Assessing the Vulnerability of Organic Farming Systems - A Case Study from the Federal State of Brandenburg, Germany

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Abstract

Impacts of climate change on agriculture have been predominantly analyzed by using biophysical and crop specific model applications. Vulnerability assessments which identify the vulnerability of regions with their farming systems are urgently required, because agricultural adaptations to climate change are related to regional specifics, and therefore research has to consider the regional level. Therefore sector- and system-specific approaches have to be developed. This paper presents the methodology of a vulnerability assessment for organic farming systems in the Brandenburg Region, which considers regional-specific climatic impact, as well as the regional-specific adaptive capacity. In this region, the cultivation and management of legume-grass swards have a key position, especially the climate change impact on legume symbiotic nitrogen fixation and nitrogen mineralization. Adaptation strategies of crop production systems include reduced soil tillage, which plays an important role also in organic farming systems (reducing soil erosion, improving water infiltration, reducing evaporation and improving soil structure, control of N-dynamics) are developed and tested by means of an action research approach.

1. Introduction

There are in principle two distinct strategies in climate policy to cope with the effects and consequences of climate change. Mitigation is the strategy in which measures are taken to reduce emissions of climate-relevant gases; in adaptation, adaptive measures are developed in response to those impacts of climate change which can no longer be avoided. While climate change mitigation focuses on global measures (e.g., worldwide targets for reducing greenhouse gases), adaptation to climate change requires regional and sector-specific approaches (LAUKKONEN et al., 2009). However, interdisciplinary studies which identify the vulnerability of regions with their farming systems are missing (OLESEN et al., 2011). In Germany, under the auspices of the German National Adaptation Strategy, such approaches are being developed in large-scale joint projects in various model regions throughout the country (BUNDESREGIERUNG, 2008). One of these model regions is Brandenburg-Berlin, in which the project “Innovation Network Climate Change Adaptation Brandenburg Berlin (INKA BB)” is currently being carried out. In this region, climate change particularly affects organic farming, which is practiced here on a large scale and makes up 10% of total farming area. The organic farmers face the considerable challenge of developing adaptive measures compliant with organic farming systems and standards, because many strategies used in conventional farming are not applicable (e.g. extensive use of glyphosate in no-tillage systems). For this reason, organic farmers from Brandenburg are working together with researchers from the Leibniz-Centre for Agricultural Landscape Research (ZALF) and the Eberswalde University for Sustainable Development, University of Applied Sciences (HNEE), to develop measures for adapting to climate change specific to organic farming. In contrast to conventional studies on climate change impacts, which focus on biophysical changes (e.g., temperature increases, water availability, CO_2 fertilization effect) and effects on plant growth (e.g., effects on photosynthetic activity), the project "Climate adapted Organic Farming" focuses on the vulnerability of organic farming systems.

2. The concept of vulnerability

The term vulnerability represents a concept, based on systems theory, which takes into account not only the external effects of climate change on human-environment systems, but also considers the internal socioeconomic factors in these systems (see FÜSSEL & KLEIN, 2006; DIETZ, 2006). According to the IPCC, "Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity." (IPCC, 2007). In accordance with this definition, the vulnerability analysis being conducted by the subproject "Climate adapted Organic Farming" includes sector-specific observation of exposure, sensitivity and adaptive capacity. According to EAKIN (2008), vulnerability is increased by the factors exposure and sensitivity, but decreased by adaptive capacity. Exposure is the extent to which the system of interest is subject to changes in climate parameters (e.g., temperature, precipitation) (BIRKMANN et al. 2011). In contrast to exposure, sensitivity describes how susceptible that particular system is being affected by these changes. It is primarily determined by inherent characteristics that exist independent of exposure (GALLOPIN, 2006). In order to actually estimate the potential effects of climate change, it is necessary to consider both exposure and sensitivity. However, the extent to which climate change effects will negatively affect the system also depends significantly on its adaptive capacity. According to the German National Adaptation Strategy, adaptive capacity describes the entirety of the skills, resources and institutions that a country or region can access in order to implement adaptive measures (BUNDESREGIERUNG, 2008). This depends on factors such as economic resources, know-how, the introduction of new technologies and innovations, institutional capacities and political will. (SCHULTZ-STERNBERG et al., 2010). Additional socioeconomic determinants of adaptive capacity are described by YOHE and TOL (2002) and GÜNTHER (2009). These include resources such as social networks, access to risk-distribution processes, and how effectively decision-makers can manage information and reach decisions.

