A story of change: Adaptive capacity, diversification & climate change

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Main interest: how to cope with climate change in water management? *More specific:* can diversification of water management infrastructure and land-use increase adaptive capacity in managed river basins?

Presentation

- An adaptation strategy (diversification) and proxy for vulnerability adaptive capacity (math)
- Application: a simple statistical approach for flood management and the Guadiana river basin, Spain/Portugal
- Institutions and adaptive capacity
- Application: Tisza river basin
- Now what: Conclusions & future work?

An adaptation strategy (diversification) and proxy for vulnerability & adaptive capacity

Why this research?

Goal: Find informative proxies for adaptive capacity and vulnerability

Method:

- Look at one of key characteristics of complex systems: diversity
- **Diversification** suggested in various fields as a means to become resilient, cope with shocks (agriculture, ecology, economics)
- Diversification one of (few) basic properties (Holland (‘95), Gunderson/Holling(‘02); Fraser(’05 & ‘07))
- [resilience alliance: diversity, wealth & connectivity determine vulnerability. Vary over system’s different development stages]

Conclusion: Adaptive capacity depends on the actions the actor

Intermezzo: Diversity & ADAM regions

Tisza

Guadiana

Inner Mongolia

Adaptive Capacity - definitions

Following Cezar:

An actor (or system) in a particular state is vulnerable to environment *e* if actor's well-being has decreased after interaction with environment.

Following Luers (2003): Adaptive capacity AC: difference in the vulnerability V under existing conditions and under the less vulnerable condition to which the system could shift:
AC = V(existing conditions) – V(modified conditions) = $V - V_{min}$

Note: Capacity to adapt is distinct from adaptations that a system has made in the past to accommodate disturbing forces. Prior adaptations are captured in the current sensitivity (and vulnerability) of the actor.

Question: Definition does not capture willingness to change &

Adaptive Capacity - definitions

Following previous slide:

Approximates adaptive capacity of an actor in interaction with its environment as the difference between:
(i) the actor's well-being given all actions it has taken so far to reduce vulnerability, and (ii) the actor's potential well-being if it took all actions possible (and combinations thereof) to reduce vulnerability.

Challenge: Find appropriate function of well-being

Next: Explore proxies for adaptive capacity, focusing on when and how diversification supports adaptive capacity

[! Diversification one of more dimensions of vulnerability]

Adaptive Capacity - Example

Actor living in environment fluctuating between two conditions with uniquely matching conditions:

	Activity a1	Activity a2
Environment e1	r1	0
Environment e2	0	r2

Well-being: long term growth rate of actors success

! Captures information about the environment & its interaction with actor.

Maximise expected value of logarithm of success in one generation

Adaptive Capacity - Example

Actor living in environment fluctuating between two conditions with uniquely matching conditions:

	Tulips	Rent canoes
Normal year	1	0
Extreme flood	0	0.7

Adaptive capacity = $V - V_{min}$

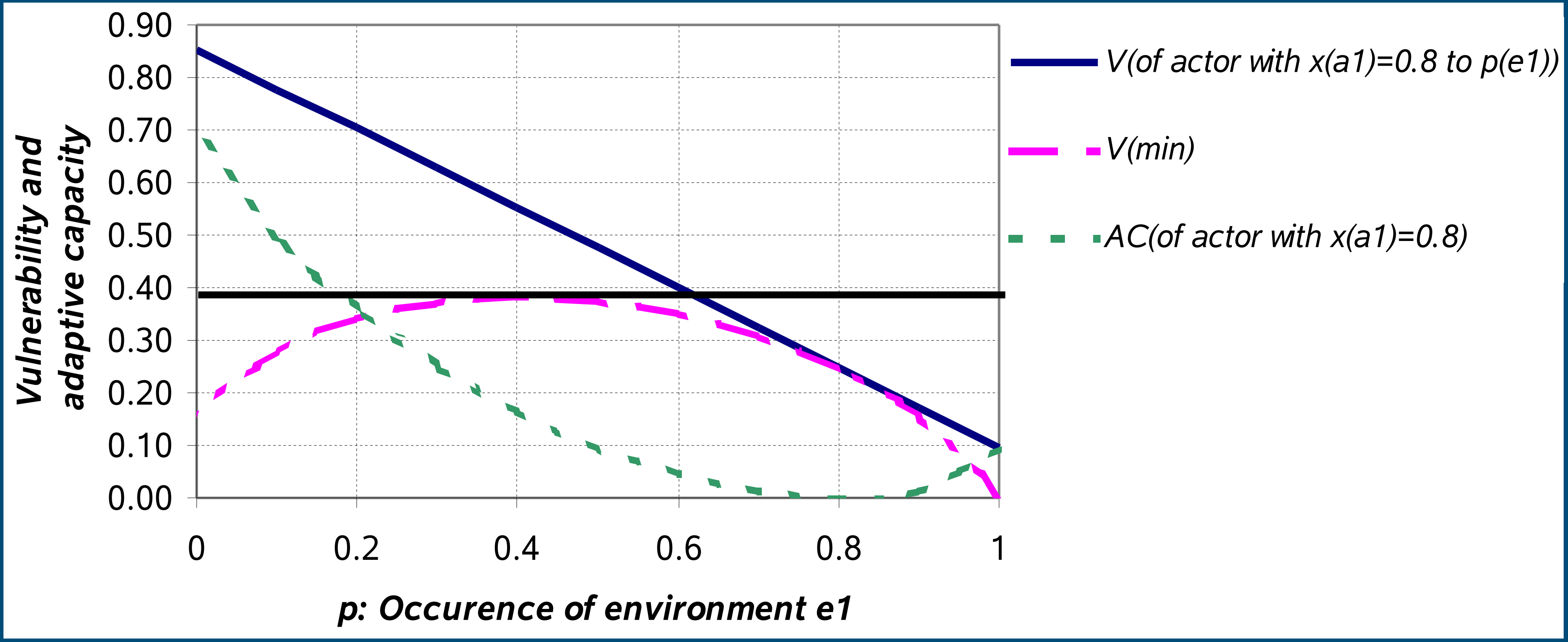
V: **long term growth rate of actor's success when investing 0.8 in tulips (& 0.2 of canoes)**

V_{min}: **growth rate when optimally adapted to environment**

Please plot V, Vmin & Adaptive cap against occurrence of environment e1

Adaptive Capacity - Example

Actor living in environment fluctuating between two conditions with uniquely matching conditions (r1 = 1, r2 = 0.7):



Adaptive Capacity - Example

Actor living in environment fluctuating between two conditions:

	Activity a	Activity b
Environment e1	a1	b1
Environment e2	a2	b2

Adaptive Capacity - Example

Actor growing living in environment fluctuating between two conditions with:

	Normal crops	Drought resist. crops
Normal year	1	0.7
Dry year	0.75	1

Adaptive capacity = $V - V_{min}$

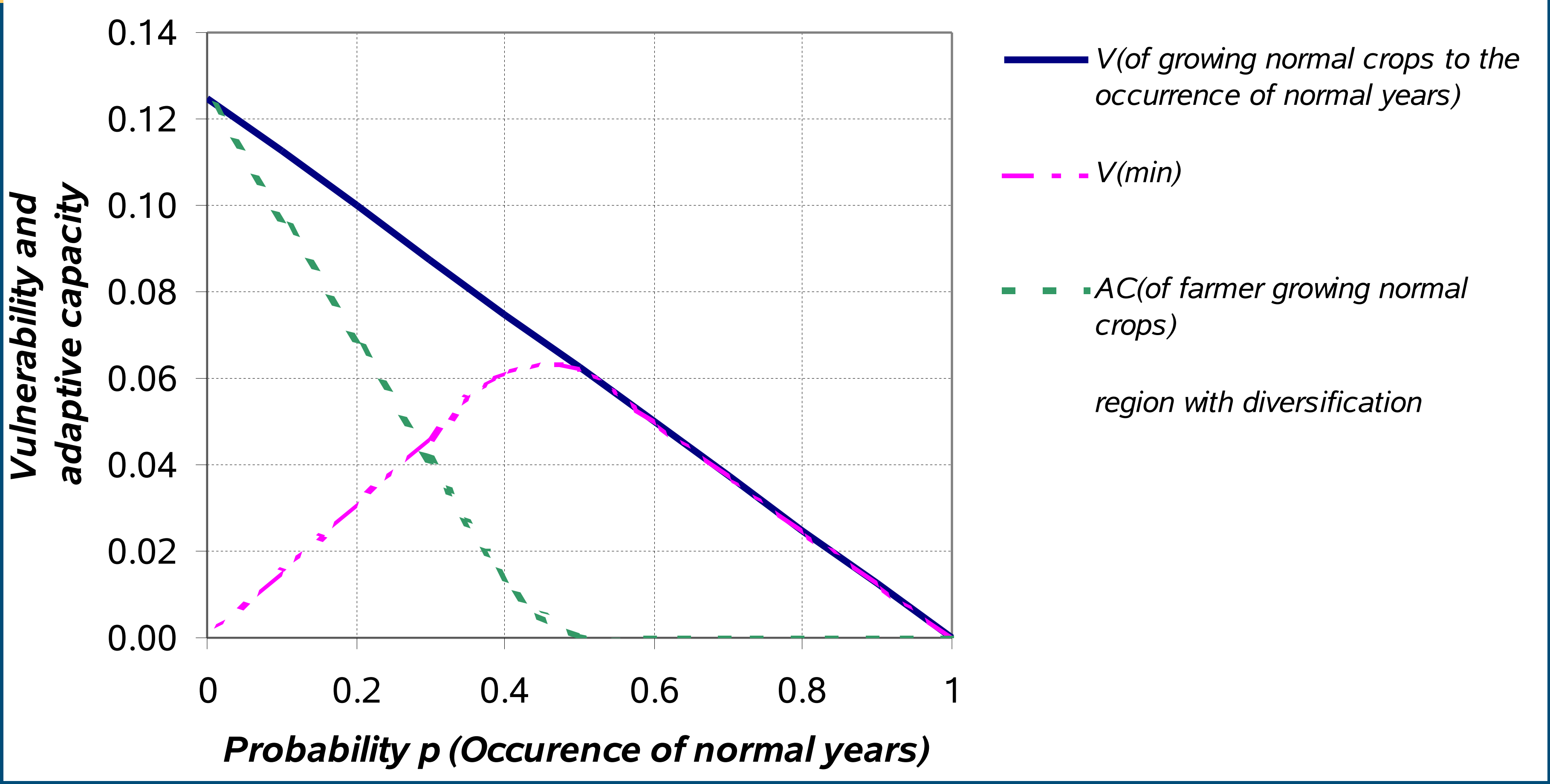
V: **long term growth rate of actor's success growing normal crops**

V_{min}: **growth rate when optimally adapted to environment**

Please plot V, V_{min} & Adaptive cap against occurrence of environment e1.

Adaptive Capacity - Example

Actor living in environment fluctuating between two conditions with inversely impacted activities (a1 = 1, a2 = .75, b1 = .7, b2 = 1):



Adaptive Capacity – criteria for proxy

1. Specify actor/system that is vulnerable, environment it is vulnerable to (combination of sensitivity, adaptive capacity or ability to cope) & preference criterion to evaluate interaction of actor & environment
2. Capture relative vulnerability and severity in its distribution
3. Account for temporal dynamics of risk, including whether vuln is temporal or chronic and what are risks of falling into vulnerability
4. Account for distribution of vulnerability in a system or among actors
5. Include a threshold of risk, danger or harm
6. Allow at least for one of three assessments: i) rating and ranking of vulnerable actors and/or systems ii) identification of process and drivers of vulnerability, iii) support policy and

Conclusion

Limitations:

- Activities need to have similar timescales
- Assumes that the performance of activities under different environments is independent and memory free
- No competition between actors over resources and the performance of each activity is linearly dependent on the investment in it
- Contribution to vulnerability and adaptive capacity other than diversification neglected in the examples

Conclusions:

- Adaptive capacity defined as the value of switching to the strategy with the minimum vulnerability, where the value is measured by the long-term growth rate (inspired by examples from economics, bio)
- Adaptive capacity of actor that should diversify to cope with its environmental conditions found to be relative entropy

Application: Guadiana river basin

- **Why this study: How to reduce climate related risks**
- **Where: The Guadiana river basin, Spain/Portugal**
- **How: Crop modelling, regional climate scenarios and risk assessment**
- **What: Results**
- **Now what: Conclusions & future work**

