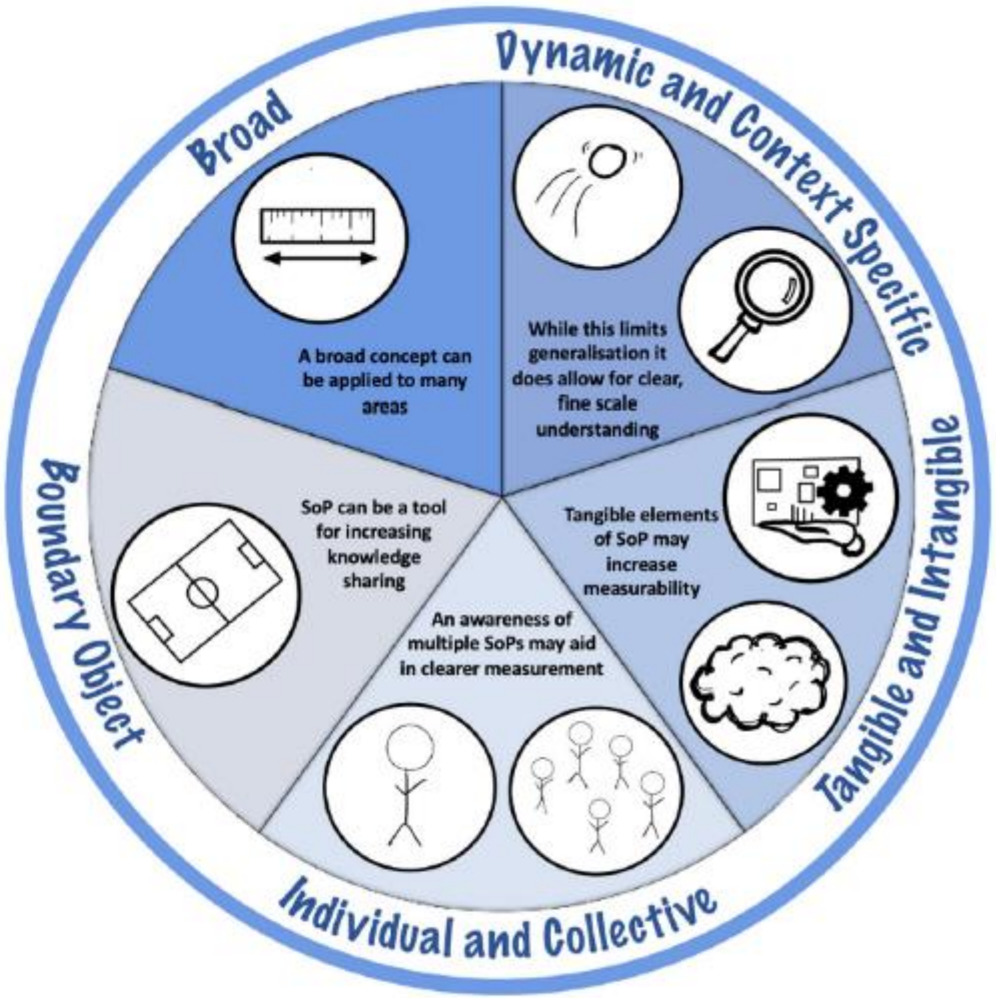
A Socio-Ecological System (SES) is:

- A system that is defined at **several spatial, temporal, and organisational scales**, which may be hierarchically linked.
- A set of **critical resources** (natural, socioeconomic, and cultural) whose flow and use is regulated by a combination of ecological and social systems.
- A perpetually dynamic, complex system with **continuous adaptation.**

CONTEXT – MOTIVATION



SENSE OF PLACE (SoP)



- It emerges from **human interactions/experience** with the environment
- It is **subjective**, but its components vary systematically
- Types of **behaviour may be predicted** by patterned relationships with place

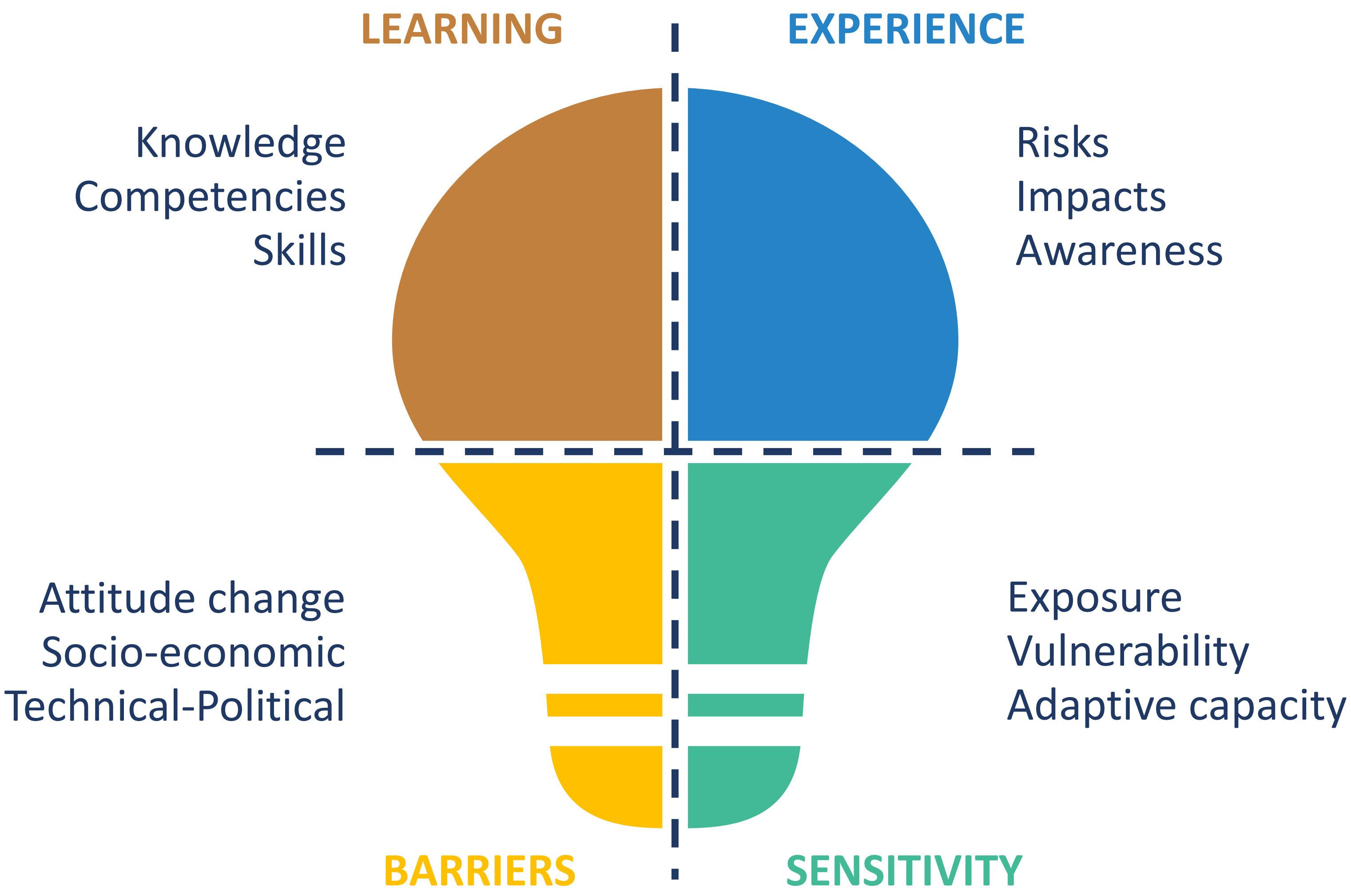
An individuals' SoP can impact how they interact with a SES (e.g. leading to **pro-environmental behaviour or increased resilience** against environmental change)

SoP has many **overlapping and oftentimes contrasting conceptualisations**

While at first appearing challenging, if approached in a considered way, it ultimately makes **SoP a valuable and eminently useable phenomena**

Sense of place has been shown to be a key factor in adaptation to ecosystem changes and transformations, as well as playing an important role in people's motivation to act on behalf of local environments

SENSE OF PLACE (SoP)



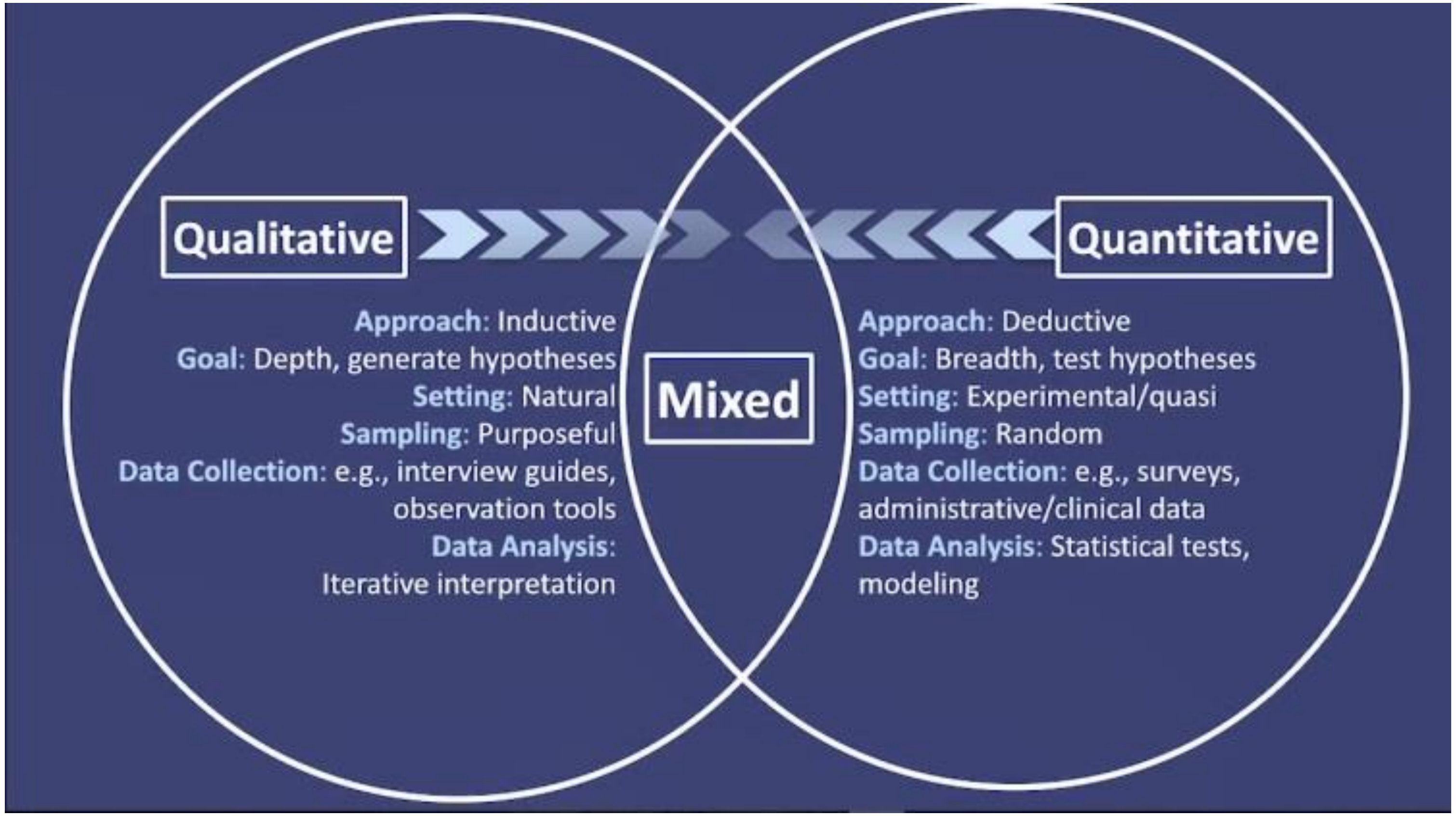
WHAT ABOUT SOCIAL DATA?

- **Why?** It can:
- uncover hidden drivers and connectors
- reveal unintended consequences, and
- generate contextualised and actionable knowledge
- **How?** It moves through:
- lived experiences, perceptions, values
- behaviours of individuals and communities conditioned or responsible of managing natural resources and SES in a changing climate

WHAT ABOUT SOCIAL DATA?

- Social/Qualitative data refers to **non-numerical information** that approximates and characterizes social systems (individuals, collectives, stakeholders).
- It can be **observed, recorded, and transcribed** for further analysis.
- It aims **to understand the social reality** of individuals, groups, and cultures **as nearly as possible as participants feel or live it.** Thus, people and groups are studied in their natural setting.
- The emphasis in qualitative analysis is **'sense making'** or **deep-understanding** a phenomenon, rather than predicting or explaining.

QUALITATIVE – QUANTITATIVE RESEARCH



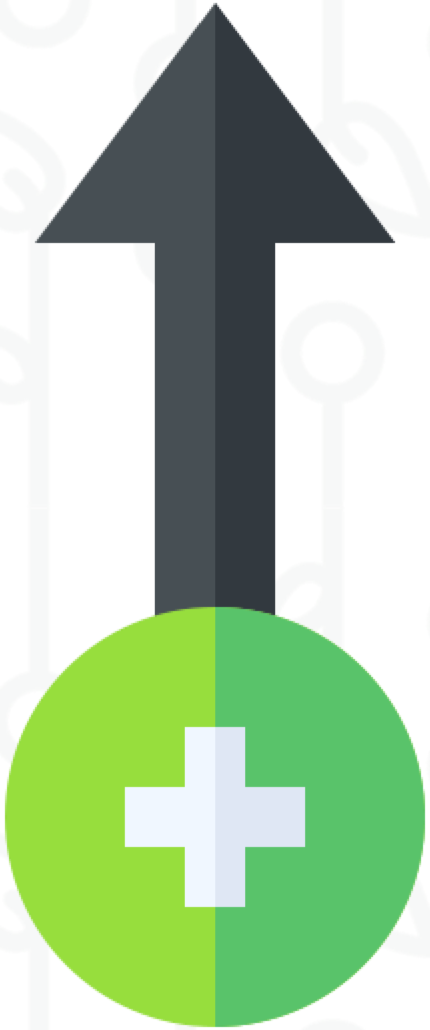
PROS

1. Provides an in-depth understanding
Explore issues that are more difficult to quantify, such as attitudes, behaviours, and opinions. Is like the “**behind-the-scenes**” information that helps us understand complex things better

2. Uncovers unexpected findings
To understand the meaning behind the numbers or to discover things that might not be apparent in the numbers or statistics

3. Captures heterogeneity and confronted viewpoints
Individuals have unique interactions with the (socio)environment that cannot be fully captured through objective measures alone

4. Complement quantitative data
It can provide context and motivation for quantitative data



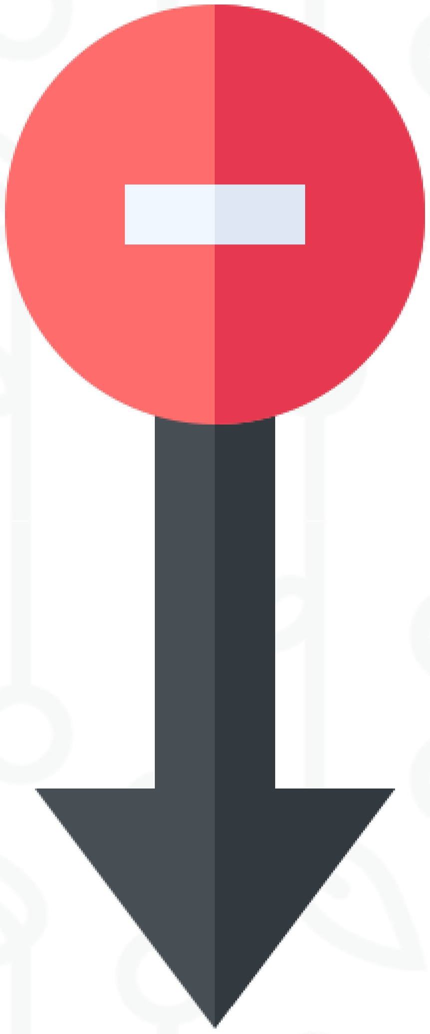
CONS

1. Time-consuming and labour-intensive
For collecting data and observation

2. Challenging data analysis
To make sense of what is not necessarily quantifiable, and figure out what individuals mean by certain words or interpreting speeches based on everyday language

3. The subjectivity of data
Data is subjective by nature; two people might interpret the same thing differently based on their own experiences and backgrounds

4. The validity/reliability of data
Both concepts are essential and related to the credibility, trustworthiness, and consistency of the data and findings, but conventional (quantitative) methods are not applicable



WHEN TO USE SOCIAL DATA?

