FACCE-MACSUR

Deliverable T2.1 Climate dependent yields

Task Leader: Ruslana Rachel Palatnik[1]*, partners involved: Zvi Baum[1], Iddo Kan[1,3,] Mickey Rappaport-Rom[1] Mordechai Shechter[1] P186; Waldemar Bojar, UTP, P100; Petra Salamon, Johann Heinrich von Thünen-Institut, vTI, P112; Alina Syp, Institute of Soil Science and Plant Cultivation - State Research Institute (Poland), P125; Peter Zander, ZALF, P147; Hermann Lotze-Campen, PIK, P183; Erwin Schmid, BOKU-INWE, P208; Franz Sinabell, WIFO, P209

[1] NRERC-Natural Resource and Environmental Research Center, University of Haifa, Israel.
[2] The Academic College of Emek Yezreel, Israel.
[3] The Robert H. Smith Faculty of Agriculture, Food and Environment; The Hebrew University, Israel.

*rusalik@gmail.com

	Instrument: Joint Programming Initiative
Topic:	Agriculture, Food Security, and Climate Change
Project:	Modelling European Agriculture with Climate Change for Food Security (FACCE-MACSUR)
Start date of project:	1 June 2012
Duration:	36 months
Theme, Work Package:	TradeM 2
Deliverable reference num.:	D-T2.1
Deliverable lead partner:	U Haifa
Due date of deliverable:	month 24
Confidential till:	–

Revision	Changes	Date
1.0	First Release	2012-07-30

Executive Summary

In this report we summarize the contributions made by four groups to the subject of climate dependent yields. The first is by Waldemar Bojar, Leszek Knopik, Jacek Żarski, Cezary Sławiński, Piotr Baranowski and Wojciech Żarski on the subject of "the impact of extreme climate changes on the forecasted agriculture production". It presents general characteristics of resources and outputs of agriculture in the Kujawsko-Pomorskie (K&P) and Lubelskie regions, based on statistical databases and the literature review. In this study, some statistically significant dependencies between the climatic parameters and yields of selected important crops in the abovementioned regions were worked out on the basis of empirical survey conducted in the University of Technology and Life Sciences and Institute of Agrophysics in Lublin. Efforts were taken to make integrated assessments of forecasted agricultural outputs influenced by climate extreme phenomena on the basis of the found dependencies' yields – precipitation and the data coming from wide area model regional outputs such as prices, areas of farmland and yields.

The second contribution is by Bojar W., Knopik L. and Żarski J. on the subject of "integrated assessment of business crop productivity and profitability to use in food supply forecasting". It examines the proposals to build a model describing the amount of precipitation and taking into account periods without rain. This model is based on a mixture of gamma distribution and one point-distribution.

The third contribution is by Iddo Kan on the Vegetative Agricultural Land Use Economic (VALUE) model. It discusses the sub-task with respect to crops of statistically estimating with statistical methods predictions of expected crop-yield contingent on climate, soil and production cost for use in existing trade models, or refined versions thereof, and how VALUE can contribute to this sub-task.

The fourth contribution was made by Christoph Muller and Richard D. Robertson on the subject of "projecting future crop productivity for global economic modelling". It supplies a set of climate impact scenarios on agricultural land productivity derived from two climate models and two biophysical crop growth models to account for some of the uncertainty inherent in climate and impact models.

Table of Contents

1 The impact of extreme climate changes on the forecasted agriculture production, *Waldemar Bojar Leszek Knopik Jacek Żarski Cezary Sławiński Piotr Baranowski Wojciech Żarski*[1]

1.1 Abstract

The study presents general characteristics of resources and outputs of agriculture in the Kujawsko–Pomorskie (K&P) and Lubelskie regions, based on statistical databases and the literature review. Some specific features of the regions with special consideration for the predicted extreme climate changes are also included. Next, some statistically significant dependencies between the climatic parameters and yields of selected important crops in the abovementioned regions were worked out on the basis of empirical survey conducted in the University of Technology and Life Sciences and Institute of Agrophysics in Lublin. Creating an appropriate method of forecasting long series of decades without precipitation was necessary to find the desired dependencies. Third, some efforts were taken to make integrated assessments of forecasted agricultural outputs influenced by climate extreme phenomena on the basis of the found dependencies' yields – precipitation and the data coming from wide area model regional outputs such as prices, areas of farmland and yields.

