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Towards an assessment of adaptive capacity of the European agricultural sector to droughts

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A B S T R A C T

Analyses of climate change vulnerability and risk have been steadily evolving, and have moved from an impact-focused towards a more risk-based approach. In the risk and vulnerability communities, the relevance of resilience and adaptive capacity (AC) are increasingly emphasized. Another emerging analytical framework is the idea of assessing AC and resilience in terms of the Sustainable Livelihoods Approach (SLA), which studies welfare as a function of multiple forms of assets ('capital') that systems and agents may utilize to both recover as well as increase resilience in the future. We assess a new method for assessing AC at a sectoral level and operationalize AC measurement based on an SLA to assess the ability of the European agricultural sector to adapt to extreme droughts. We create a set of indicators which highlight areas of high or low AC, forecast to estimated times the world will reach 2° of warming using Shared Socioeconomic Pathway (SSP) and Representative Concentration Pathway (RCP) scenarios to drive AC indicator projections based on a fixed effects model. We find that based on this approach, Central and Northern Europe rank higher in overall capacity than countries on the periphery, and projections to 2 °C do not change results to a large degree. We critically reflect on the use of this approach and suggest possible use cases for results in larger studies of sectoral vulnerability, and highlight key data gaps and the need for a stronger empirical basis for selection of indicators, which constrain our ability to assess AC.

Practical Implications

As climate change is predicted to have major impacts in the future, particularly upon the agricultural sector in some regions of the EU, this work attempts to move beyond biophysical impacts to assess the capacity of these regions to adapt to change. Southern areas face the possibility of increased droughts, and increased warm and dry conditions are forecast for southern and central Europe, with the possibility of up to 10% losses in crop yields by 2080. These assessments underscore the need to further investigate the potential impacts on the broader socioecological system. One possible avenue lies in emerging risk methodologies, which emphasize assessing the socio-ecological system as a whole. Our work provides an assessment of the adaptive capacity of the agricultural sector of the EU facing drought hazard.

Adaptive capacity (AC), ''the ability to adjust, take advantage of opportunities, or cope with consequences. (IPCC, 2014),'' has been assessed before on both a global and regional level, but the research methods, sectors of study, and spatial scales have differed greatly. This work can be seen as a first step, and while the process of assessing AC is still in relative infancy at this scale and for individual sectors, it presents valuable avenues for further research and a valid option for a way to convey important information to stakeholders and to emphasize the ideas of risk based analysis and the resilience of systems to change.

The Sustainable Livelihoods Approach has been utilized in previous AC assessments and provides a broad framework for organizing the different forms of assets to which people have access, and helps describe the use to which these assets may be put. SLA was developed conceptually by Ellis (2000) and views livelihoods strategies as made of activities that are invented, adapted and adopted in response to changing availability to five types of capacities or assets:

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1. Human capacity: the education, skills and health of household members.
2. Social capacity: reciprocal claims on others by virtue of social relationships and networks, close social bonds that aid cooperative action and social bridging and linking via which ideas and resources are accessed.
3. Natural capital: the natural resource base such as productivity of land, and actions to sustain productivity, as well as water and biological resources.
4. Physical capacity: items produced by economic activity from other types of capital; this may include infrastructure and equipment.
5. Financial capacity: the level, variability and diversity of income sources and access to other financial resources that combine to contribute to wealth.

Based on the SLA framework, we assemble an index of adaptive capacity consisting of human, natural, physical, and financial capacities, based on both theoretical and empirical links of proxy indicators as drivers of adaptive capacity. The selected indicators can be found in Table 1. These indicators are aggregated at a national level to provide an indication of areas with high or low adaptive capacity of the agricultural sector, and allows for comparisons between EU countries, shown in Fig. 1. Countries in the central European region are found to have higher overall adaptive capacity than those on the periphery to the south and east. France scored strongly in all four capital estimates, and has the highest overall capacity index value, whereas Germany, which did not over- or under-perform in any particular category, but was usually near to the median value, results in a more moderate score. Southern and eastern countries suffer from a lack of physical and human (and to a lesser extent, natural) capacity compared to the core, however there is some bolstering of values from financial capital, where southern drought-prone countries score highly due to strong insurance mechanisms.