3. Application to organic farming in Brandenburg

When these three components of vulnerability are applied to organic farming in Brandenburg, a nuanced picture emerges:

In terms of exposure (the nature and extent of climate shifts), evidence indicates that Brandenburg will be hit especially hard by climate change effects compared to other regions in Germany (GERSTENGARBE et al., 2003; ZEBISCH et al., 2005). Already, lower annual precipitation, milder winters with increased precipitation, and decreased precipitation in early summer present challenges for organic farmers. In addition, extreme weather events, such as heavy precipitation and heat waves, are becoming increasingly frequent (MLUV, 2008). According to GERSTENGARBE et al. (2003), the climatic water balance can be expected to continue to worsen. Already, the mean annual potential evaporation (628 mm y-1) is higher than the mean annual precipitation (600mm y-1). The following climate change effects can be expected by the year 2055, according to SCHULTZ-STERNBERG et al. (2010), based on the available climate projections for Brandenburg:

- Increase in average annual temperatures of 1.4 - 3°C
- Decrease in annual precipitation of 30 - 50mm
- Shift in seasonality of precipitation (decreased in summer, increased in winter)
- Increase in potential evapotranspiration
- Decrease of actual evapotranspiration in summer and increase in winter, while annual sum total remains steady (SCHULTZ-STERNBERG et al., 2010)

Due to its sensitivity, the organic farming systems in Brandenburg will be very susceptible to the predicted climate change effects described above. This high level of sensitivity is a consequence of the sites used by most large-scale organic farms in Brandenburg, which are characterized by sandy soils with low available water capacity (BACHINGER, 2002). Such sites are particularly susceptible in the face of climate change, leading to decreased crop yields (see WEIGEL, 2010; ZEBISCH et al., 2005; MLUV, 2008). One reason for this increased susceptibility are difficulties with sufficient nitrogen (N) supply, an already existing problem for organic agriculture which could be exacerbated by the predicted effects of climate change. Increasing water shortages could severely limit the growth of the forage and grain legumes the main N sources of organic farming systems. This would result in marked deficiencies in forage and nitrogen supplies. Such problems already cause a low to zero livestock density at many large-scale organic farms. However, this approach limits the farms' availability of farmyard manure, as a valuable flexibly applicable nitrogen source. In addition, the N supply of non-leguminous crops is limited through the widespread sandy soils with low natural humus content. In particular, the increasingly mild winters with increased precipitation enhance the risk of nitrogen losses caused by increased N-mineralization and subsequent nitrate leaching (see WEIGEL, 2011; THOMSEN et al., 2010; EITZINGER et al., 2009; RUSTAD et al., 2001). Moreover, increasing pre-summer droughts decreases severely the microbial nitrogen mineralization at sandy soils with a low water holding capacity (see LEIRÓS et al., 1999; STANFORD et al., 1974). Winter cereals are most affected due to the high nitrogen demand during this period. To assess the sensitivity of organic farming in Brandenburg in more detail, the project uses regionalized multi-year climate projections for Brandenburg from the climate model STAR within a model for predicting the yield of herbage from legume-grass swards (see BACHINGER & REINING, 2009). This allows for the yield simulation and, therefore, the symbiotic nitrogen fixation of legume-grass swards for different regions up to the year 2055. How severely organic farming in Brandenburg will be affected by the described negative climatic effects, is integrally related to the adaptive capacity of the different farms. In the project, knowledge about the adaptive capacity is generated using combined plot and on-farm experiments as well as periodical SWOT analyses, planned and carried out collaboratively by farmers, agricultural consultants and scientists (action research approach). In this manner, four organic farms in Brandenburg are currently testing new climate-adapted cropping techniques, in practice. Simultaneously these measures are investigated within multifactorial plot experiments at the research station at ZALF

i) Optimizing the supply of nitrogen and water for winter wheat (Gut Wilmersdorf)
ii) Water-efficient establishing of cover crops after cereals (Ökodorf Brodowin)
iii) Optimizing crop sequence of forage rye corn silage (Landgut Pretschen)
iv) Increasing crop diversity using winter peas and summer rye with reduced tillage (Beerfelder Hof)

3.1 Preliminary results of the on-farm experiments

All ongoing experiments are focused on the following combination of cropping measures; reduced tillage versus inverting tillage, crop cultivars, modified sowing dates, and cover crops. Additionally, an innovative tillage device the so called ‘ring cutter’ from HEKO agricultural machinery is being tested. It allows for a shallow overall tillage, an effective root transection while preserving soil structure and moisture at stubble tillage and killing of legume-grass swards (increasing adaptive capacity by introducing innovations)

Results from the plot and farm experiments can be summed up as followed;

- Perennial legume-grass can be effectively and timely killed with the ring cutter, at both damp (spring) and dry (summer) soils (i).
- Stubble tillage (ring cutter) with simultaneous cover crop establishment can improve the soil organic matter reproduction through higher biomass production (ii).
- Diversification of sowing dates of winter cereals (i) and silage maize (iii) combined with different tillage measures improves the adaptive capacity through risk reduction and optimization of the N-management in crop sequences.
- A combination of a shallow inverting tillage with topsoil loosening could be a promising trade off between soil erosion protection and sufficient N-mineralization at sandy soils (iii).