1.2 Discussion of the findings

A comprehensive exploration of the integrated scenarios of mitigation, adaptation and residual climate impacts will require significant contributions from climate modelling, integrated assessment modelling and impact/adaptation/vulnerability research. Nowadays, the problem is too complex to reach such a comprehensive integration within individual crosscutting studies; however, such studies will be of great importance to obtain a better-integrated view on mitigation and adaptation (Kriegler, 2012: 807–822). The analysis of climate change impact, adaptation and vulnerabilities depend, to great extent, on the assumptions about underlying socio-economic developments but employed socio-economic scenarios to a lesser degree. This is caused by the multitude of contexts and scales of such analysis (Kriegler , 2012: 807–822). Differences in a wide area of models regarding socio-economic scenarios and specific situations of the analysed regions may concern the

[1] Edited parts of the authors' original paper are included in this report.

unemployment level, the tax system structure and its imperfections, the share of informal economy, the barriers to capital flow and trade imbalances, biased saving behaviours, the presence or absence of social safety nets and can change the assessment of modelled scenarios in the future (Babiker, Eckaus, 2007: 600–609), (Guivarch et al., 2011: 768–788). The regional case study approach presented in this study can develop shared socio-economic pathways as one of the many contributions and collaborative work between integrated assessment and the impact/adaptation/vulnerability researchers (Kriegler, 2012: 807–822).

1.3 Conclusions

The calculation of the future agricultural output volume and value in Kujawy & Pomorze affected by the changes in yields of cereals, wheat, barley and potatoes, expected changes to their yields because of precipitation and its distribution, extreme changes in 2030 and 2050 and large-scale spatial model assumptions allow one to create some forecasts with a defined probability of occurrence of extreme output changes compared to average ones. In this way, the elaborated method of forecasting long series without precipitation was positively verified. Projections of producer prices from the selected model baseline scenarios (GAMP) were also possible after the comparison of models based on regional empirical data. This allows one to forecast the levels of outputs of selected crops in agriculture in the surveyed regions in 2030 and 2050, calculated according to differentiated simulated assumptions. It can help with conducting a more appropriate agricultural and trade food policy to ensure food safety in different spatial scales of Europe and balance the food supply and demand in the perspective of the next 40-50 years. The survey conducted in the Lubelskie voivodship does not confirm essential and statistically-verified dependencies between precipitation levels, its distribution and their impact on the yield of wheat.

This can be, to some extent, explained with a smaller deficit of water in Lubelskie, as compared to this deficit in K&P. This allows one to conclude that the impact of specific regional climatic conditions in Poland for the production of some crops, e.g. wheat, cannot be excluded, although in quantitative hold it is not always possible to verify it statistically. Hence, the impact of specific conditions of different regions on the dependency yield – the precipitation is different. This allows one to verify the formulated hypothesis positively, meaning that extreme precipitation events can strongly influence the agricultural output of important crops within the analysed regions in a view of average trends forecasted on the basis of large-scale spatial models and data.

1.4 References

BABIKER, M.H. AND R.S. ECKAUS (2007): Unemployment effects of climate policy. Environmental Science and Policy 10 (7–8), 600–609.

GUIVARCH, C., R. CRASSOUS, O. SASSI AND S. HALLEGATTE (2011): The costs of climate policies in a second best world with labour market imperfections. Climate Policy 11, pp. 768–788.

KRIEGLER, E., B.C. O'NEILL, S. HALLEGATTE, T. KRAM, R.J. LEMPERT, R.H. MOSS AND T. WILBANKS (2012): The need for and use of socio-economic scenarios for climate change analysis: A new approach based on shared socio-economic pathways. Global Environmental Change 22, pp. 807–822.

2 Integrated assessment of business crop productivity and profitability to use in food supply forecasting, *Bojar W., Knopik L., Żarski J.*[2]

2.1 Abstract

Climate change suggests long periods without rainfall will occur in the future quite often. The previous approach showed that the dependence of crop-yields due to the size of rain is statistically significant. The study examines the proposals to build a model describing the amount of precipitation and taking into account periods without rain. This model is based on a mixture of gamma distribution and one point-distribution. In the work on the basis of rainfall data, one can estimate parameters of the mixture. Estimators of these parameters were constructed using the method of maximum likelihood. Available data on precipitation allows for the confirmation of the hypothesis of the adequacy of the proposed model's rainfall. Long series of days or decades without rainfall allow one to determine the probabilities of adverse developments in agriculture (droughts). This could be the basis for forecasting crop yields in the future.

