P3.2. Climate change and agricultural production risks

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1. Three research questions of the project

- Will changes in drought occurrence (frequency/persistence) increase crop production risks by affecting physical and chemical properties of agricultural soils? (Task 1)
- How will changes in climate, water availability and associated production risks alter the spatial distribution of land suitability for agricultural production? (Task 2)
- What are the possibilities offered by either financial market or agronomic instruments to manage relevant climate-change induced production risks in Swiss agriculture? (Task 3)

2. Research Summary

More frequent and persistent periods of agricultural droughts (insufficient soil moisture supply) during the cropping season present a difficult challenge to European farmers. In Phase 2, the project GRASS provided a quantification of drought risks in Swiss agricultural regions (Calanca, 2007) and an evaluation of consequences for crop production at the field scale (e.g. Torriani et al. 2007). In Phase 3, we will further examine implications of increasing drought risks for agricultural production resulting from effects either on soils and water availability, or on farm profitability, and evaluate in more detail options for risk management.

Task 1. *To investigate long-term changes in soil properties*. More frequent and persistent periods of hot and dry weather (droughts) could threaten soil fertility and the potential for soils to act as a carbon (C) sink. If the rate of organic matter (SOM) decomposition exceeds the rate of input and stabilization of C from plant residues, soils may turn from a C sink to a source of atmospheric CO_2. SOM stabilization depends on residue input quality, physicochemical properties and soil biological activity, all of which may be affected directly by more frequent and persistent dry spells and high temperatures, and indirectly through shifts in vegetation towards more xeric, drought-tolerant plant species. Modelling these changes at decadal to centennial time-scales remains a challenge due to limitations in current SOM models, but new experimental information could help improving the models. We currently investigate SOM amounts, SOM fractions and turnover rates along altitudinal gradients to infer the effect of temperature (e.g., Leifeld et al., 2008). In AGRISK, we will examine the hypothesis that frequent/persistent droughts will cause measurable changes in soil properties that affect SOM stabilization and turnover. Special attention will be given to the role of root dynamics, soil respiration, and C partitioning. Improved models will be used to test the long-term sensitivity to regional climate scenarios of SOM and C stocks in representative soil types.

Subtask 1.1: Characterizing changes in physical and chemical characteristics of soils either exposed to experimental soil water manipulation or from natural soil moisture gradients. We will build on work carried out in Phase 2 and complement investigation of plant-related changes by other groups (UNI Be, ETHZ).

Subtask 1.2: Improving the formulation of SOM turnover in mechanistic models such as PROGRASS (developed in Phase 2) and RothC based on results from Subtask 1.1

Subtask 1.3: Modelling direct and indirect effects of changes in temperature and soil moisture on soil C stocks at the decadal to centennial scale, with an emphasis on grassland soils in Switzerland.

Task 2. *To develop and apply a general methodology for the assessment of land suitability for agricultural production (cropland, grassland).* Shifts in the suitability of land available for agriculture are expected as a result of changes in temperature and water availability. Warming will favour regions where currently temperature is a major constraint (higher altitudes), but more frequent and persistent dry spells will increase the area at risk from limited soil water availability and therefore negatively affect the possibilities for rain-fed production.

Subtask 2.1: Development of a methodology for the assessment of climate suitability which explicitly takes into account risks from climatic extremes, in particular droughts. The development will be guided by existing approaches to agro-ecological zonation (e.g. Sivakumar and Valentin, 1997; http://www.fao.org/ag/agl/agll/aez.stm) but will more

systematically quantify the role of climate variability. Moreover, it will take advantage of advances in modelling landscape configuration based on optimization.
Subtask 2.2: Development of future scenarios of land suitability as constrained by projections for climate and water availability and under assumed levels of nutrients inputs and management.
Subtask 2.3: Application of the methodology developed in Subtasks 2.1 and 2.2 to create distribution maps of land suitability for Switzerland and selected areas in Europe.