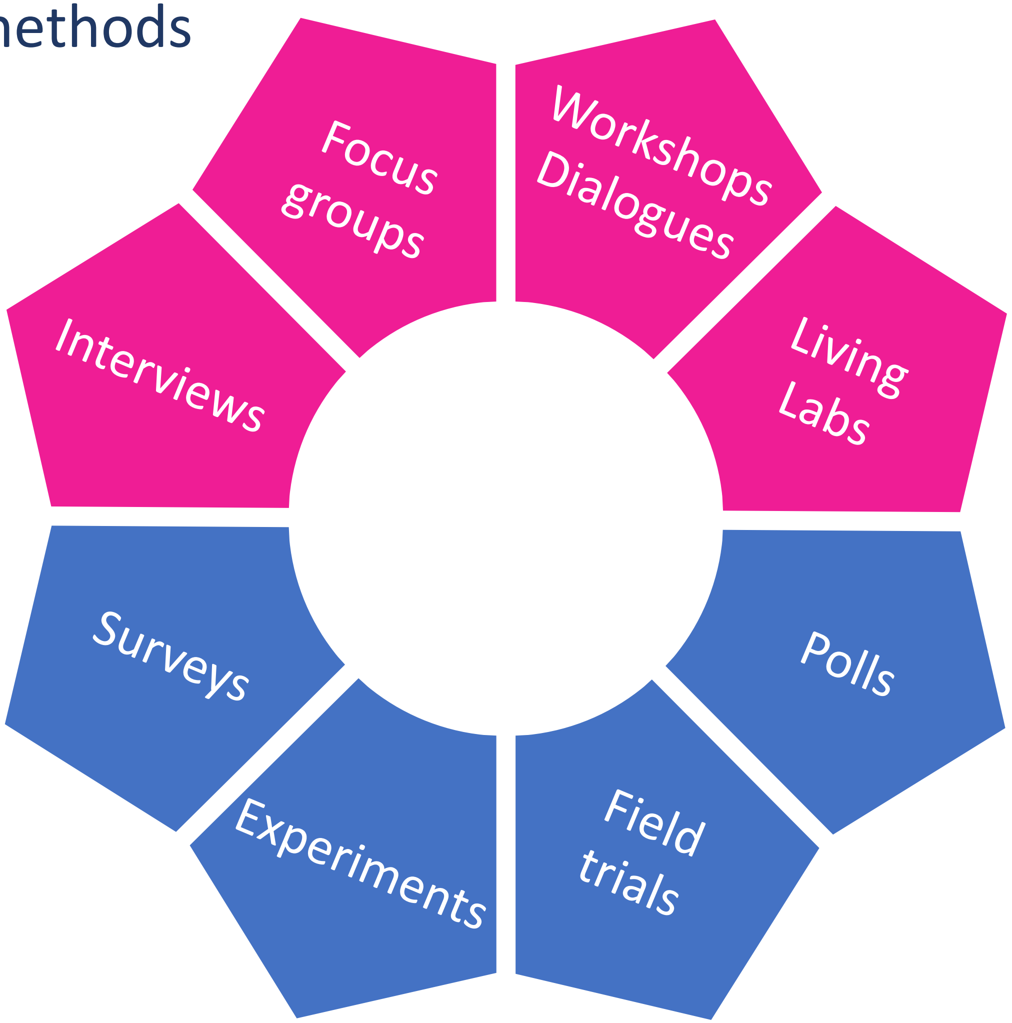
- When nature of a problem cannot be understood by an objective, distant approach: **you need to 'get close' to the reality/participants**
- When **little is known or understood** about the topic
- When complex processes of **interaction** are to be understood
- When the topic seems to be **socially constructed** and knowledge is not neutral

DATA SOURCES

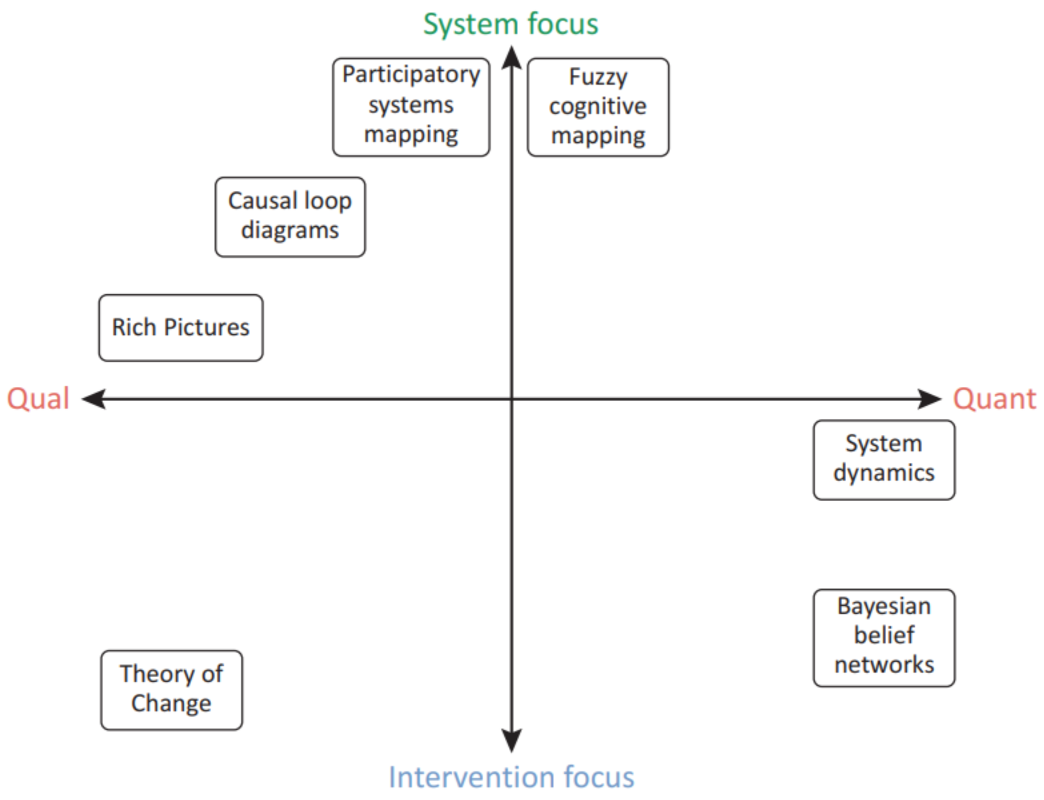
Collected first-hand by researcher	SOURCE	Collected by others
Specific to current research	PURPOSE	May have different original purpose

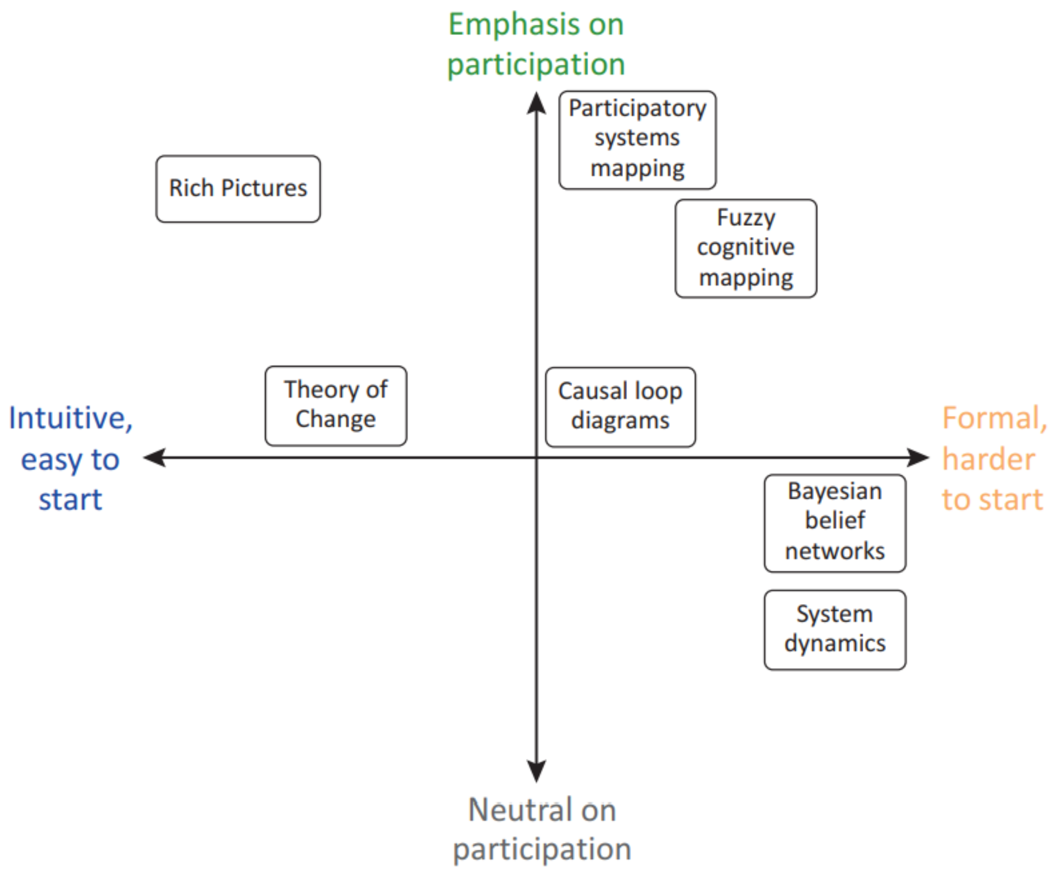
DATA SOURCES

Main collection methods



DATA ANALYSIS





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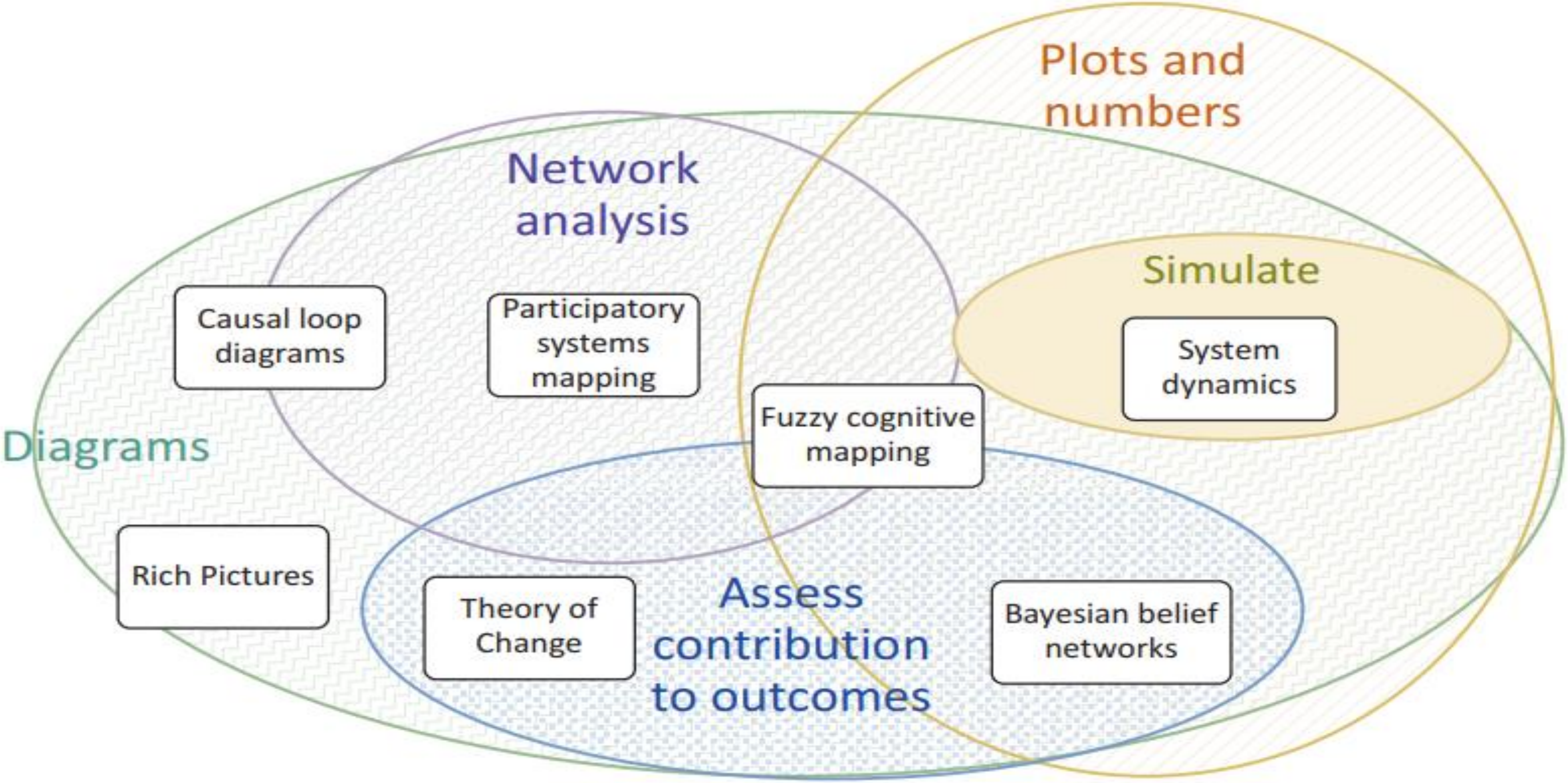