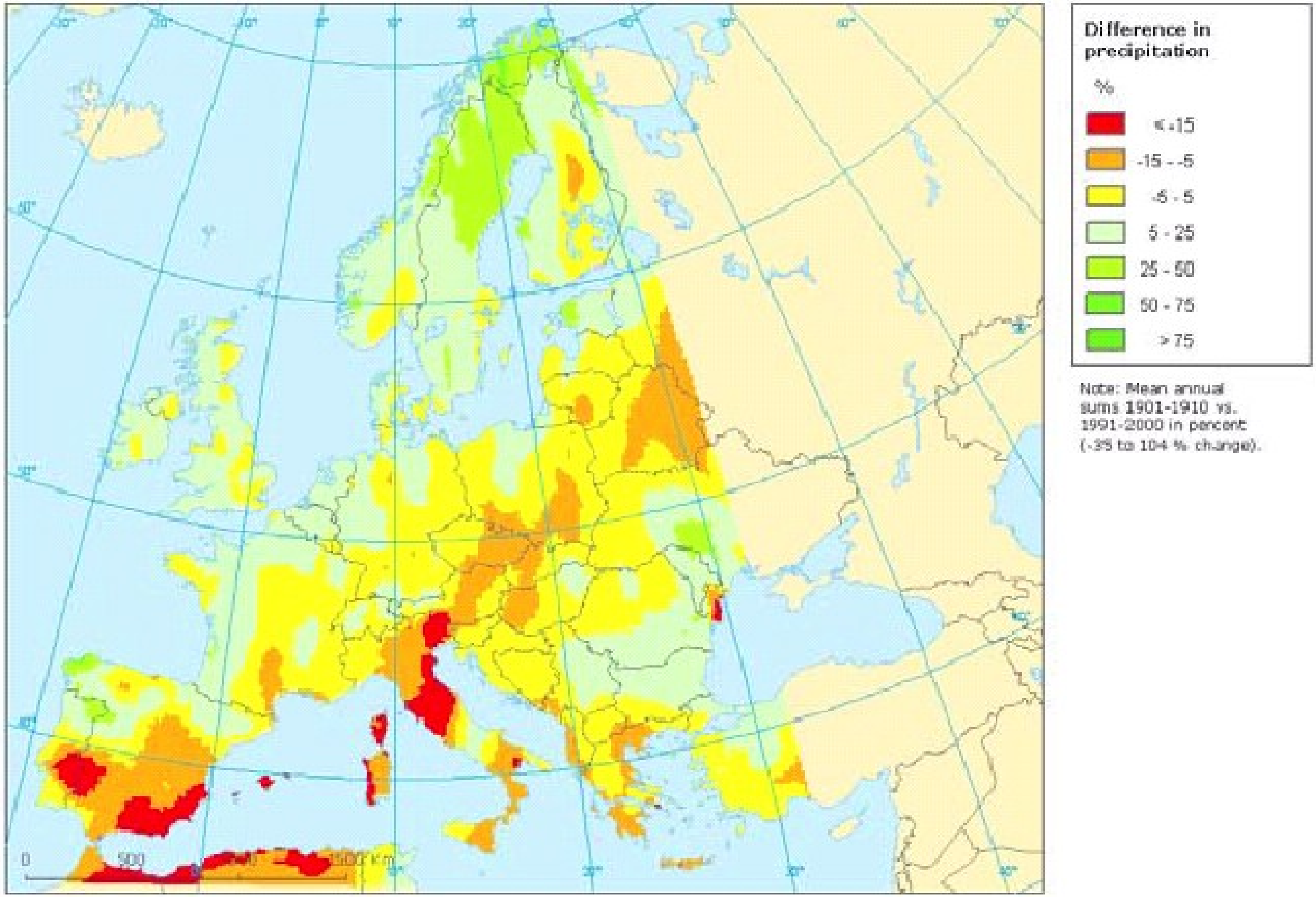
Why this study?

Goal:

- How to adapt to an uncertain climate?
  This study: Find land use/crop patterns that reduce climate risks
- Diversification suggested in various fields as a means to become resilient, cope with shocks (agriculture, ecology, economics)
- Study diversification (here: of agricultural crops) as adaptation strategy (here: to stabilise farmer income)
- Here we define: risk = variance in farmers' income
  (less variance -> better adapted)

Why: Gaudiana river

Figure A3 **Trend in mean annual rainfall during 1900~1998 over the Mediterranean region**



Note: The numerical values in the grids indicate the rainfall changes in percent when the evolution follows a significant trend (P < 0.01).

Source: Hulme, 1999.