As discussed in Section 2, adaptive capacity is only one factor for the impact of extreme events, and when combined with exposure and hazard, produces an estimate of vulnerability. AC can be projected via the use of scenarios describing possible futures, and combined with estimates of future biophysical impacts. Due to the new and novel aspects of our AC assessment, uncertainties and lack of consistent and high-resolution data limits the predictive power of this first order estimate of vulnerability, but we can demonstrate how future work building off of the concepts discussed here can be used. Combining the AC index with estimates of drought hazard impacts from the EPIC model results in an estimate of crop-specific future vulnerability to drought, seen in Fig. 2 below, for varying RCP/SSP combinations.

While this assessment differs from previous ones in its sector- and hazard-specific nature, the use of such a framework provides a basis upon which to frame the organization of AC into four distinct capacities; human, natural, physical, and financial. Due to the specific nature of the assessment, key indicators derived from the SLA framework differ greatly compared to previous AC assessments, which were much broader in nature and used more abstract proxy variables. A more focused approach may provide a clearer picture which is more relevant for the actual hazards facing the agricultural sector, and provide a more accurate assessment of the system's ability to cope with future changes. While our results agree to some extent with previous assessments, findings should not be seen as completely robust, due to a lack of data, and the limitations of the indicator approach to allow for consideration of all possible contributors to adaptive capacity.

The capitals framework does well to illustrate the various assets people or systems have to adapt to change, and goes beyond current vulnerability assessments which view capacities as physical and/or financial capitals with commensurable assets, but how to incorporate the more abstract notions of adaptive capacity and inform probabilistic risk assessments is still an open question Using such a framework to describe capacities is a valuable effort, in that it conveys the idea that the ability of people and systems to adapt to change goes beyond just having fiscal resources or physical goods to help, but that human assets and social bonds, as well as the natural environment, are all critical to facing a changing future climate.

1. Introduction

As disaster impacts continue to increase (IPCC, 2012) amid the threat of climate change – reiterated by broad scientific consensus – there is a growing importance on developing strategies to reduce vulnerability to both current and future extreme events (IPCC, 2012). As emphasized in the latest IPCC Assessment Report, a changing climate will amplify existing risks and create new ones which are unevenly distributed, with greater impacts on disadvantaged communities at all levels of development (Chambwera et al., 2014). In order to effectively make decisions regarding adaptation to future changes, policymakers need an approach which can link climate-driven impacts and scenarios for the future with greater understanding of the overall system in question, such as governance, equity, economic assessments and the diverse set of possible responses to future risks, to both highlight areas that may be vulnerable now and in the future, and recommend policy options to increase resilience (IPCC, 2014).

Risk, as used in the study of extreme events, is a function of vulnerability, exposure, and a hazard. Vulnerability, the propensity of a system to be adversely affected (IPCC, 2012) is influenced by adaptive capacity (AC), "the ability to adjust, take advantage of opportunities, or cope with consequences (IPCC, 2014)." The main challenge in being able to assess adaptive capacity is being able to reveal it, as it is a latent property of a system, only emerging once a system is subject to external stress or shock (Engle, 2011). This

Table 1
Adaptive capacity indicators used in assessment of agricultural sector of the EU.

Human capital	Natural capital	Physical capital	Financial capital
Percentage of farm managers with full agricultural training	Productivity of land	Value of buildings and machines	Total farm cash flow
Farm managers/owners with other gainful employment	Irrigation prevalence	Total current assets (e.g. non-breeding livestock, stores of agricultural products)	Farm solvency
Number of scientists working in agricultural sector	Fertilizer use	Total breeding livestock assets	Crop insurance index score

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