Behaviour Modelling

Decision-Making processes

Agent-Based Models

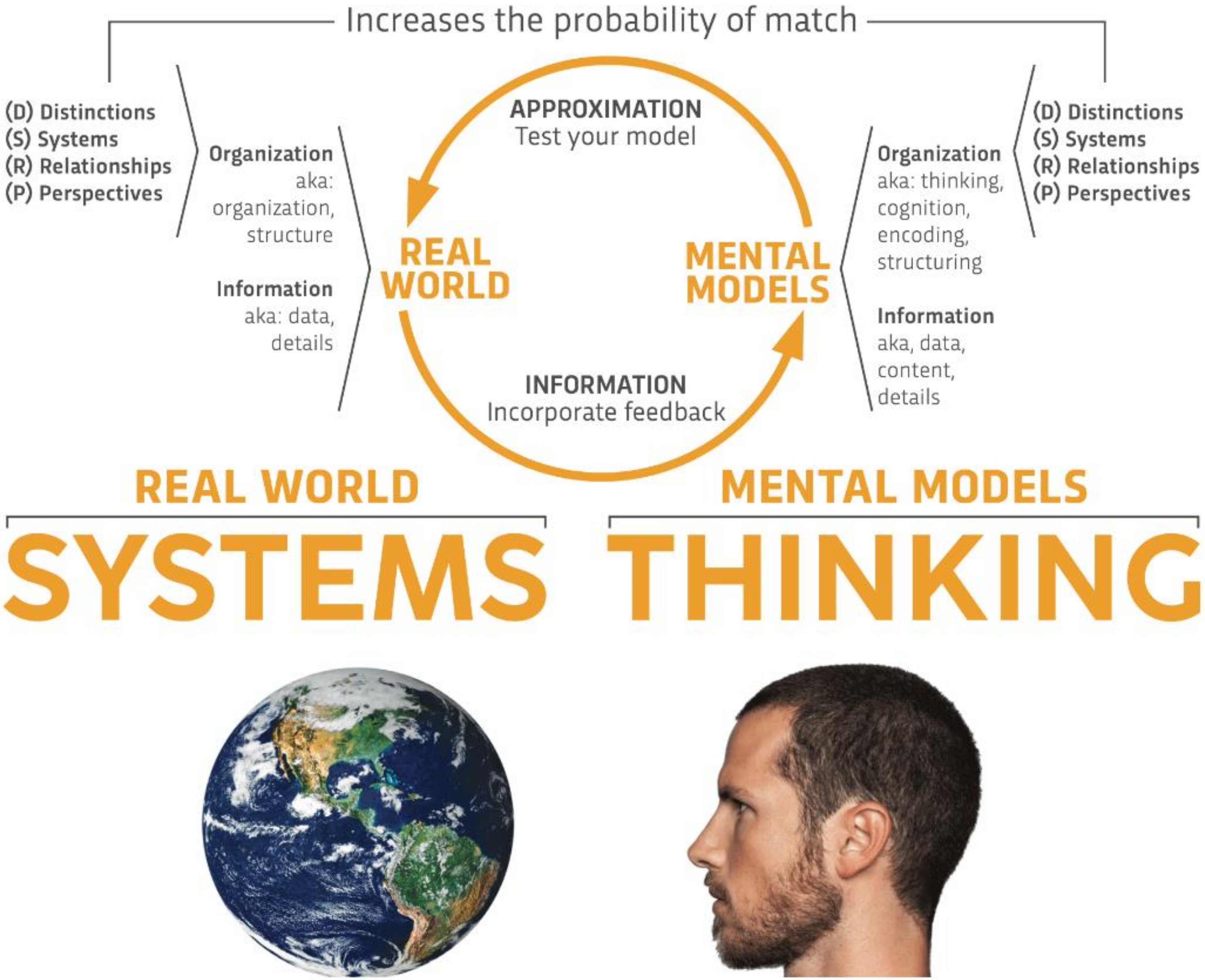
MOTIVATION

- Behavioural modelling attempts **to explain why an individual makes a decision** and how to **predict future behaviour.**

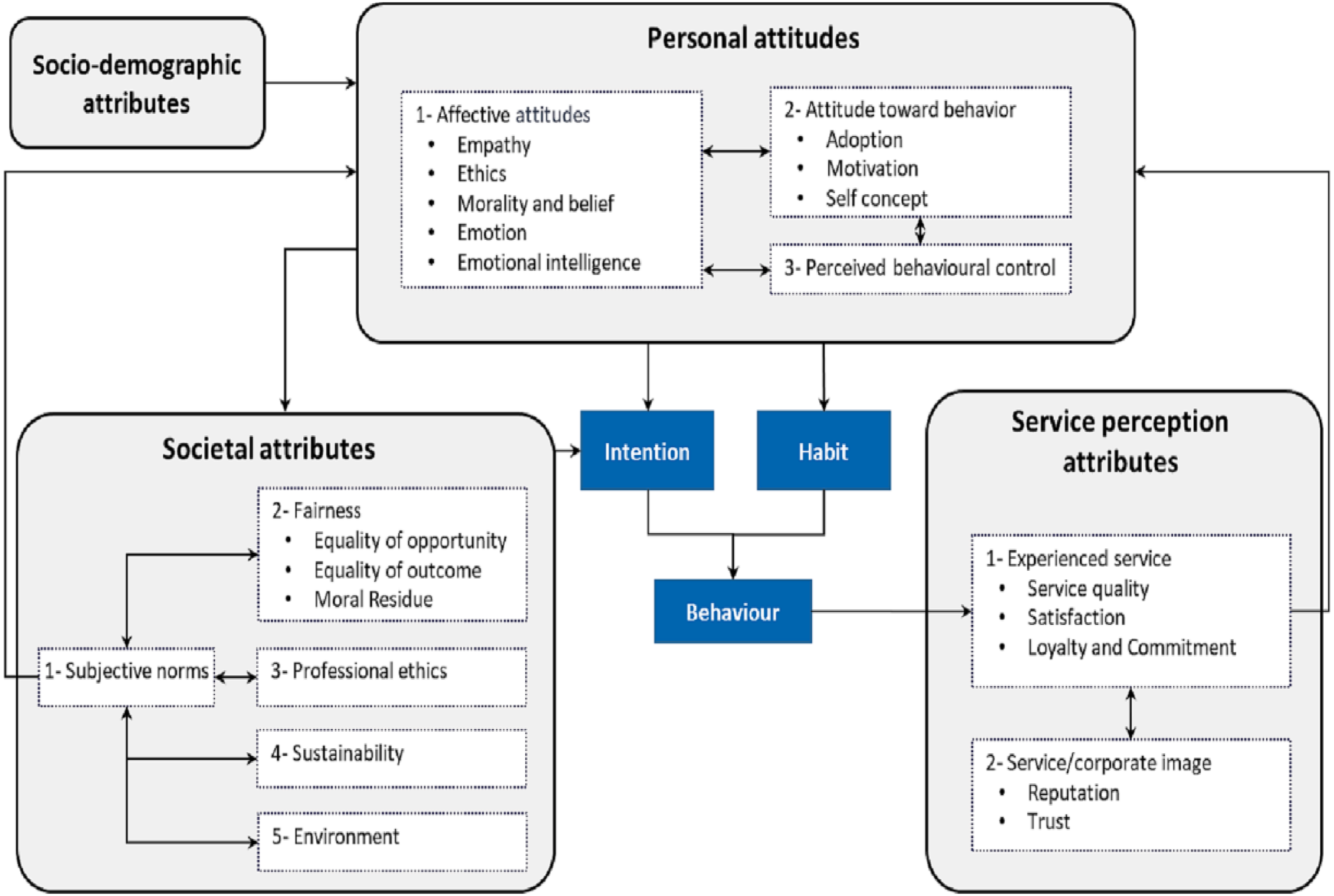
- It tries to capture some of the **psychology of decision making** to provide a better **simulation** of how decisions are made by an individual and the probability of a particular individual making one choice over another.

- It mainly consists of analysing data to **categorize subsets of individuals** who share similar attitudes/actions and decision triggers.

SYSTEMS THINKING

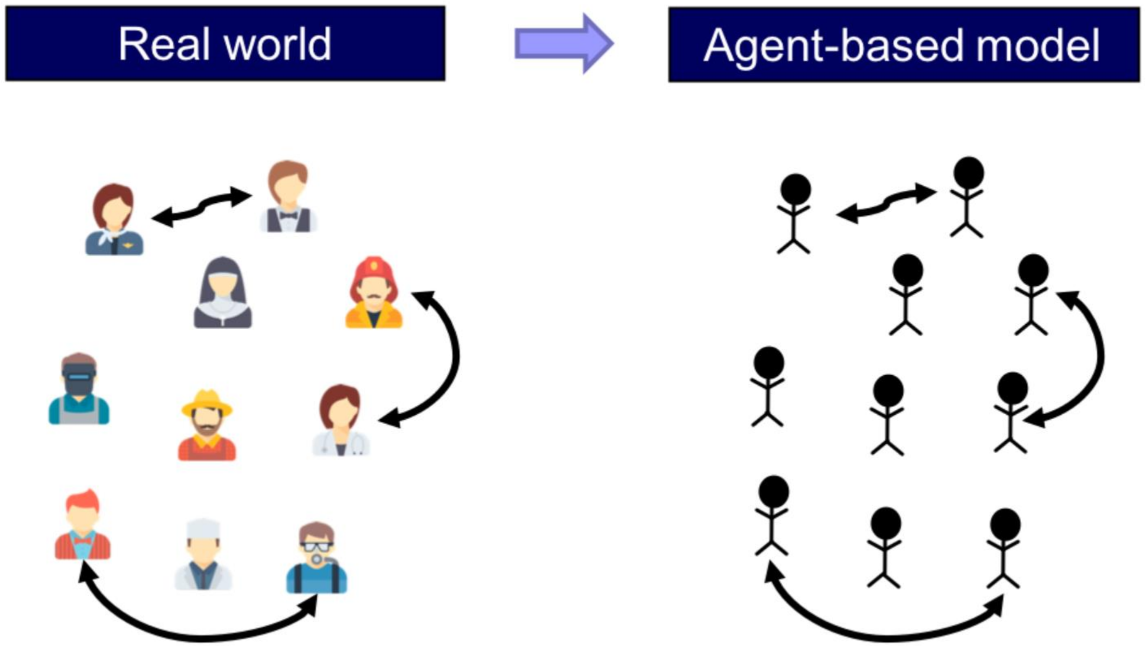


SYSTEMS THINKING



AGENT-BASED MODELS (ABM)

- Are computer simulations used to study the interactions between people (agents), things, places, and time.
- The **agents are programmed to behave and interact** with other agents and the environment in certain ways.
- These interactions produce **emergent effects** that may differ from effects of individual agents.
- It is **not limited to observed data** and can be used to model the **counterfactual or experiments** that may be impossible or unethical to conduct in the real world.



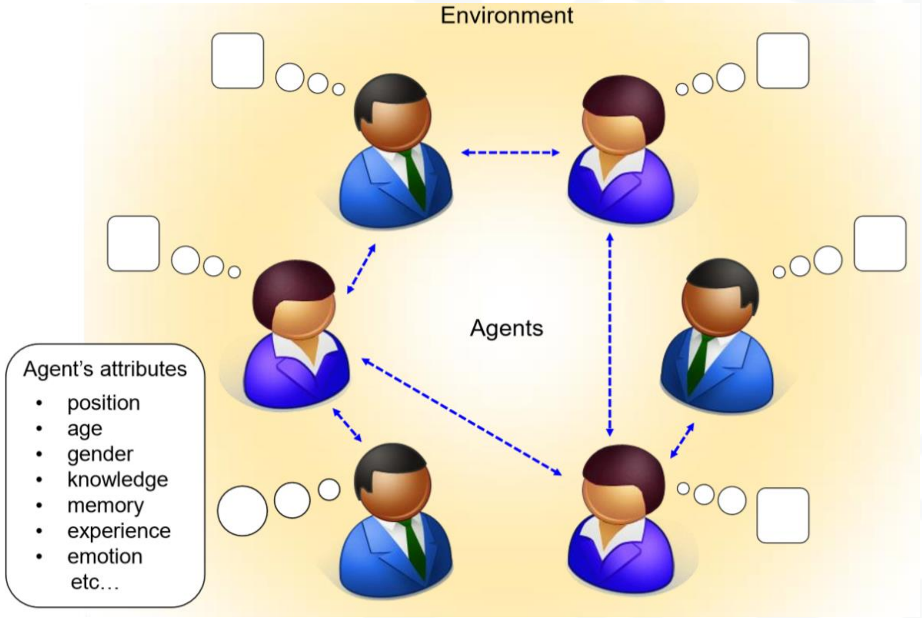
WHAT IS AN AGENT?

- Agent is a **distinct part** of the (computational) model that is meant to represent a decision-maker (player).

- **Agents could represent** human beings, non-human animals, institutions, firms, etc.

- Agents have ***individually-owned variables***, which describe their internal state (e.g. a strategy), and are able to conduct certain computations or tasks, i.e. they are able to run ***instructions*** (e.g. to update their strategy).

- **Instructions = decision rules** or **rules of behaviour,** and often imply some kind of interaction with other agents or with the environment.



ADDED-VALUES

- **Agents' heterogeneity.** Agents are explicitly represented in the model and can be as heterogeneous as the modeler deems appropriate.

- **Interdependencies between processes** (e.g. demographic, economic, biological, geographical, technological) that have been traditionally studied in different disciplines, and are not often analysed together.

- There is **no restriction on the type of rules** that can be implemented in an ABM, so **models can include rules** that link disparate aspects of the world that are often studied in different disciplines.

- **The micro-macro link (local interactions).** ABM is particularly well suited to study how global phenomena emerge from the interactions among individuals, and also how these emergent global phenomena may constrain and shape back individuals' actions.

ABM captures emergent phenomena

ABM provides a natural description of a system

ABM is flexible

COVERING DIFFERENT TOPICS AND THEORIES

References	Main output	Agents	Adaptation measures	Theory	Parameterization and Calibration	Output Validation	Location
Wens et al. (2020)	Drought risk	F	Long-term	EUT, PMT	Expert knowledge, social surveys, interviews.	Historical data on average maize yields and poverty	Kitui, Kenya
Van Duinen et al. (2016)	Agricultural income, Water demand	F	Long-term	CM	Interviews, surveys, expert knowledge.	–	Zeeland, The Netherlands
Hailegiorgis et al. (2018)	Adaptive capacity of households	F	Short-term	PMT	Census data and scientific literature	Face-validity tests. Historical data and field visits	South Omo Zone, Ethiopia
Acosta-Michlik and Espaldon (2008)	Vulnerability to global environmental change	F,G	Government policies	CM	Interviews, social surveys and cluster analysis	–	Tanauan City, Philippines
Pouladi et al. (2019)	Amount of water reaching Urmia Lake through Zarrineh river	F	Long-term	TPB	Interviews, social surveys and cluster analysis	Observed time-series of river discharge	Zarrineh River/Urmia lake, Iran
Mehryar et al. (2019)	Impact of policies on groundwater use	F,G	Short-term, long-term and government policies	No	FCM, interviews and cluster analysis	Historical data on groundwater use	Rafsanjan, Iran
Hyun et al. (2019)	Irrigation decisions under future climate scenarios	F	Short-term	TPB	Trial and error	Historical precipitation data	San Juan River Basin, Upper Colorado River Basin, USA.
Zagaria et al. (2021)	Transformational adaptation to water scarcity	F	Short-term and long-term	No	Interviews and Census data	–	Romagna, Italia

Agents:
F: Farmer
G: Government
R: Regulator

Theory:
EUT: Expected Utility Theory
PT: Prospect Theory
PMT: Protection Motivation Theory
TPB: Theory of Planned Behaviour
CM: Consumat

… AND DISCIPLINES

Disciplines combined	Features feasible in ABMs	Illustrative policy question
Economics & psychology	Market interaction, bounded rationality, uncertainty, and learning	How robust are traditional policy insights under bounded rationality?
Economics, psychology & sociology	Market interaction, social networks, human needs, quality of life, endogenous preferences, role of information	What policy combinations lead to climate mitigation while enhancing human quality of life at the same time?
Economics & political science	Coalition formation, firm heterogeneity, distributional effects	How does lobbying by companies influence policy outcomes?
Sociology & psychology	Bounded rationality, social networks, heterogeneous preferences	Which network topology enhances propagation of low-carbon behavior?
Political science & psychology	Collective action, voting, opinion formation, and social learning	How does opinion formation contribute to climate-policy acceptance?
Economics & sociology	Household heterogeneity, consumer practices, social interaction, learning	How does social interaction influence diffusion of green consumer practices?
Economics, psychology, sociology & political science	Market interaction, social networks, bounded rationality, and voting behavior	How to adapt policy over time to meet policy goals and assure sufficient support?
Economics, geography, and psychology	Spatial modeling, life satisfaction, physical environment, human needs	Which urban policy mix minimizes emissions under equal or increasing life satisfaction?
Sociology, psychology and media sciences	Information filtering, echo chambers, bounded rationality, opinion polarization	How to regulate green advertising in electronic social networks?
Agriculture, geography, economics	Life-cycle assessment, farm management, cropping activity, risk aversion, subsidies	How to design policy mixes (regulation and subsidies) for farmers to reduce emissions while guaranteeing viability?

