

Building resilience to climate change in agriculture: the role of robust appraisal methods

Agriculture is highly exposed to climate change, as farming activities directly depend on climatic conditions. Some climate changes may be positive, however many will be negative often aggravating existing environmental problems. In Europe, agriculture plays an important role in food and livelihood provision. Research can support farmers to enlarge their portfolio of strategies and adaptation options, both old and new, to manage increasing climate risks. However, research should not only explore impacts and adaptation options but go one step further: helping to decide to which extent measures should be implemented, appraising adaptations options to weigh costs vs. benefits. In our work, we first gather potential impacts of climate change in the agricultural sector in Europe which include direct effects of climatic variability and climatic extremes on livestock performance and indirect effects on the quantity and quality of feed for the livestock. Considering these impacts, we present an extensive range of predominantly farm-level adaptation options to counteract these. Second, we classify the adaptation options according to whether they would be implemented reactively or anticipatorily. We conclude that a large part of adaptation measures in the agricultural sector will be reactive, as many management decisions are made over short decision horizons, thus adaptation would not need to begin occurring until the climate clearly is changing in a particular way. Put differently, many decisions have a short lifetime. Historically, we have also seen that the agricultural sector does respond to myriad factors including market prices, consumer demand as well as changing weather, where 'adaptation is the norm rather than the exception' (Rosenzweig and Tubiello, 2007). Appraisal in a context of short term adaptations can occur through standard cost-benefit analysis once the climate change impact has been observed. Anticipatory adaptation, i.e. implementing adaptation options before the climate change occurs is needed for capital-intensive investments with a long lifetime. For this, the inherent uncertainty about future climate change impacts makes it challenging to provide meaningful appraisals (Ranger et al., 2010). The costs of adaptation might be observable and immediate, the benefits are uncertain in terms of when (or if) the benefits (avoided damages) will occur, and how large they will be. Decision-makers are often sceptical about the accuracy and reliability of climate projections, choosing to wait for better climate impact information before making adaptation decisions. However, given the complexity, timescales and uncertainties involved in regional climate prediction, climate scenarios will always be inherently uncertain, and waiting may increase vulnerability as well as potentially making the implementation of options more expensive. For anticipatory adaptation measures, we therefore suggest the use of so-called 'robust decision-making methods' for appraisal. Robust approaches deliver adaptation goals by selecting projects that meet their purpose across a variety of plausible

futures and are thus particularly suited for deep uncertainty (Hallegatte, 2009, Lempert and Schlesinger, 2000). Generally, robust approaches do not assume a single climate change forecast but integrate a wide range of climate scenarios. Various mechanisms are used for this purpose, including identifying the least vulnerable strategy across scenarios. *Robust Decision Making* which can be applied to complex decisions with differentiated adaptation options and many stakeholders such as water basin management (Lempert and Groves, 2010). Real option analysis defines adjustable strategies by integrating the idea that we learn about climate change impacts over time decreasing uncertainty (Dixit and Pindyck, 1994). Such strategies can be applied to flood risk infrastructure (Gersonius et al., 2013) or farm buildings. Finally portfolio analysis reduces overall risk by diversification of assets both for long-lived decisions such as conservation management (Ando and Mallory, 2012) and for increased climate variability such as wider temperature ranges for livestock. In our work, we provide concrete examples on how the adaptation options, both long life time/anticipatory and short life time/reactive measures can be appraised technically by providing modelling suggestions and specifying the data necessary as guidance to decision-maker in the agricultural sector.

Keywords: agriculture, climate change, adaptation, economic appraisal, robust decision-making

150 word summary:

Research can support farmers to enlarge their portfolio of adaptation options to climate change. We focus on appraising adaptation options to climate change, helping to decide to which extent measures should be implemented. We conclude that a large part of measures in the agricultural sector will be reactive, as many management decisions are made over short decision horizons. Appraisal in this context can occur through standard cost-benefit analysis. Anticipatory adaptation, i.e. implementing adaptation options before the climate change occurs is needed for capital-intensive investments with a long lifetime. However, the inherent uncertainty about climate change impacts make appraisals challenging. For anticipatory adaptation measures, we therefore suggest the use of 'robust decision-making methods' for appraisal. Robust approaches deliver adaptation goals by selecting projects that meet their purpose across a variety of plausible futures and are thus particularly suited for deep uncertainty. We provide concrete examples on how these could be accomplished technically as guidance to decision-makers in the agriculture.

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