Diversification & Portfolio management

- Challenge: to find a robust set of activities that can handle unexpected shocks or events (portfolio)
- When portfolio management: 1) more than one possible investment 2) investment subject to risk 3) same conditions do not affect all investments equally
- ! For land use management !
  Portfolio: set of activities / crops / water services
- Risk: variance of revenue of land uses (cropping pattern)

Portfolio theory:

- Start: revenue over a number of years (modelled or observed)
- Note: NOT damage exclusively but look at changes in revenue

Portfolio management

Terminology	Definition in MPT	Application in this paper
Investment	Items within a portfolio (also called asset)	Different crop types
Portfolio	Set of investments held by a person or an organization	Cropping pattern of different crops grown in an area (grid cell of 12.5 x 12.5 km
Correlation	A measure of the degree to which assets are equally affected by external conditions	A measure of the degree to which crops are equally affected by climate change
Diversifi-cation	Dividing the investment into a variety of (partly-) uncorrelated assets	Growing different crops in an area (grid cell)
Revenue $\overline{R}$	Total revenue (or return) is a measure of the combined income gain (or loss) from a portfolio.	Mean annual revenue earned from the crops grown (price times yield per acre) over a 30 year simulation period.
Risk V	The uncertain outcome of an investment. Risk is measured by the standard deviation or variance of portfolio revenue	Risk is defined as the variance of the revenue in an area (grid cell) over 30 years (1961-1990 or 2071-2100)
Efficient frontier	Portfolios on the efficient frontier are optimal in both offering maximal expected revenue for a given level of risk and minimal risk for a given revenue	Cropping patterns on the efficient frontier are optimal in both offering maximal expected revenue for a given level of risk and minimal risk for a given revenue

Table 3: Terminology used in this paper compared to MPT

Portfolio management

Expected mean revenue

$$\overline{R}_{cropping_{pattern}} = \sum_{i=1}^{n} \overline{R}_i * X_i$$

Risk of cropping pattern

$$V_{cropping_{pattern}} = \sum_{i=1}^{n} X_{i^2} V_i + 2 \sum_{i=1}^{n} \sum_{j=i+1}^{n} X_i X_j \sigma_{ij}$$

Share of crop A in cropping pattern with lowest risk

$$X_{A_{MinV}} = \frac{V_B - \sigma_{AB}}{V_A + V_B - 2\sigma_{AB}}$$

Share of crop A in cropping pattern with best return risk ration

$$X_{A_{OptCP}} = \frac{\left(R_A - R_{risk_{free}}\right) V_B - \left(R_B - R_{risk_{free}}\right) \sigma_{AB}}{\left(R_A - R_{risk_{free}}\right) V_B + \left(R_B - R_{risk_{free}}\right) V_A - \left(R_A + R_B - 2R_{risk_{free}}\right) \sigma_{AB}}$$

How: crop model, climate model, risk

Simulate crop yields (**barley, sunflower**, durum wheat, sorghum, maize) with CropSyst (Cropping Systems Simulation Model) specifying a.o. soil properties, fertilizer, irrigation, CO_2 concentrat.

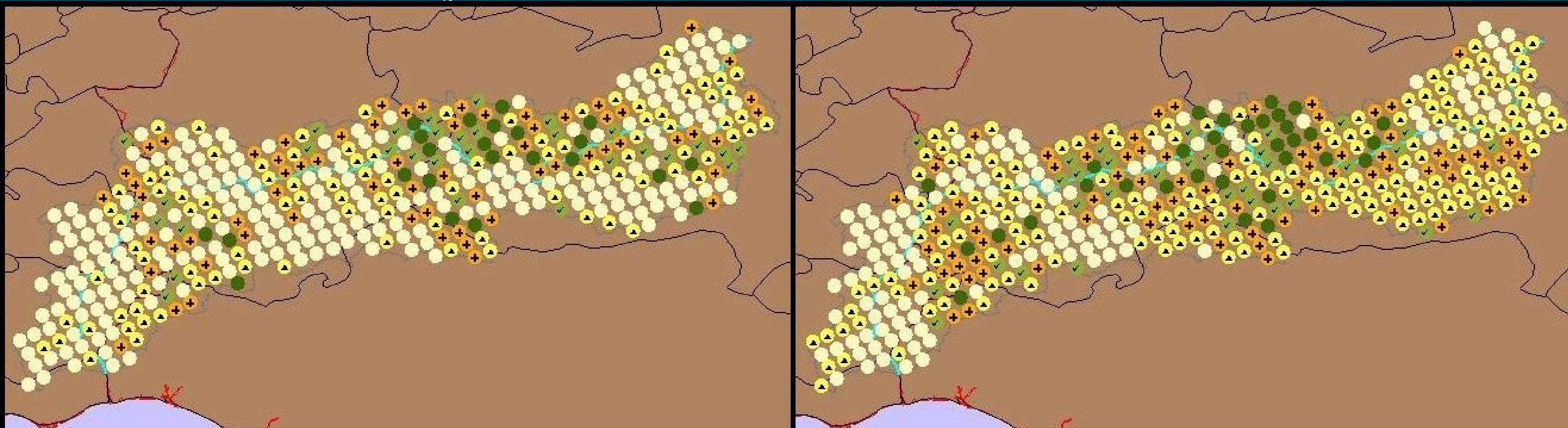
Simulate for climate scenario baseline years 1961-1990; Future climate scenario: A2 2071-2100. Daily data regional climate model HIRHAM, 12.5km grid resolution (PRUDENCE project)