Action! From the Adda river (IT)

Farmers' survey on climate change behavior

ABNexus – decisions on crops and irrigation methods

CONTEXT

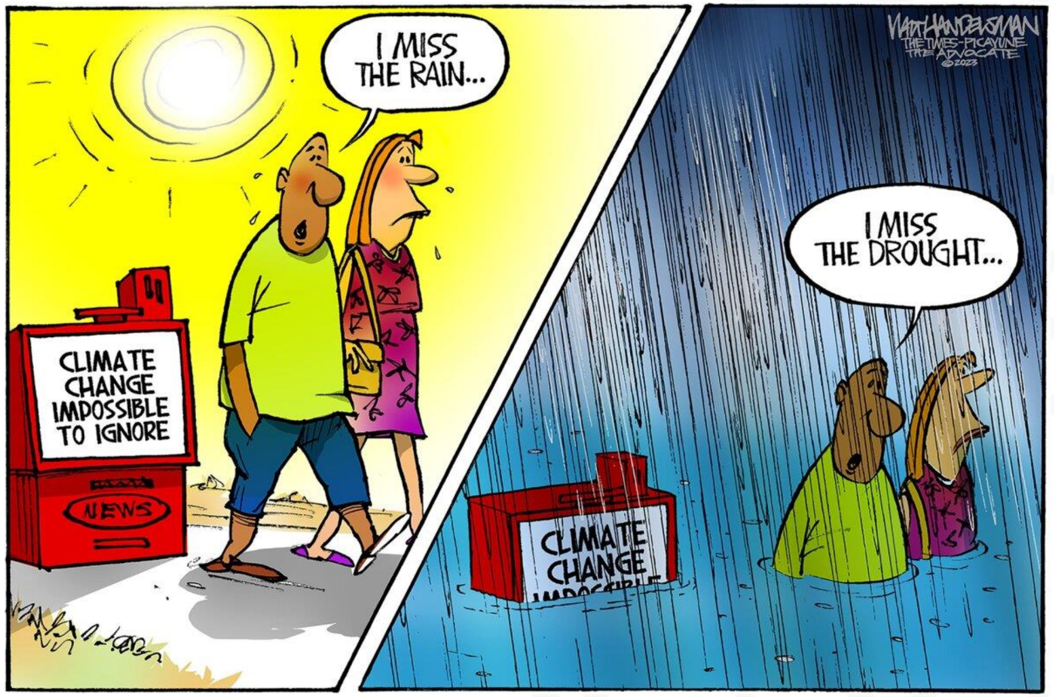
WATER SCARCITY

Water and climate change are inextricably linked.

Climate change affects water systems in complex ways.

Water at the centre of the climate crisis

WATER EXTREMES



CONTEXT

EXTREME EVENTS FREQUENCY & INTENSITY

DIRECT IMPACTS ON CROPS & LIVESTOCK

FARMERS' ACTIONS & DECISIONS

ADAPTATION PATHWAYS & LOCAL STRATEGIES

- Farmers develop their activity under **uncertainty/risk scenarios**
- Farmers are not '**blank slates**', they **socially construct** risk:

Experiences
Knowledge exchange
Cognitive factors

→ **Risk preferences**
Farmers' heterogeneity

→ Robust & anticipated decisions

RESEARCH QUESTIONS

- Do farmers (and irrigation districts managers) **perceive** and **respond to climate change**, and what about their **adaptive capacity**?

- Can farmers **behavior** be used to identify different **rationalities** and **risk** preferences?

- How **agent-based modelling** can **anticipate** and **support** farmers' **decisions** at the farm scale?

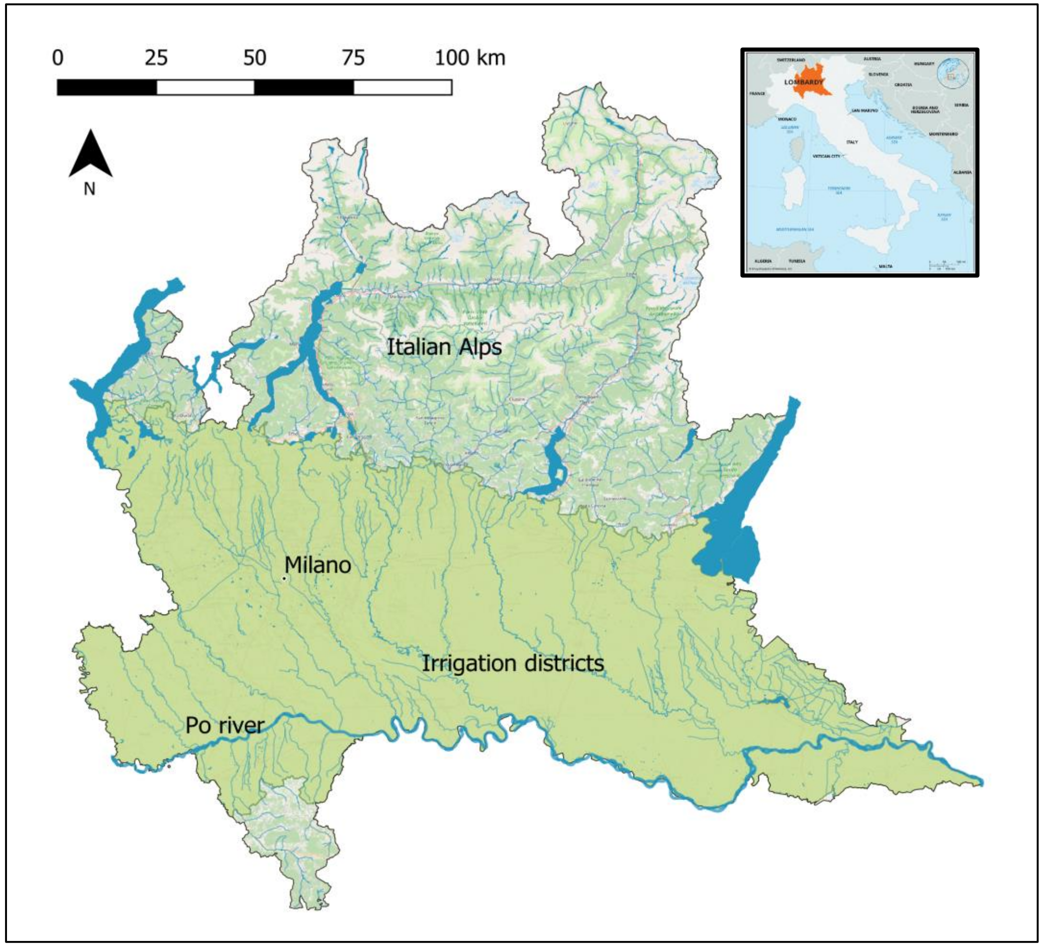
GOAL

Exploring farmers' expertise and attitudes when facing climate change for improving robustness in decision-making

cropping

irrigation system

CASE STUDY



MULTI-OBJECTIVE WATER NEEDS

- Densely populated
- Agriculture and industry clusters
- Complex water management: stakeholders
- Peak of water need in summer season

A ROBUST AGRICULTURAL SYSTEM

- 52,000 farms, 40% of the area
- Water managed through yearly concessions based on historical use
- Surface irrigation as the most adopted technique

CLIMATE IS CHANGING

- Frequency & intensity extreme events
- Change in rainfall peaks timings
- Increased temperature change sowing window

CASE STUDY

Landslides and floods wash away roads overlooking Lake Como in northern Italy where it's feared severe storms could cause 'disaster'

- Strong winds and torrential rain have swept across northern Italy

Crisi idrica del Po: 125 comuni italiani rischiano il razionamento dell’acqua

SOS acqua in tutta Italia e in particolare al Nord. I comuni potrebbero essere costretti a chiudere i rubinetti nelle ore notturne.

More than 60 people rescued after Italy's Lake Como hit by mudslides and floods

Italy Suffers Its Worst Drought In 7 Decades; Lombardy Region Declares State Of Emergency

The drought in Italy has dried up rivers that are essential for irrigation, notably the Po, endangering almost 3 billion euros in agriculture

Climate: Over 1bn in damage to Italian agriculture

Fruit yields down by half this year says Coldiretti

Allarme siccità: il fiume Po tocca il record negativo

Registrati oltre 100 mc/s in meno del minimo storico di aprile. E il 35,3% delle aree agricole irrigue, negli scorsi 24 mesi, ha sofferto di siccità severa-estrema




DATA AND METHODS

DATA SOURCES

Lombardy region, Adda river basin (Italy)

- Triple-loop **SURVEY** → 460 Farmers from irrigation districts
- Semi-structured **INTERVIEW** → Managers from 12 irrigation districts

Context drivers & Experiences

DATA COLLECTION

April – November 2022

- Farmer & farm characteristics
- Climate change awareness
- Perceived impacts
- Measures & Barriers

- Extreme events
- Impacts & adaptation
- Water management
- Risk assessment

Behaviors & Preferences

Social learning →

DATA ANALYSIS

TOOLS

OUTPUT

Farmers heterogeneity & patterns

Cluster mapping

Risk preferences

Agent-Based Model

ABNexus

MECHANISMS

Agro-hydrological environment

Economic incentives

Climate scenarios

OUTPUT

Changes in crop patterns & irrigation methods

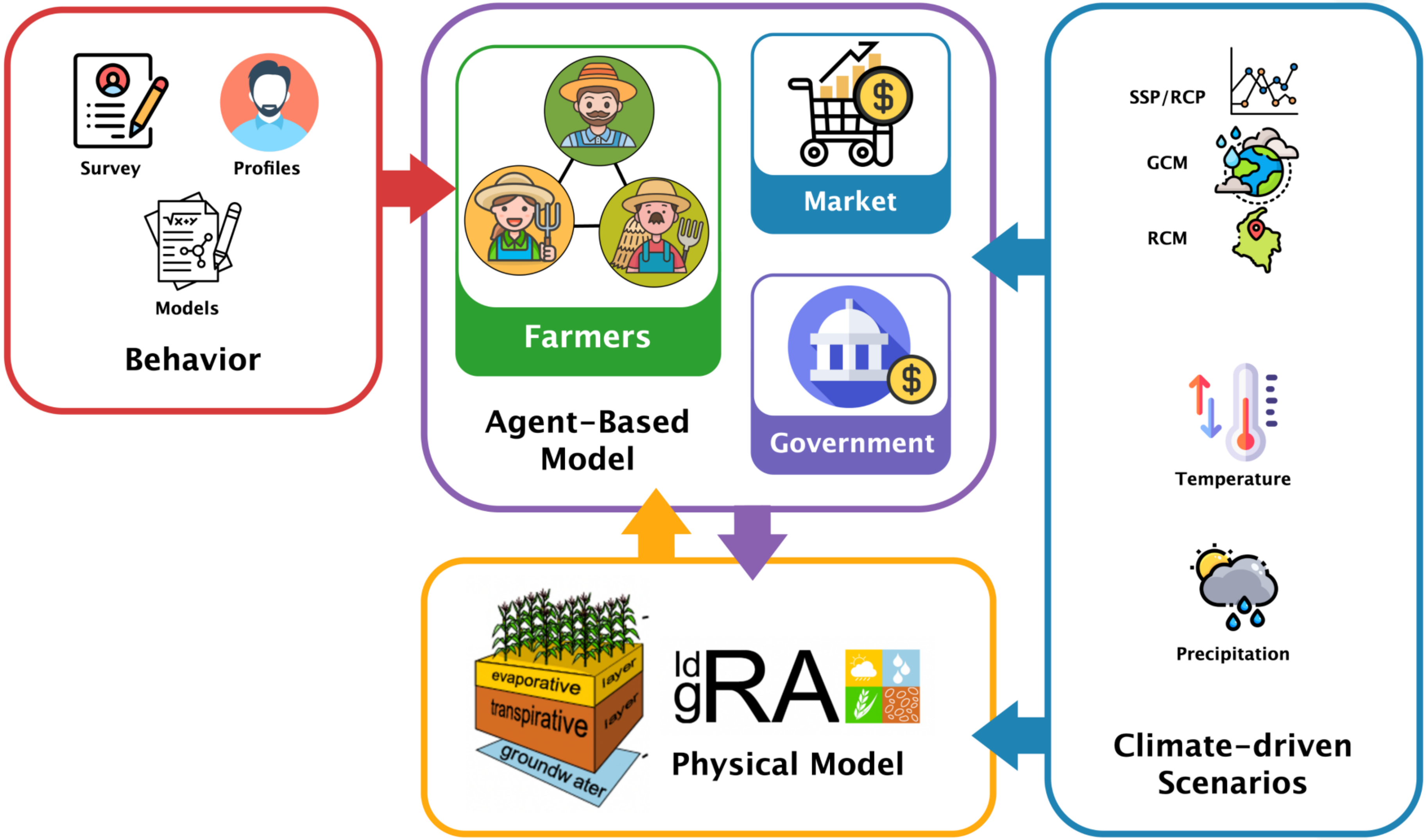
Performances under different rationalities & uncertainties