4. Discussion

Based on the preliminary results a set of different climate change adaptation options, aiming on “compromise-based management”, appear particularly promising; e.g. tilling in the damp spring months avoiding harmful soil compaction, timely sowing of summer cereals using minimum-tillage for erosion prevention, increasing infiltration, reducing evaporation and adjusting soil nitrogen dynamics by combining different reduced and inverting tillage systems (see BLOCH und BACHINGER, 2010, REYER et. al 2011).

The action research approach of the ongoing project (SWOT analyses, on farm research) shows that organic farms in Brandenburg are innovatively oriented and open to invest in climate-adapted cropping techniques and crops (e.g. winter peas, summer rye, proso millet and lentils), which are supported by marketing channels specific to organic products (ROLLE, 2011).

According to DARNHOFER (2005) farms with diversified cropping systems are better able to react to and recover from changes (climate, market, agrarian policies etc.), which positively affects their resilience and adaptive capacity. Therefore farms within the same region with the same exposure can differ greatly in their adaptive capacity, which depends first and foremost on the farm manager’s knowledge and experience, the available resources, and the farming system of each farm. Up to now organic farming appears to have an increased adaptive capacity, but further investigations based on entire vulnerability analyses are needed.

References

Bachinger, J. (2002): Ökolandbau in Nordostdeutschland. In: Forschungsreport (25), S. 30–34.

Bachinger, J. & Reining, E. (2009): An empirical statistical model for predicting the yield of herbage from legume-grass swards within organic crop rotations based on cumulative water balances. In: Grass and Forage Science (64), S. 144–159.

Birkmann, J.; Böhm, H. R.; Buchholz, F.; Büscher, D.; Daschkeit, A.; Ebert, S. et al. (2011): Glossar Klimawandel und Raumentwicklung. In: E-Paper der ARL (10).

Bloch, R.; Bachinger, J. (2010): Anpassung an den Klimawandel im Praxistest. Innovationen im Ökologischen Landbau. In: Forschungsreport (2), S. 18–21.

Bundesregierung (2008): Deutsche Anpassungsstrategie an den Klimawandel. vom Bundeskabinett am 17. Dezember 2008 beschlossen.

Darnhofer, I. (2005): Resilienz und die Attraktivität des Biolandbaus für Landwirte. In: Michael Groier und Markus Schermer (Hg.): Bio-Landbau in Österreich im internationalen Kontext. Zwischen Professionalisierung und Konventionalisierung. Wien: Bundesanst. für Bergbauernfragen (Forschungsbericht / Bundesanstalt für Bergbauernfragen, 55), S. 67–84.

Dietz, K. (2006): Vulnerabilität und Anpassung gegenüber Klimawandel aus sozial-ökolgischer Perspektive. Aktuelle Tendenzen und Herausforderungen in der internationalen Klima- und Entwicklungspolitik. Freie Universität Berlin; Institut für ökologische Wirtschaftsforschung; Technische Universität Berlin (Global Governance und Klimawandel, 1/2006).

Eakin, H. (2008): Human Vulnerability to global environmental change. Hg. v. C. Cleveland. Environmental Information Coalition, National Council for Science and the Environment. Washington, D.C (Encyclopedia of Earth).

Eitzinger, Josef; Kersebaum, Kurt Christian; Formayer, Herbert (Hg.) (2009): Landwirtschaft im Klimawandel. Auswirkungen und Anpassungsstrategien für die Land- und Forstwirtschaft in Mitteleuropa. 1. Aufl.: Agrimedia. Clenze.

Füssel, H.-M. & Klein, R. (2006): Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking. In: Climatic Change 75, S. 301–329.

Gallopin, G. C. (2006): Linkages between vulnerability, resilience, and adaptive capacity. In: Global Environmental Change (16), S. 293–303.

Gerstengarbe, F. W.; Badeck, F.; Hattermann, F.; Krysanova, V.; Lahmer, W.; Lasch, P. et al. (2003): Studie zur klimatischen Entwicklung im Land Brandenburg bis 2055 und deren Auswirkungen auf den Wasserhaushalt, die Forst- und Landwirtschaft sowie die Ableitung erster Perspektiven. Hg. v. F. -W Gerstengarbe. Potsdam-Institut für Klimafolgenforschung e.V. Potsdam (PIK-Report, 83).