Crop revenue: Mean annual revenue earned from the crops over a 30 year simulation period (gross revenue: price times yield per acre)

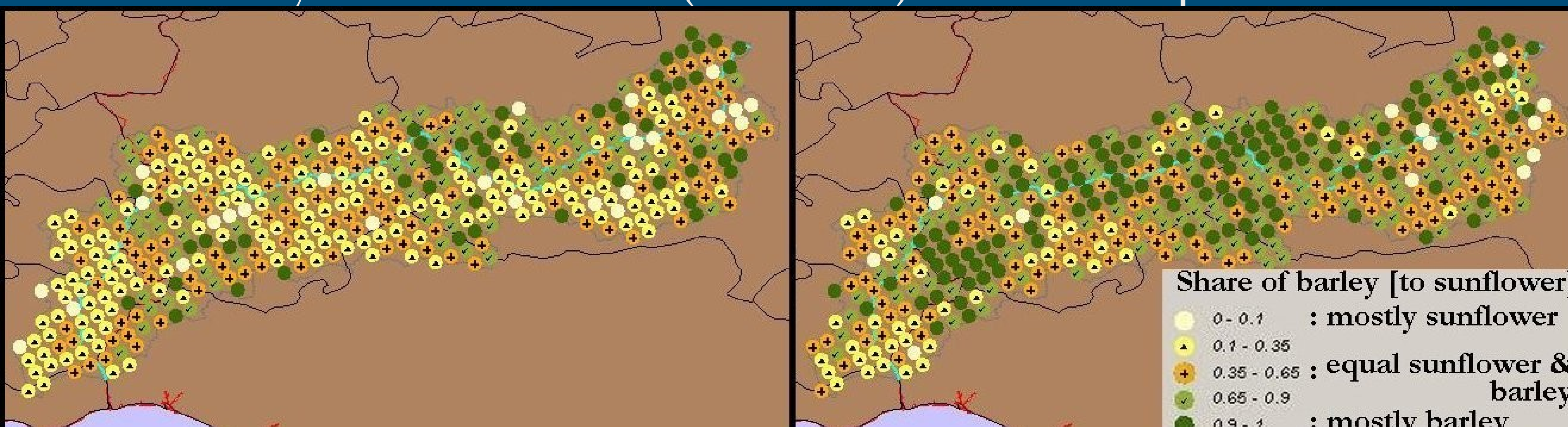
Risk: variance of revenue of cropping pattern (mix of crops) in

Cartoon: mixing two crops in Gaudiana basin

Scenario baseline years 1961-1990; climate scenario A2 2071-2100



Share barley for lowest risk (variance) in total crop revenue



Share barley for best revenue – risk (var.) ratio for total crop

Lessons & Conclusions

- Word of caution: Analysis & previous figure do **NOT** include all relevant crops + land uses. Assessment crop revenue very simple; e.g. subsidies not included. Crop selection not only for adaptation.
- Risk is not (only) snapshot. For adaptation you have to take into account a range of climate conditions and how these conditions impact your activities.
- Diversification can reduce risk depending on local situation. Given your activities and the climate conditions, there is an upper limit to diversification beyond which risks cannot be 'diversified away'.
- Climate change modifies (co)variance of crops (less yields). Re-evaluation of cropping patterns can provide higher risk security.