Decisions & Strategies

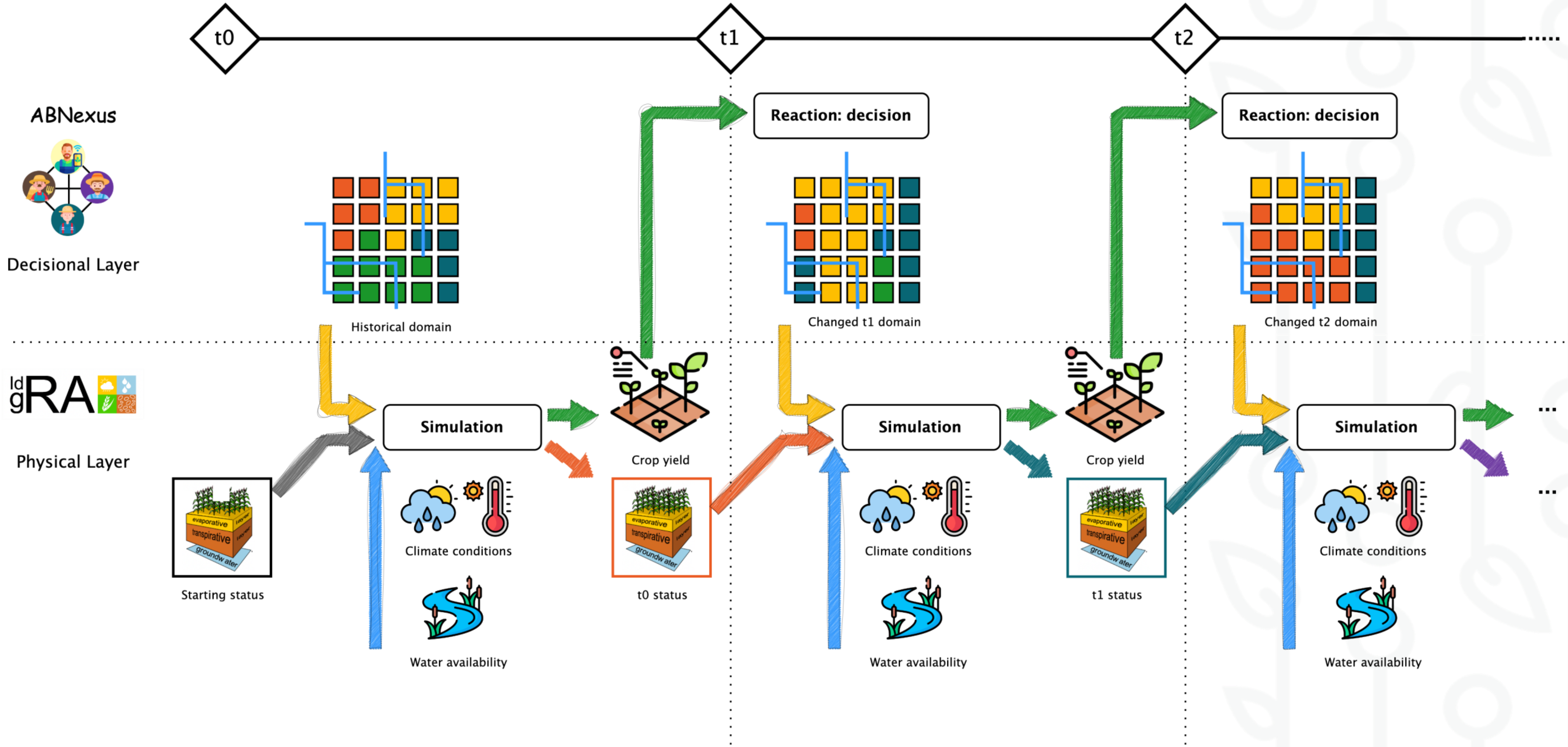
Anticipated decisions

New knowledge

Survey + IdrAgra = ABNEXUS



Survey + IdrAgra = ABNEXUS



RESULTS – FARMERS' DOMINANT PROFILE

Farmer

Man, 45-64 years, higher education, experience >30 years, union farm & consortia membership, non off-farm activity, no succession intention

Farming

Size >20ha, irrigated, conventional crops (maize), livestock, use of fertilizers, irrigation canal as main water source, non renewable energy use

Variable	Profile
Age	**45-64 years (56%)**
Gender	**Male (80%)**
Education	Professional/High education (38%)
Experience	**>30 years (50%)**
Labor force	Family members (49%)
Irrigation Consortium membership	**Yes (74%)** Oglio Mella, Chiese, Muzza
Off-farm activity	**No (69%)**
Succession intention	**No (55%)**

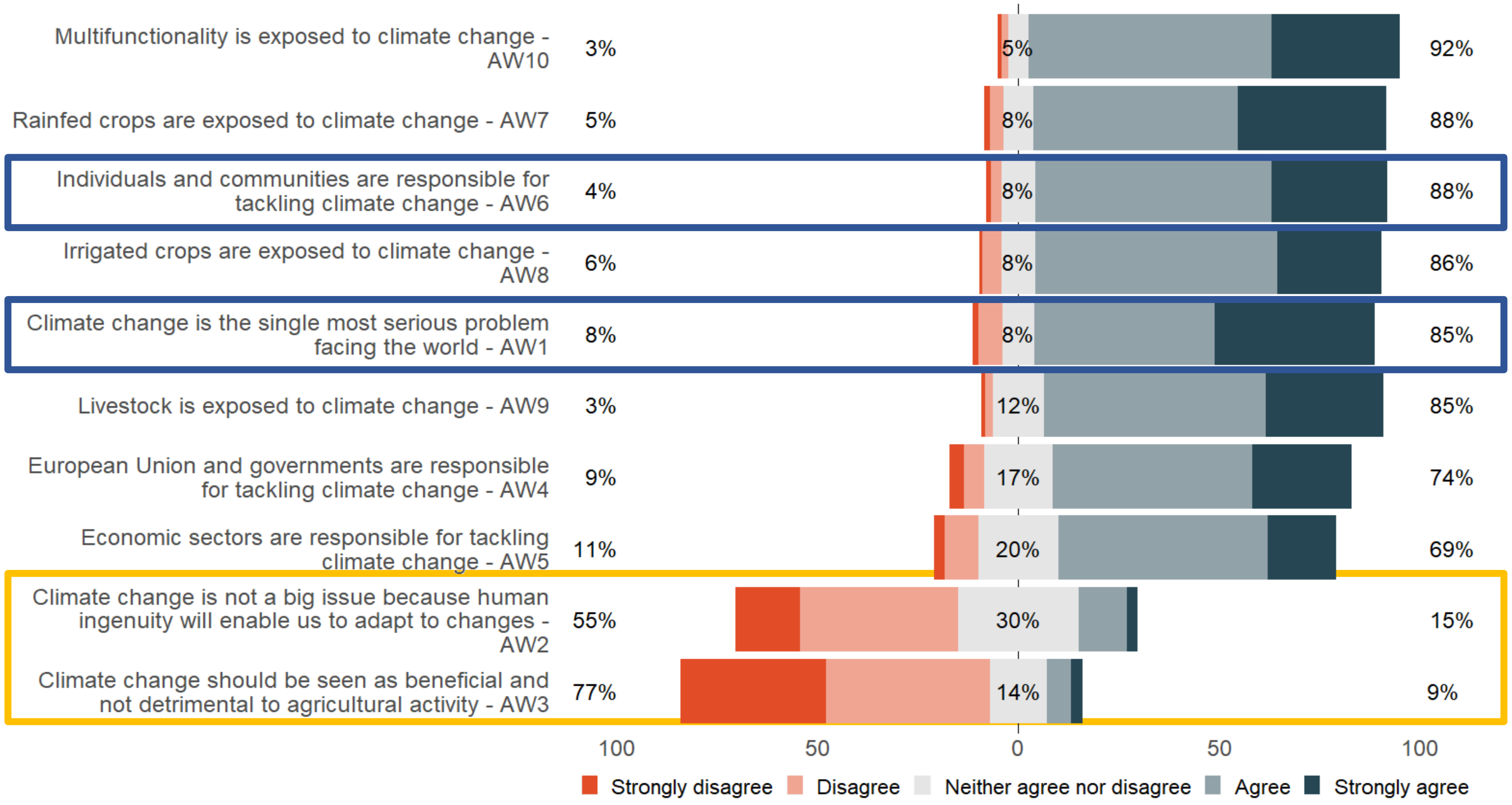
Dependence?

Variable	Profile
Farm size	**>20 ha (50%)**
Production system	**Conventional (75%)**
Main crop	**Maize (66%)**
Livestock	Yes (52% - cattle 66%)
Fertilizers	Mineral, compound, organic (78%)
Farming practice	Irrigated (72%)
Renovable energy use	**No (63%)**
Non-conventional water sources	**No (99%)**

Attitude change?

RESULTS – FARMERS' DOMINANT PROFILE

CLIMATE CHANGE AWARENESS



Responsibility statements: Individuals & communities

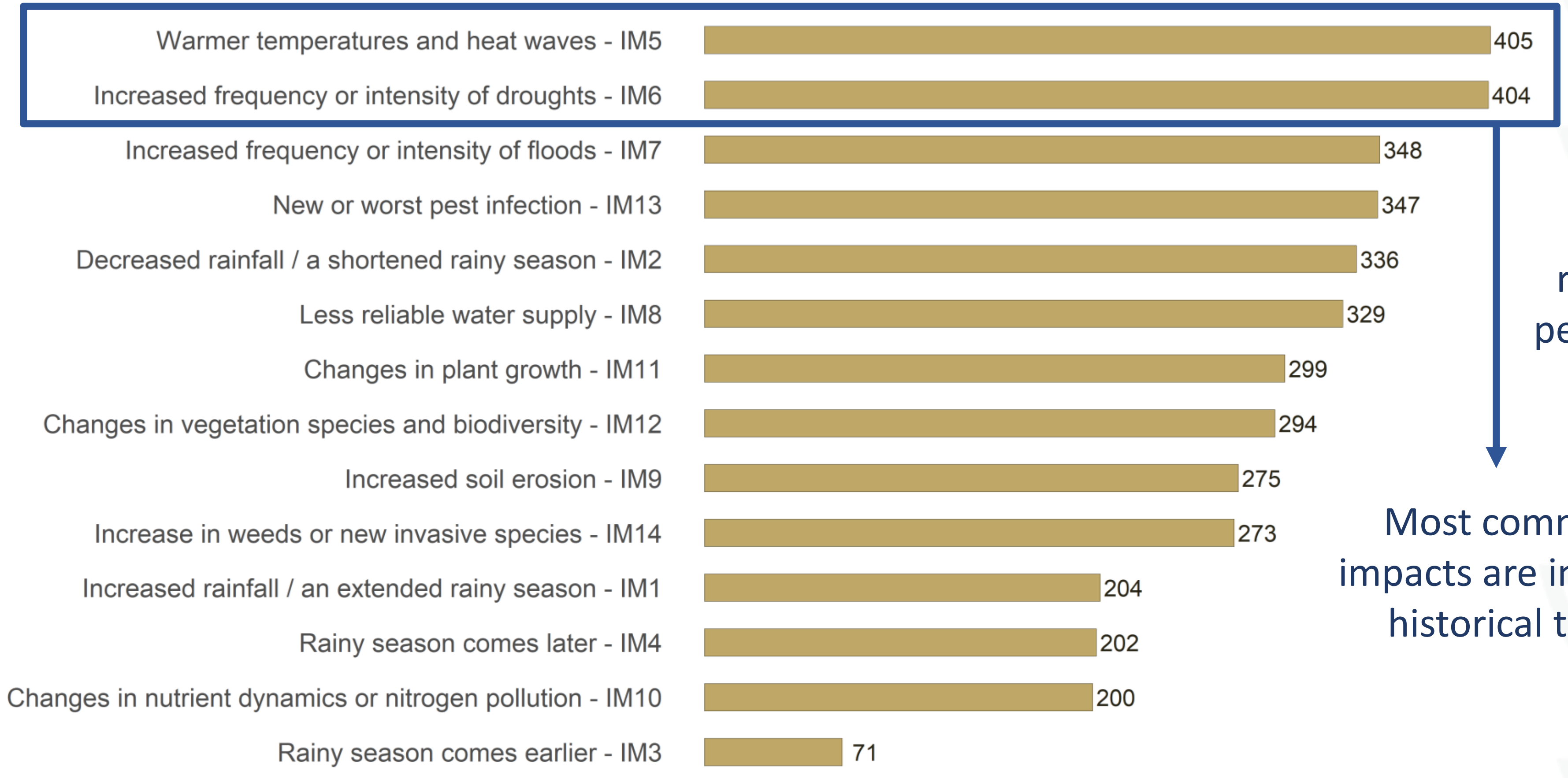
Farmers are aware of climate change

Little confidence on human ingenuity

Climate change is not beneficial to agriculture

RESULTS – FARMERS' DOMINANT PROFILE

CLIMATE CHANGE PERCEIVED IMPACTS

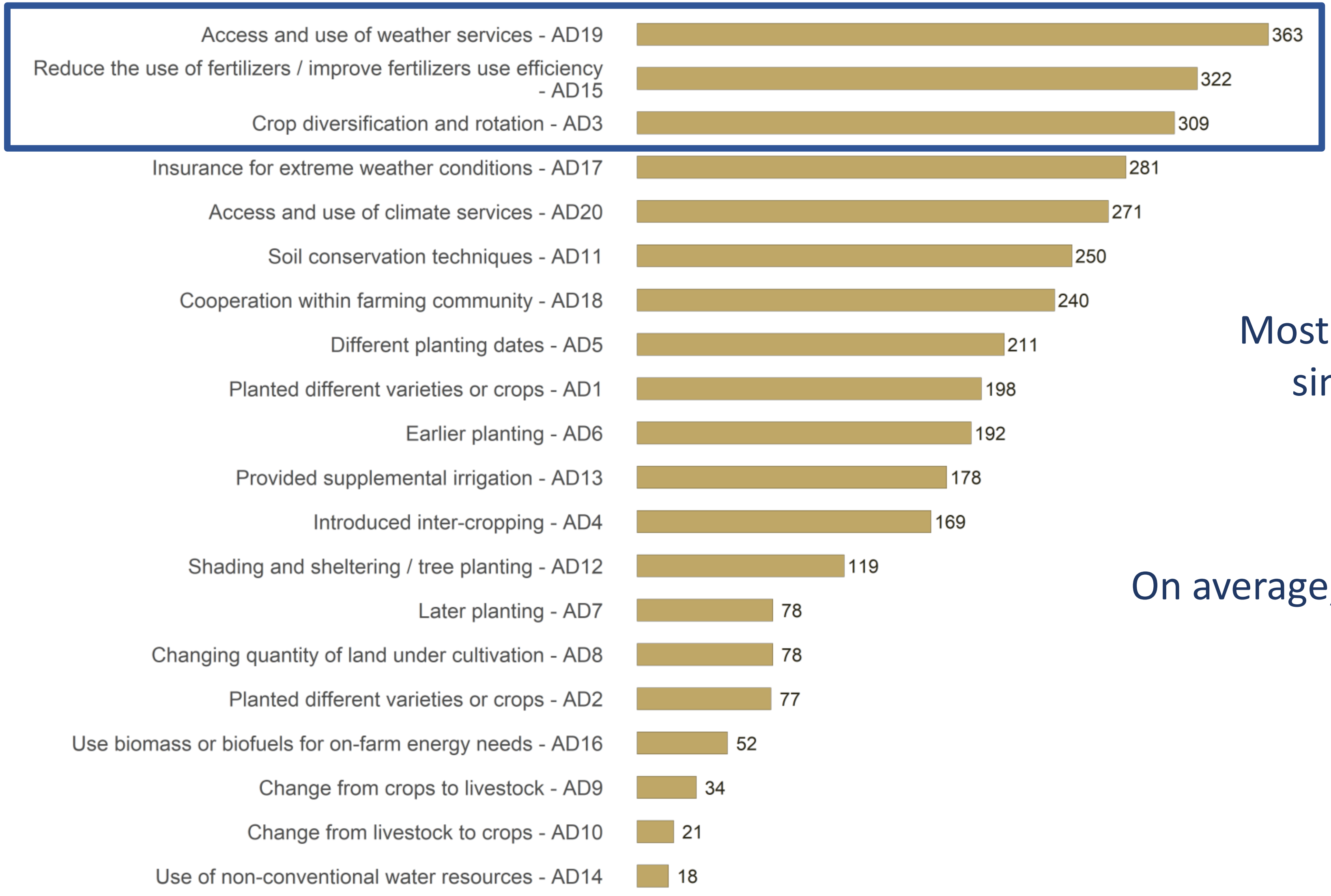


On average, 9 out of 14 impacts are perceived

Generally, farmers have a reasonable understanding and perception of the most relevant impacts

Most commonly recognized impacts are in line with recent historical trends in the area