Task 3. *To evaluate options for farm risk management:* Changing frequencies of extreme climate events, in particular drought, heat waves or heavy precipitation, in association with changes in mean temperature are becoming a specific concern for farm operations. Thus, improved risk management strategies will be necessary to cope with increasing agro-climatic risks. The aim of Task 3 will be to investigate the prospective role of climate-related risk management in Swiss agriculture, thus expanding the work of Torriani et al. (2008) and Finger et al. (2008) in Phase 2. In order to find efficient options for future risk management, potential measures will be identified, evaluated and compared from an economic and sustainability perspective. The considered time horizons for this analysis are the years 2030 and 2050. Different adaptive strategies ranging from agronomic measures such as irrigation to financial instruments (e.g. insurances, weather derivatives) will be considered. Taking into account trends and developments on national and international insurance markets, future demand for climate-related risk management will be analyzed.
Subtask 3.1: Identifying adaptation instruments that are potentially applicable and useful for agricultural production in Switzerland, taking into account short- and long-term needs for adaptation.
Subtask 3.2: Evaluation of financial market instruments to manage future climate-related risks in Swiss agriculture.
Subtask 3.3: Comparison of different adaptation measures to manage future climate-related risks, with an emphasis on risks associated with extreme events.

3. Data and methods

All Tasks: The same climate scenarios from PRUDENCE, ENSEMBLES and, depending on availability, from P2.1 and P2.3 will be used.

Task 1. *Climate change and soil properties*: **Data**: Experimental results from the PLANT/SOIL project obtained during Phase 2 and 3, and from other ongoing ART projects (SNF, COST, EU) (e.g., SOM amounts, SOM fractions, SOM turnover along gradients). **Methods**: Soil samples obtained from control and drought-treated plots at the two remaining sites in the PLANT/SOIL experiment will be analyzed. Samples taken at the start of the experiment are also available but have not been investigated so far. Retrieval of additional soil samples from other experiments such as the long-term experiment in the Southern Swiss Alps (A. Stampfli, UNI Be) will be considered, together with samples collected and analyzed from soils along natural soil moisture gradients. Established methods for SOM fractionation (Zimmermann et al. 2007a) and analyses of soil physical properties (e.g. wettability, hydrophobicity) will be used. **Models**: PROGRASS (Lazzarotto et al., 2008) and RothC (Zimmermann et al., 2007b).

Task 2: **Data:** Spatially explicit data for climate, soil and terrain, and for land use. Several GIS layers will be available from an ongoing country-wide project on crop water requirement. Crop-specific data for water requirements will be collected from ART experts. ***Methods:*** Combination of GIS and statistical and/or dynamic models. In particular, we envisage using an approach known as Bayesian Belief Network in which variables are linked together according to their dependencies, and which allows considering uncertainties in model results (Holzkämper et al., 2008).

Task 3: *Risk management:* **Data:** Farm-level data (management, yield, performance), weather data from different meteorological stations, survey data, crop simulation model output. **Methods:** Literature review, empirical field research methods (interviews), statistical models (using, e.g., extreme value analysis, bootstrap, multivariate statistics), economic modelling (e.g. linear and non-linear programming). For the latter, functional yield relationships for major crops will be inferred from crop simulation model outputs.

4. Milestones and deliverables

After 18 months:

- Sources of samples identified, soil analytical methods and sampling design established, explorative analysis of test samples completed (Task 1);
- Concept and modelling framework established, and model evaluation for land suitability mapping tested; data sources identified (Task 2);
- Climate-related risk and most promising risk management strategies are identified; effectiveness of different financial market instruments is analyzed and compared (Task 3).

After 36 months:

- Soil samples from experimental plots taken and analyzed, data evaluated and compared with simulation model results; long-term model simulations completed (Task 1);
- Maps of land suitability for different time slices, with uncertainties, available (Task 2);
- Optimal design of future insurance products developed, optimal strategies to cope with climate-related risks (agronomic and financial market) determined (Task 3).

5. Contribution to the WP3 and collaboration with other NCCR projects and 3rd parties

Field data will be used from P3.1, the Swiss Fluxnet, associated ART-projects and the project of A. Stampfli (UNI Be). Climate scenarios will be used - when available - from P2.1 for Europe and P2.3 for Switzerland. Simulation results will be provided to P3.3. Results for market and price developments will be used from P4.2 and information will be shared with P4.1 and P4.2 regarding (financial) risk management and international regulations. Collaboration with SwissRe and Swiss Hail-Insurance regarding index-based insurance will be continued. Further external collaboration will exist with partners in EU FP7 (ACQWA), the Federal Office of Agriculture, the Swiss Agency for Development and Cooperation (Project PACC) and with partners in associated NSF and COST projects.

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