Günther, Elmar (Hg.) (2009): Klimawandel und Resilience Management. Interdisziplinäre Konzeption eines entscheidungsorientierten Ansatzes. 1. Aufl.: Gabler Verlag / GWV Fachverlage GmbH Wiesbaden. Wiesbaden.

IPCC (Hg.) (2007): Climate Change 2007: Synthesis Report. IPCC, Geneva, Switzerland, 104 pp. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland.

Laukkonen, J.; Blanco, P. K.; Lenhart, J.; Keiner, M.; Cavric, B.; Kinuthia-Njenga, C. (2009): Combining climate change adaptation and mitigation measures at the local level. In: Habitat International 33, S. 287–292.

Leirós, M. C.; Trasar-Cepeda, C.; Seoane, S.; Gil-Sotres, F. (1999): Dependence of mineralization of soil organic matter on temperature and moisture. In: Soil Biology & Biochemistry 31 (3), S. 327–335.

MLUV (2008): Landespolitischer Maßnahmenkatalog zum Klimaschutz und zur Anpassung an die Folgen des Klimawandels. Hg. v. Umwelt und Verbraucherschutz Landes Brandenburg (MLUV) Ministerium für Ländliche Entwicklung.

Olesen, J. E.; Trnka, M.; Kersebaum, K. C.; Skjelvåg, A. O.; Seguin, B.; Peltonen-Sainio, P. et al. (2011): Impacts and adaptation of European crop production systems to climate change. In: European Journal of Agronomy 34, S. 96–112.

Reyer, C.; Bachinger, J.; Bloch, R.; Hattermann, F. F.; Ibisch, P. L.; Kreft, S. et al. (2011): Climate change adaptation and sustainable regional development: a case study for the Federal State of Brandenburg, Germany. In: Reg Environ Change.

Rolle, E. (2011): Anpassungskapazität von landwirtschaftlichen Betrieben in Brandenburg an den Klimawandel - eine Fragebogenstudie. Masterarbeit. Hochschule für nachhaltige Entwicklung Eberswalde (FH), Eberswalde. Fachbereich Landschaftsnutzung und Naturschutz.

Rustad, L. E.; Campbell, J. L.; Marion, G. M.; Norby, R. J.; Mitchell, M. J.; Hartley, A. E. et al. (2001): A Meta-Analysis of the Response of Soil Respiration, Net Nitrogen Mineralization, and Aboveground Plant Growth to Experimental Ecosystem Warming. In: Oecologia 126 (4), S. 543–562.

Schultz-Sternberg, R.; Bartsch, R.; Hommel, R. (2010): Brandenburg spezifische Boden-Indikatoren für ein Klimamonitoring und Grundlagen zur Ableitung von Wirkungs- und Alarmschwellen. Hg. v. Landesumweltamt Brandenburg (Fachbeiträge des Landesumweltamtes, 114).

Stanford; G.; Epstein, E. (1974): Nitrogen Mineralization-Water Relations in Soils. In: Soil Science Society of America 38, S. 103–107.

Thomsen, I. K.; Lægdsmand, M.; Olesen, J. E. (2010): Crop growth and nitrogen turnover under increased temperatures and low autumn and winter light intensity. In: Agriculture, Ecosystems and Environment 139 ((1-2)), S. 187–194.

Weigel, H.-J. (2010): Kulturpflanzen im Klimawandel - Schaden und Nutzen. In: Agrarsoziale Gesellschaft e.V. (ASG) (Hg.): Klimaschutz- und Anpassungsstrategien in Landwirtschaft und ländlichem Raum. Ländlicher Raum 61 (3). Göttingen.

Weigel, H.-J. (2011): Klimawandel – Auswirkungen und Anpassungsmöglichkeiten. In: Gerold Rahmann und Ulrich Schumacher (Hg.): Praxis trifft Forschung. Neues aus dem Ökologischen Ackerbau und der Ökologischen Tierhaltung 2011. Landbauforschung - vTI Agriculture and Forestry Research 354. Braunschweig: vTI, S. 9–28.

Yohe, G.; Tol, R. S. J. (2002): Indicators for social and economic coping capacity - moving toward a working definition of adaptive capacity. In: Global Environmental Change 12.

Zebisch, M.; Grothmann, T.; Schröter, D.; Hasse, C.; Fritsch, U.; Cramer, W. (2005): Klimawandel in Deutschland – Vulnerabilität und Anpassungsstrategien klimasensitiver Systeme. Hg. v. Umweltbundesamt. Potsdam Institut für Klimafolgenabschätzung. Dessau-Roßlau (Climate Change, 08/05).