RESULTS – FARMERS' DOMINANT PROFILE



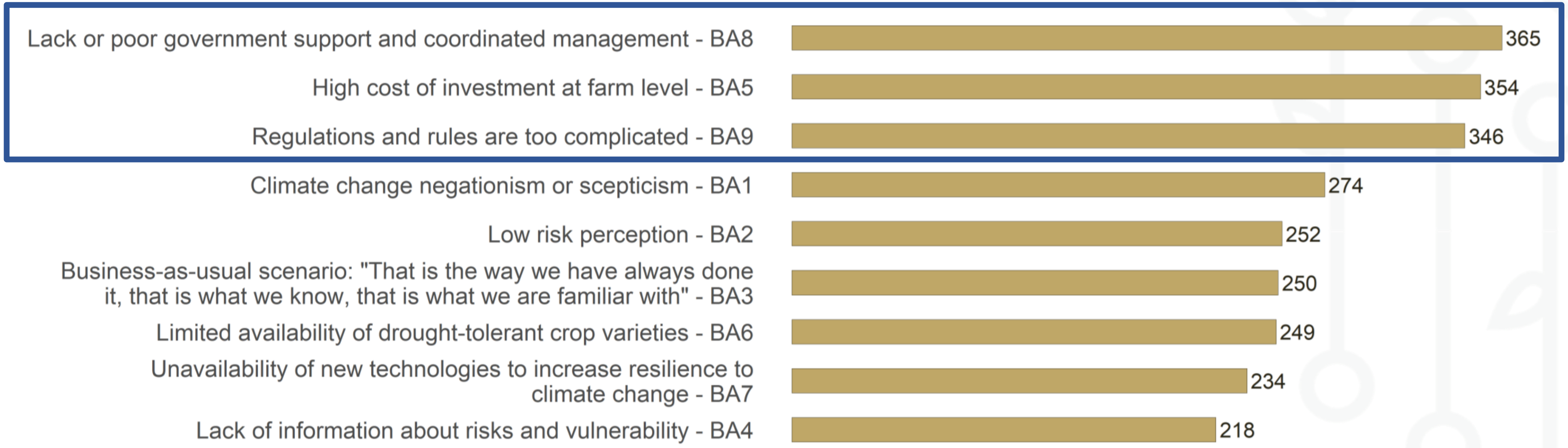
CLIMATE CHANGE ADAPTATION MEASURES

Most common measures are simple, cost-effective and well-known ones

On average, 7-8 out of 20 measures have been implemented

RESULTS – FARMERS' DOMINANT PROFILE

CLIMATE CHANGE ADAPTATION BARRIERS

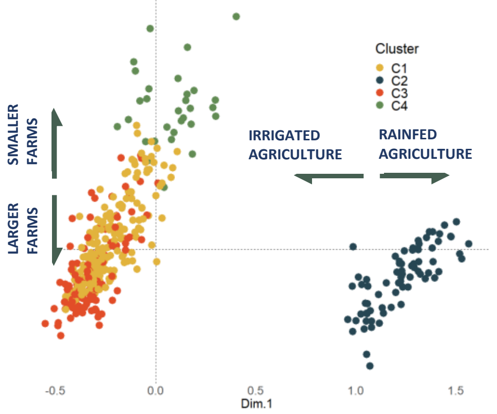


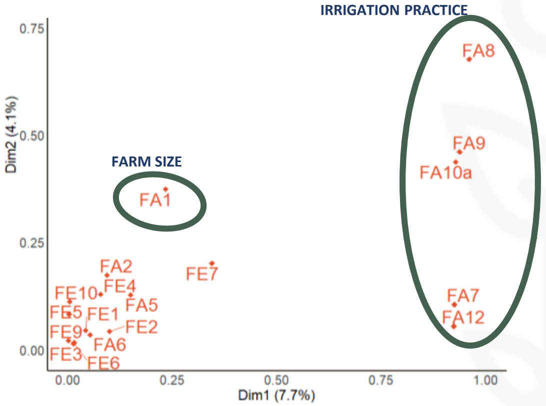
On average, 5-6 out of 9 barriers are selected as relevant

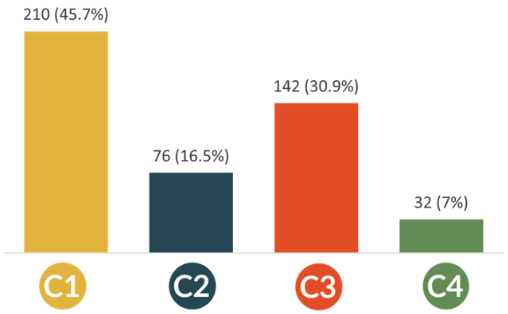
Most common perceived barriers have exogenous drivers

RESULTS – FARMERS HETEROGENEITY

- Low explained variance
- Farm size and irrigation practice as most relevant variables
- 4 clusters







C1

CLUSTER 1 **(46%)**

Older farmers, traditional methods
Adapted through **crop diversification**
Key attitude: most isolated

C2

CLUSTER 2 **(16%)**

Younger farmers, rainfed farms
Adapted through **cooperation**
Key attitude: most insecure

C3

CLUSTER 3 **(31%)**

Older farmers, larger farms
Adapted through **crop insurance**
Key attitude: most confident

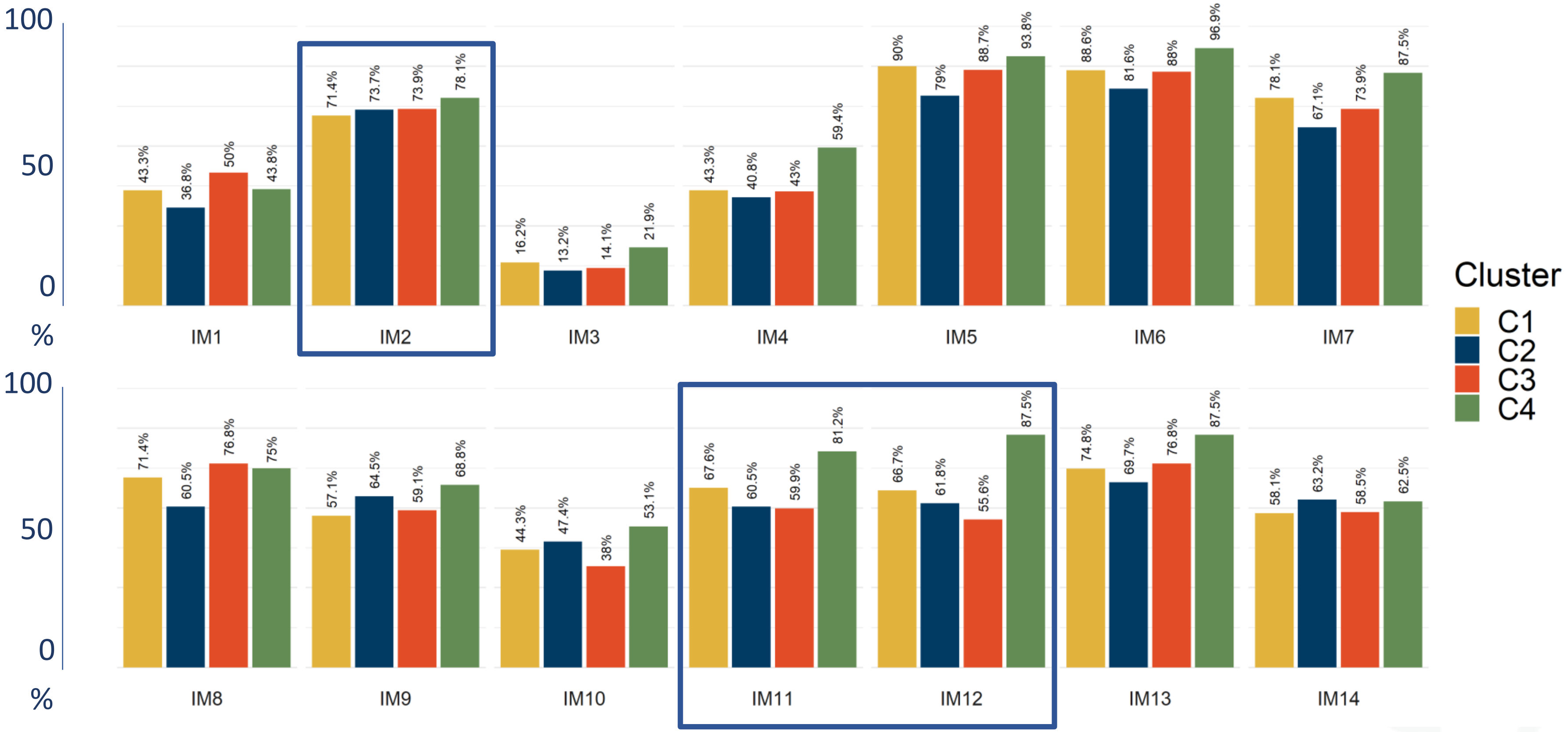
C4

CLUSTER 4 **(7%)**

Younger farmers, innovative methods
Adapted through **climate services**
Key attitude: most aware

RESULTS – FARMERS HETEROGENEITY

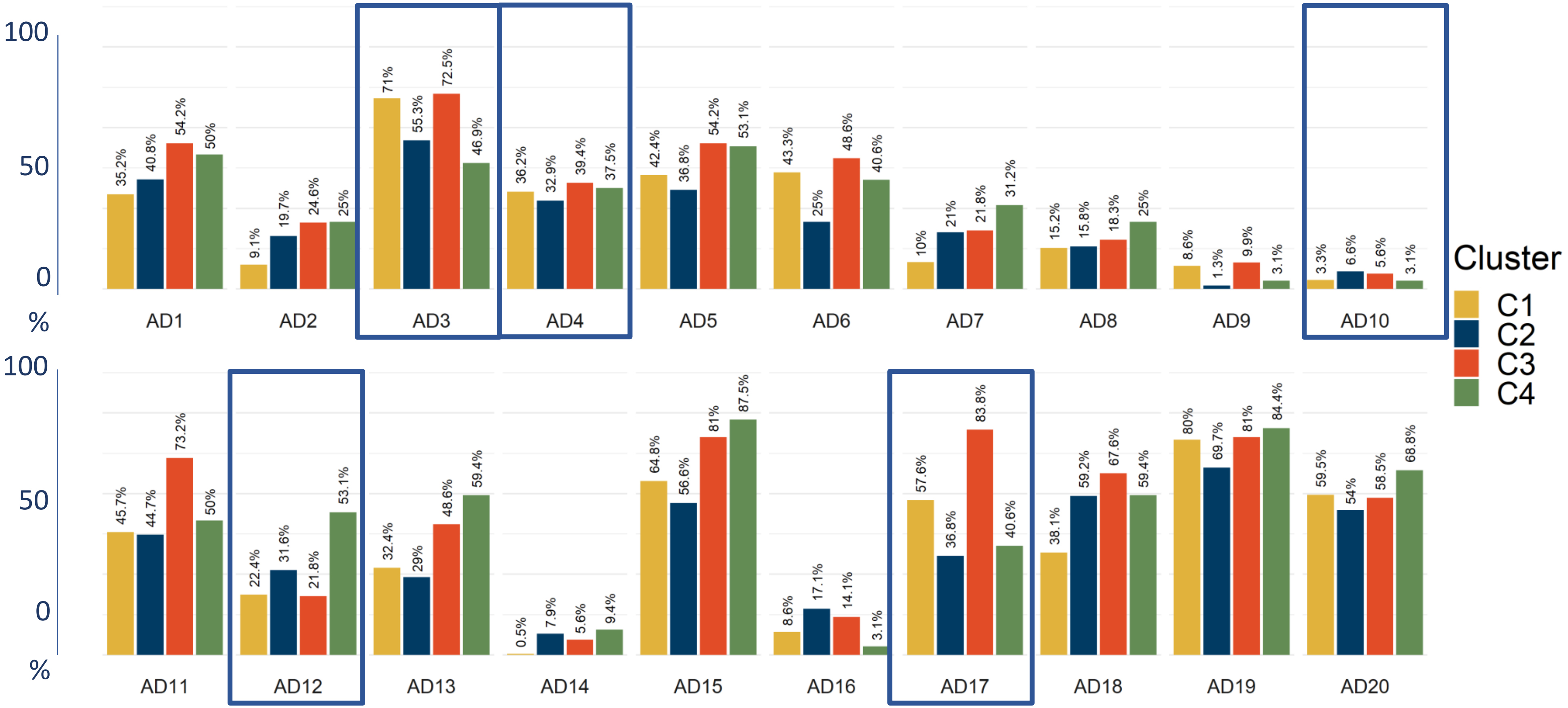
CLIMATE CHANGE PERCEIVED IMPACTS



IM1 Increased rainfall
IM2 Decreased rainfall
IM3 Rainy season comes earlier
IM4 Rainy season comes later
IM5 Warmer temperatures & heatwaves
IM6 Increased frequency or intensity of droughts
IM7 Increased frequency or intensity of floods
IM8 Less reliable water supply
IM9 Increased soil erosion
IM10 Changes in nutrient dynamics
IM11 Changes in plant growth
IM12 Changes in vegetation species & biodiversity
IM13 New or worst pest infection
IM14 Increase of weeds or new invasive species

RESULTS – FARMERS HETEROGENEITY

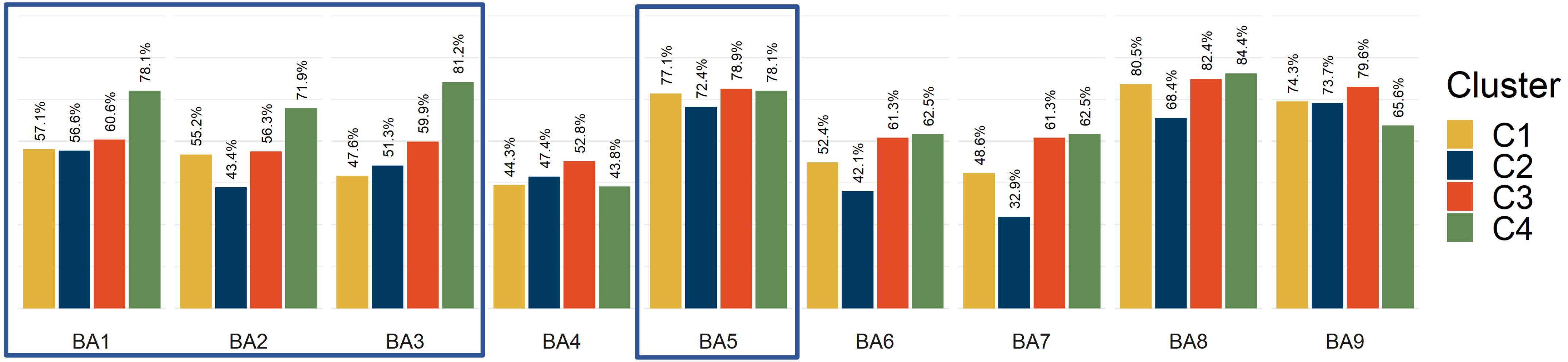
CLIMATE CHANGE ADAPTATION MEASURES



AD3 Crop diversification
AD4 Introduced inter-cropping
AD10 Change livestock to crop
AD12 Tree planting
AD17 Crop insurance

RESULTS – FARMERS HETEROGENEITY

CLIMATE CHANGE ADAPTATION BARRIERS



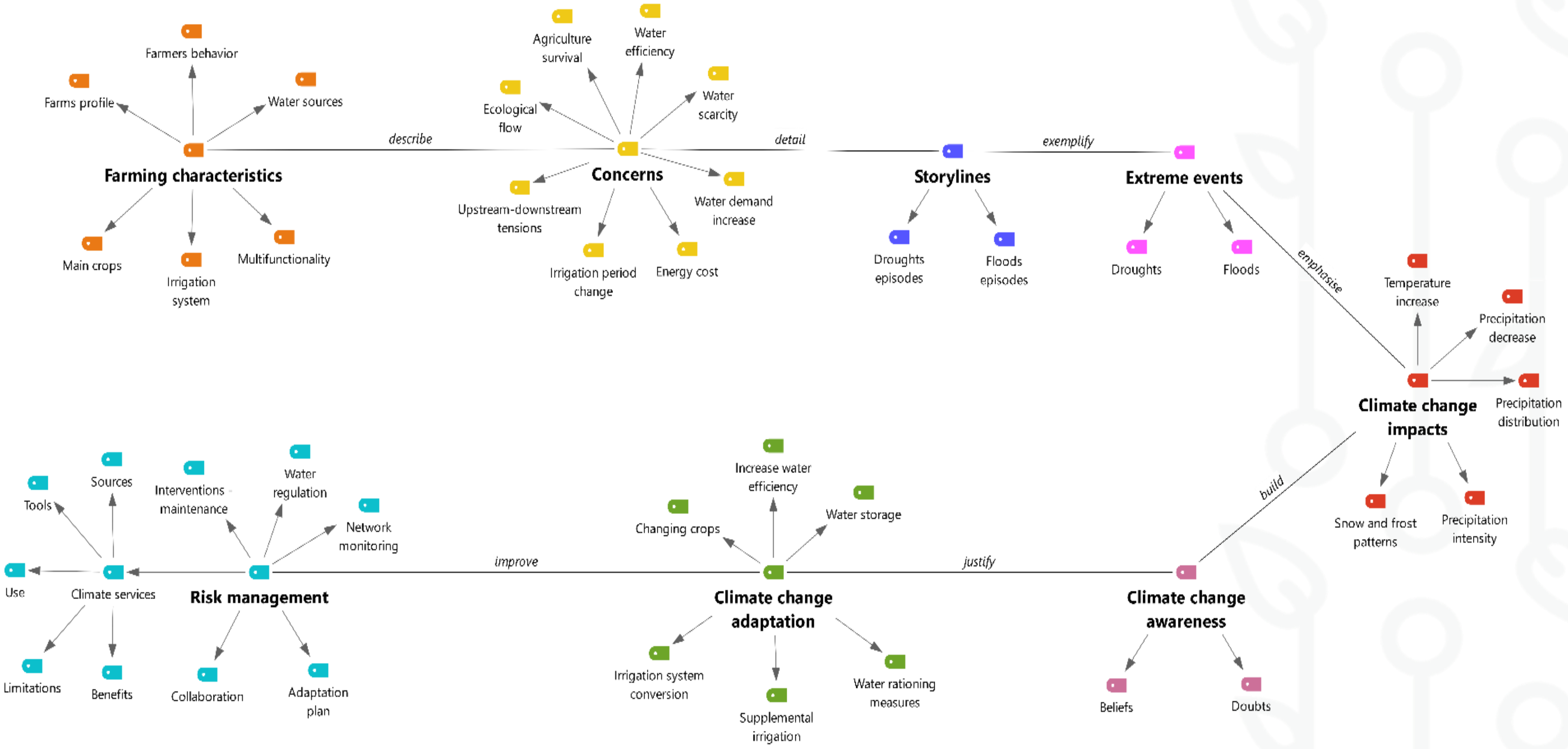
BA1 Negationism
BA2 Low perception risk
BA3 BAU
BA4 Lack of information

BA5 High cost of investment at farm level
BA6 Limited availability of drought-tolerant crop varieties
BA7 Unavailability of new technologies

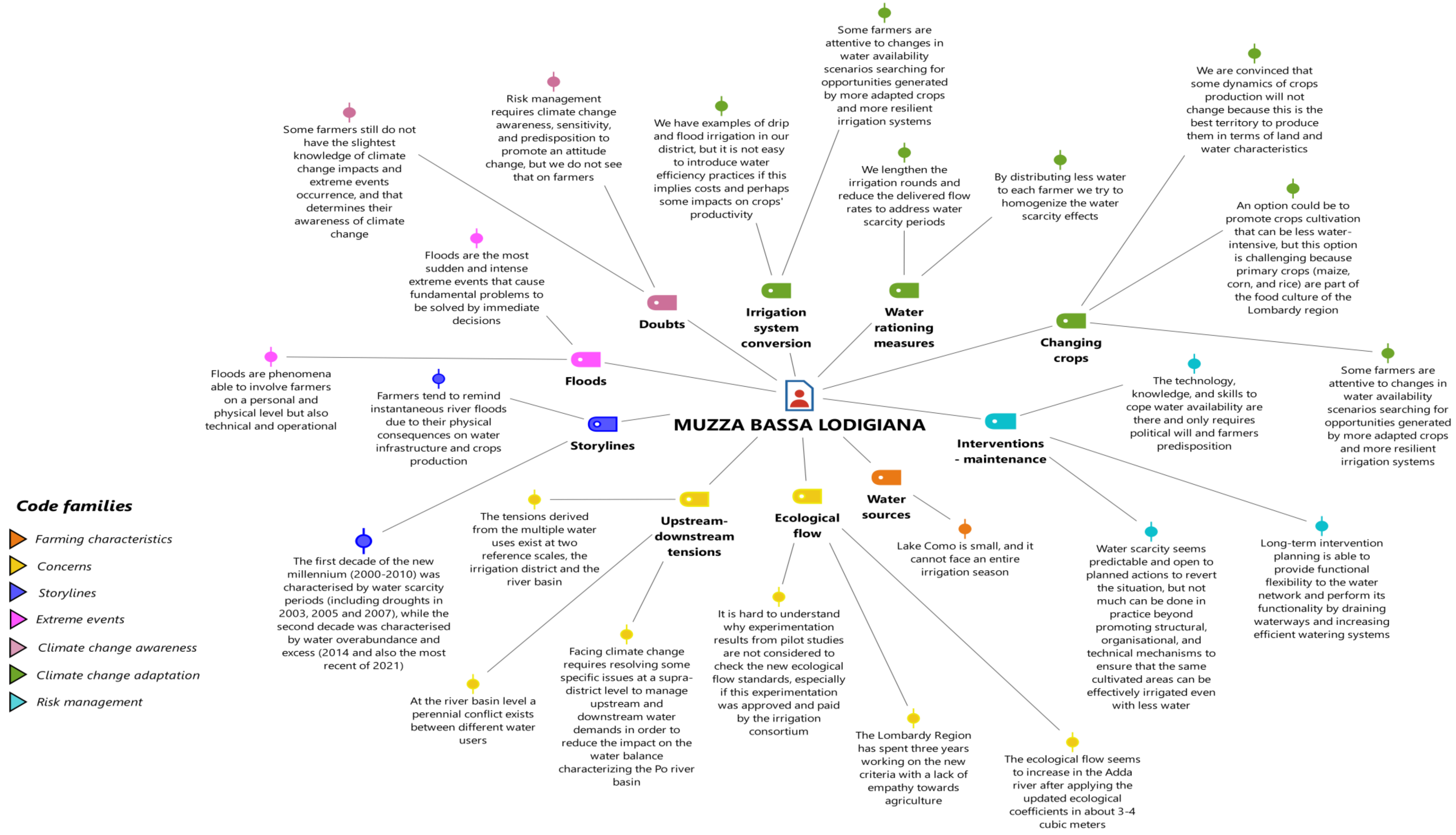
BA8 Lack or poor government support
BA9 Regulations and rules are too complicated

RESULTS – IRRIGATION DISTRICT MANAGERS NARRATIVES

Codes map



RESULTS – IRRIGATION DISTRICT MANAGERS NARRATIVES



RESULTS – IRRIGATION DISTRICT MANAGERS NARRATIVES

- **Agriculture is highly vulnerable** to physical impacts of climate change and also socially at risk due to **uncertain generational change** and a **lack of recognition** for farmers' role in the agri-food chain.

- Most managers believe that **water supply is becoming a key limiting factor** as the irrigation session grows longer.

- The increased demand for water in summer exacerbates this scenario as long as the main crops are cereals and horticulture, which are **water-dependent crops.**

- The last 20 years have witnessed the **expansion of irrigation practices** in previously untapped areas, driven by the cultivation of new crops (watermelon, melon).

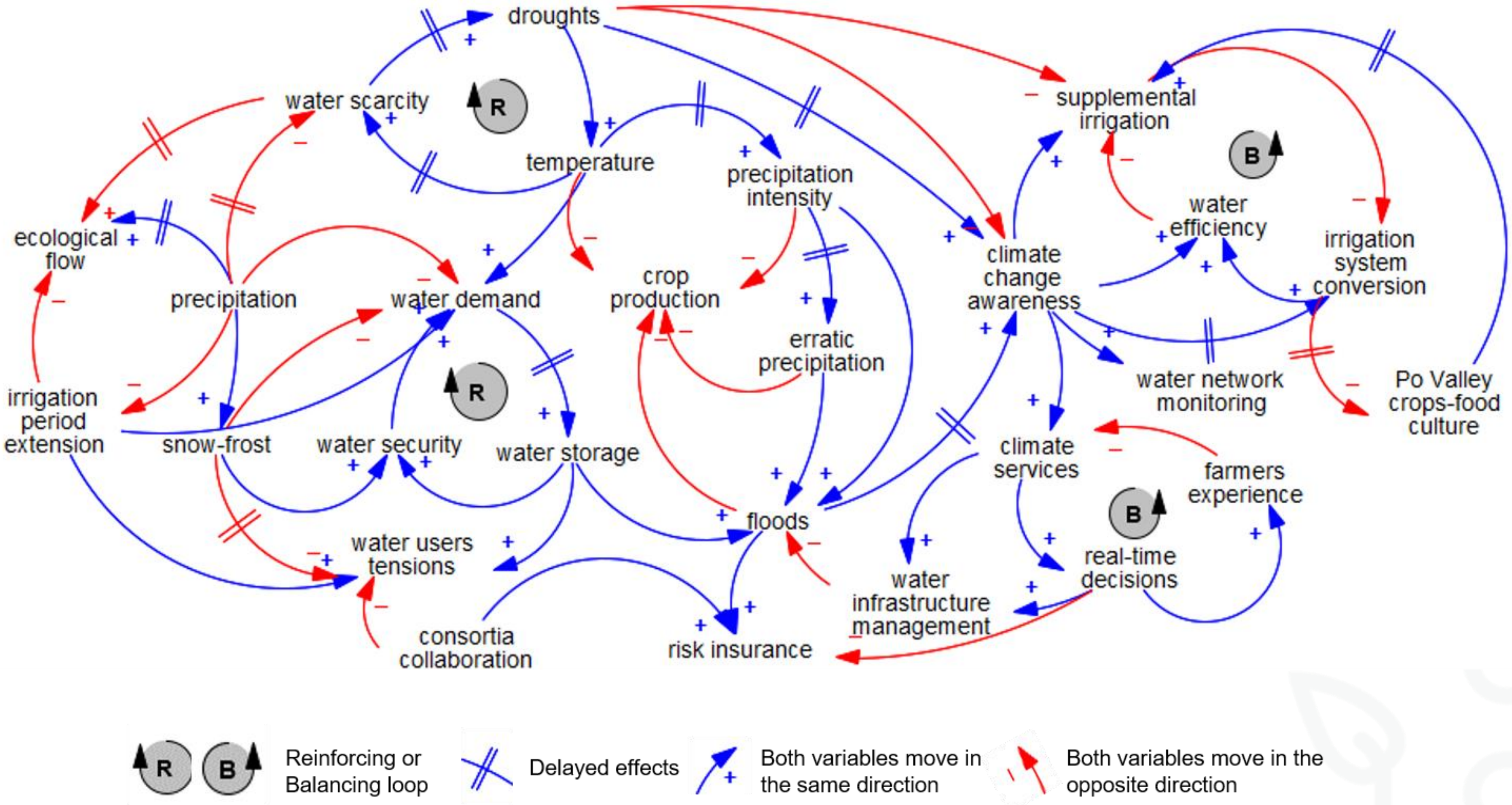
Droughts and **floods** as the most **perceived events.**

Droughts are becoming **more frequent** than in the past, even appearing during winter.

Droughts are often viewed as **unpredictable** and have notable **spatial impacts** across multiple counties.

Floods and **heavy rainfalls** are typically **confined to specific areas** and have the potential to greatly disrupt agricultural production in just a few hours.

RESULTS – IRRIGATION DISTRICT MANAGERS NARRATIVES



- **Reinforcing** water scarcity & water (in)security
- **Balancing** water supply/efficiency & decision-making/experience

RESULTS – ABNEXUS – Risk preferences

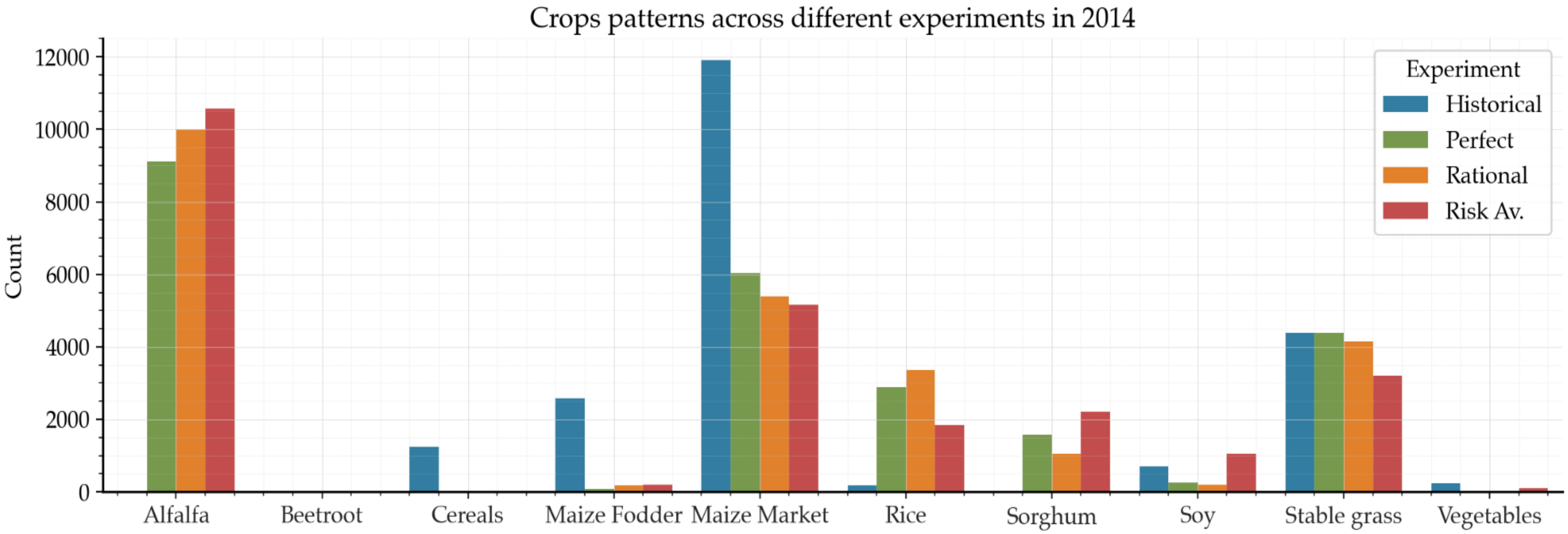
Indicator	Variable (survey)	Criterion	C1	C3	C4
Age[1]	FE1 - Age	The older, more risk averse	Risk averse	Risk averse	Risk prone
Insurance[2]	AD17 - Insurance use	More insurance use, more risk averse	Risk averse	Risk averse	Risk prone
Fertilizer use[3]	AD15 - Fertilizer reduce	More fertilizer, more risk averse	Risk averse	Risk prone	Risk prone
Adaptive capacity[4]	AD1-20 - average num. of implemented measures	More implementation of measures, less risk averse	Risk averse	Risk prone	Risk prone
			Risk averse	Risk neutral	Risk prone

Older, lower educated, and highly experienced farmers tend to focus on **weather adverse scenarios**

Younger, higher educated, and less experienced farmers focus on the **options able to give better performance**

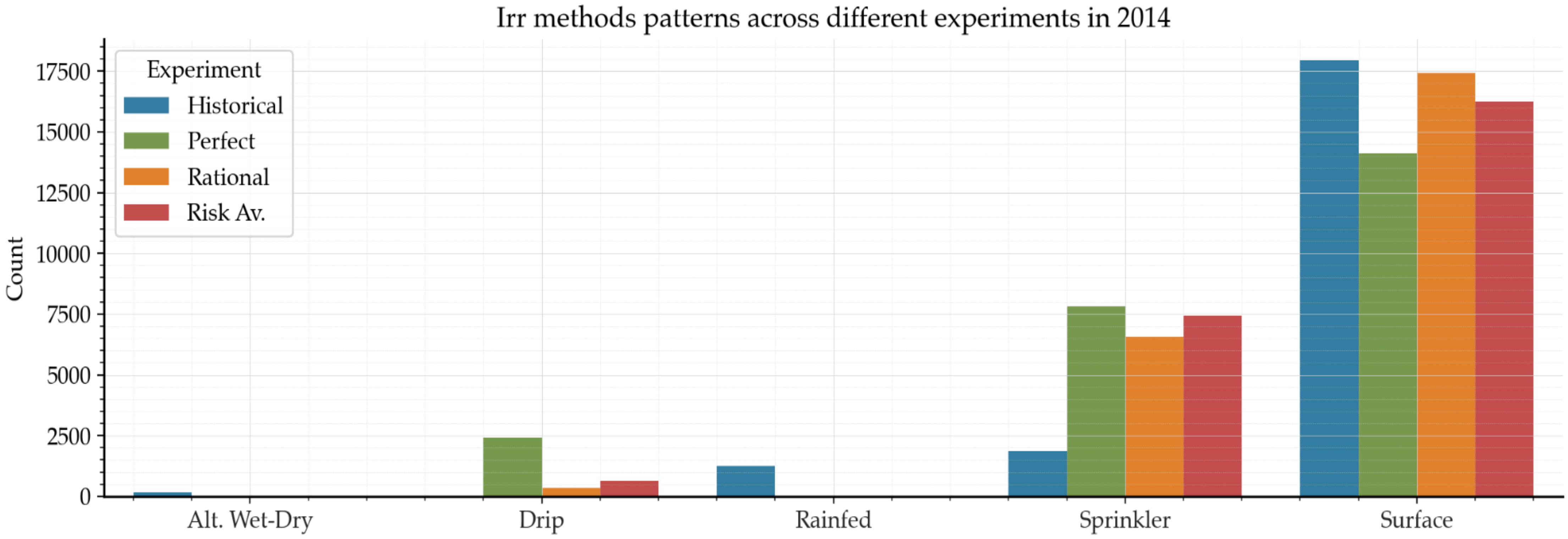
1 Yu et al. 2021, 10.1080/13669877.2014.940597
2 Hossain et al. 2022, 10.1016/j.jclepro.2022.130584
3 Qiao & Huang. 2020, 10.1016/S2095-3119(20)63450-5
4 Jin et al. 2020, 10.1080/09640568.2020.1742098

RESULTS – ABNEXUS – FARMERS BEHAVIOUR



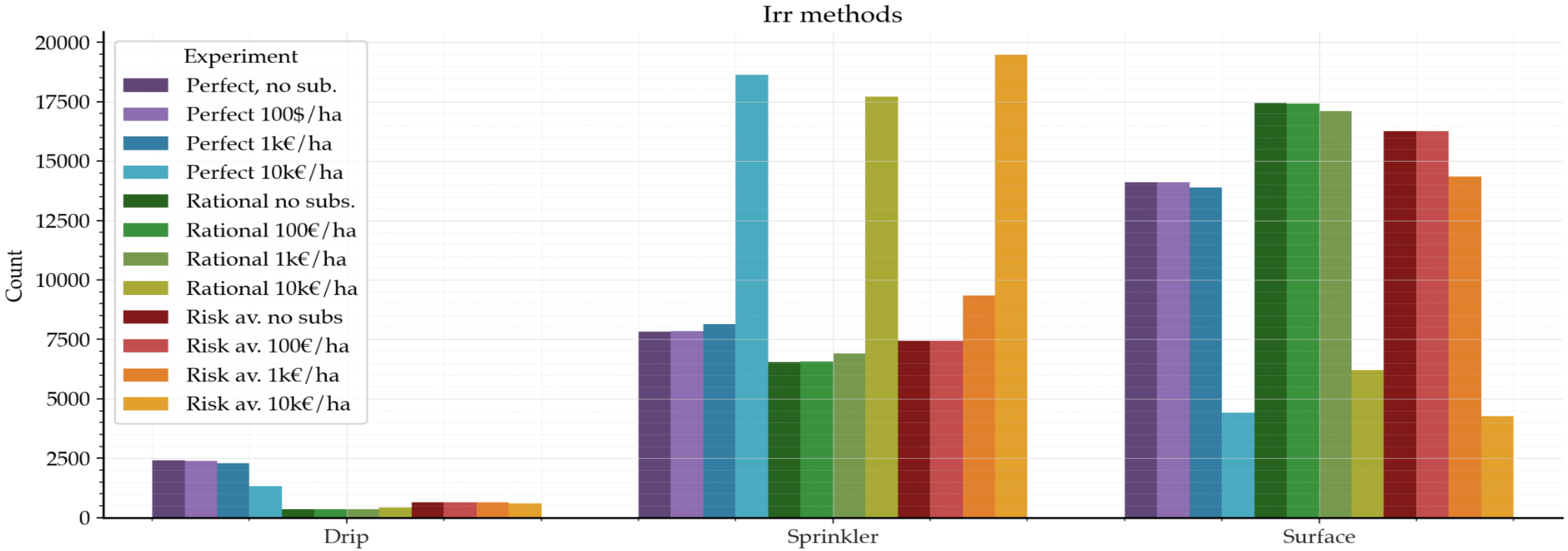
- Agents' shift from predominantly cultivating maize to diversifying into a broader range of crops.
- Rice gains prominence and alfalfa and sorghum emerge as attractive alternatives to maize for fodder, especially among agents exhibiting differentiated risk-aversion behavior.

RESULTS – ABNEXUS – FARMERS BEHAVIOUR



- Surface irrigation continues to be the most widely used technology, with variations in adoption rates depending on the agents' behavioral specifications.
- The model predicts an increased adoption of sprinkler irrigation, particularly in fields that were partially irrigated or rainfed.

RESULTS – ABNEXUS – FARMERS BEHAVIOUR – SUBSIDIES

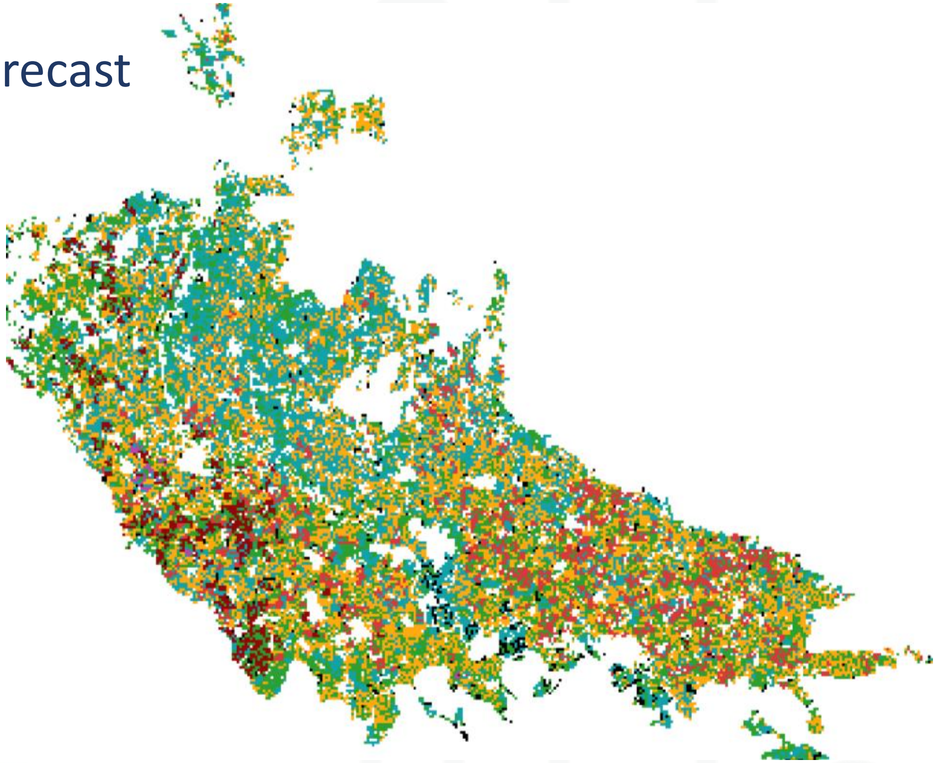


Irrigation methods patterns in 2014 under different levels of subsidies for sprinkler technology adoption.

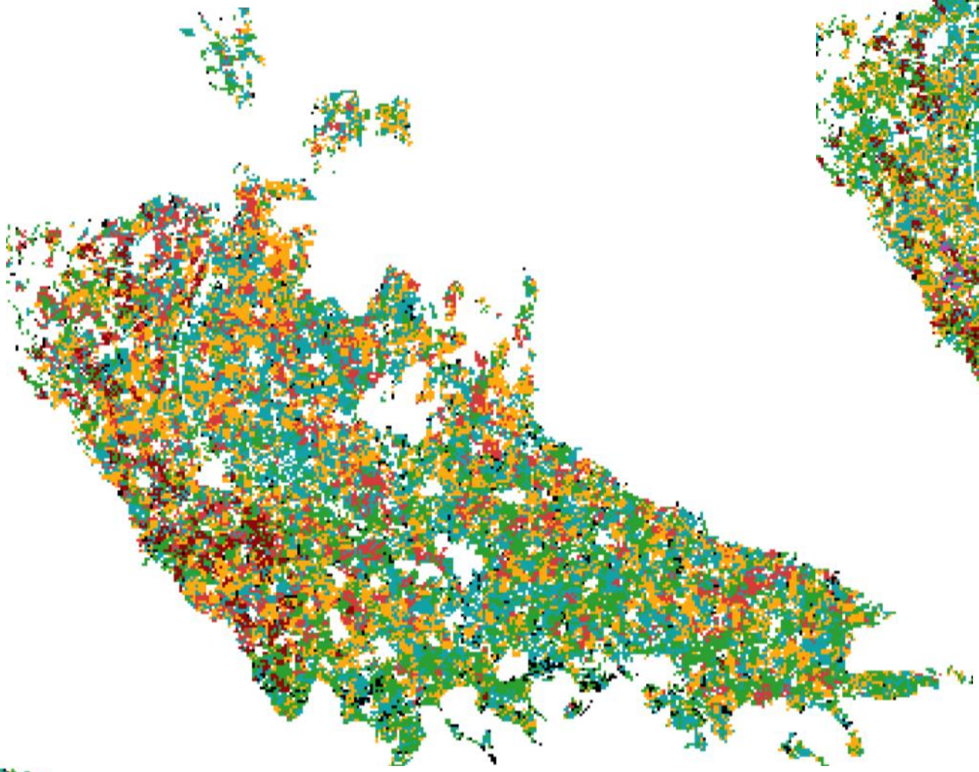
- Only the highest subsidy level, €10,000/ha, triggers a substantial shift towards sprinkler technology.
- The transition to sprinkler irrigation primarily occurs from surface irrigation technology, with limited differences between the various behavioral definitions of the agents.

RESULTS – ABNEXUS – FARMERS BEHAVIOUR – MAPS

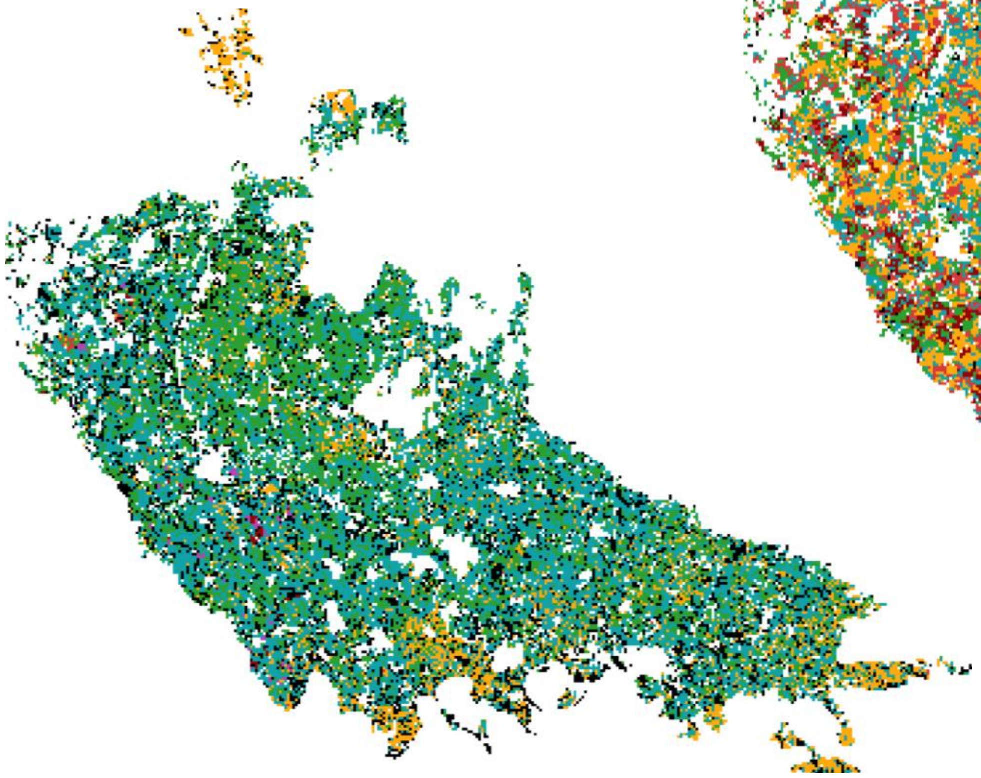
Perfect Forecast



Risk Av. Diff.



Historical Observations



FINAL REMARKS

- **Social learning** (surveys & interviews) provides **new datasets** for **behavior analysis** (heterogeneity).
- The **triple-loop approach** contributes to enrich **governance** and reinforce **decision-making** processes.
- **ABM** support **anticipation on decisions** and can be **combined** with **social data**

- **Farmers** do not follow a unique **pattern** when facing to climate change (clustering)
- **Rationality vs Risk preferences** → risk aversion significantly influences farmers' decisions on crops (more legumes) and irrigation methods (less AWD)
- **ABNexus** can be used to **evaluate farmers' decisions** under different **risk preferences.**

ENVIRONMENTAL INTELLIGENCE LAB

THANKS FOR YOUR ATTENTION!

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