Forecasted crop yields in the future (the years 2030 and 2050) can be used for assessment of the productivity and profitability of some selected crops in Kujavian-Pomeranian region. Assumptions and parameters of large-scale spatial economic models will be applied to build up relevant solutions. Calculated with this approach, output could be useful in expecting a decrease in the agricultural output in the region. It will enable

[2] Edited parts of the authors' original paper are included in this report.

one to shape effective agricultural policy in order to know how to balance the food supply and demand through appropriate managing with stored raw food materials and/or import/export policies.

Used precipitation-yields the dependencies method allowing one to verify the earlier used methodology through a comparison of the obtained solutions concerning forecasted yields and close to it to an uncertainty analysis.

2.2 Introduction

Precipitation is a key component that links the atmosphere and the portions of the Earth's surface where water is in solid form through complex processes. Thus, accurate knowledge of precipitation levels is a fundamental requirement for improving the prediction of weather systems and of climate change. In particular, some of the weather forecast models use data assimilation techniques that require accurate precipitation estimates at high spatial and temporal resolutions.

In many applications, such as climate change, hydrology and meteorology, rainfall phenomena play a significant role. In numerous applications, the processes involved depend on microstructure of rain. The microstructure of rain is defined by raindrop size distribution, which represents the expected number of the raindrop per unit of the raindrop's diameter interval and the per unit volume of air. This is in the most popular form, although numerous studies assume more general exponential or gamma distributions. The problem with the approach is that the raindrop size distribution definition assumes the temporal stationary and spatial homogeneity of the rain, which is in practice never reached, even at a small scale of the order of typical inter-drop distance. Observed climate change causes undesired trends in the precipitation level and frequency of what it can influence essentially yields and agricultural production output. On the basis of the proved precipitation changes in the Kujavian-Pomeranian regions in Poland, one can forecast crop yields in the future (for the years 2030 and 2050) [Bojar et al. 2013]. It can be used for the assessment of productivity and the profitability of some selected crops the in Kujavian-Pomeranian region. Assumptions and parameters of large-scale spatial economic models will be applied to build up relevant solutions. Socio-economic and technical criteria could be useful in the study of and especially forecasted cropping areas, yields, prices and costs, which will be employed to estimate the possible economic effects of forecasted more often periods of droughts. Calculated with this approach, the output could be useful for anticipating a decrease in the agricultural output of the surveyed crop (spring barley) yield in the region. It will enable one to shape, in a wider scope, effective agricultural policy to know how to balance the food supply and demand through the appropriate management of stored food raw materials and/or import/export policies. Secondary, met with the abovementioned methods, precipitation-yield dependencies allow one to verify an earlier-used methodology [Bojar, Knopik 2013] through a comparison of obtained solutions concerning forecasted yields in the future and closed to it an uncertainty analysis.

2.3 Discussion and Conclusions

The calculation of the future agricultural output volume and value in the Kujavian and Pomeranian region affected by the changes in yields of spring barley allows for an estimate associated with it and a risk of an imbalance in the food supply and demand. The found solution is based on expected changes to barley's yield due to precipitation and its distribution, extreme changes in 2030 and 2050 and large-scale spatial model assumptions. This allows one to create some forecasts with a defined probability of the occurrence of extreme output changes compared to average ones. Projections of producer prices from the selected model baseline scenarios (GAMP) were also possible after the comparison of models based on regional empirical data. This allows one to forecast the levels of outputs of selected crops in agriculture in the surveyed regions in 2030 and 2050, calculated according to differentiated simulated assumptions. It can help with conducting a more appropriate agricultural and trade food policy to ensure food safety in different spatial scales of Europe and balance the food supply and demand in the perspective of the next 40-50 years.

2.4 References

Bojar W., Knopik L., Żarski J., 2013. Analiza wpływu warunków klimatycznych na plonowanie roślin uprawnych w regionie kujawsko-pomorskim (Analysis of the impact of climate conditions on crop yields in the Kujavian-Pomernian region). Studies & Proceedings of the Polish Association for Knowledge Management. No. 64. pp. 31-44.

Bojar W., Knopik L. 2013. Paper presented at MACSUR project workshop at the Leibniz Centre for Agricultural Landscape Research (ZALF), Mücheberg, Germany November 18-20, 2013 titled: "Integrating TradeM and CropM MASCUR
models for regional case studies in Poland". (University Bydgoszcz, Poland)
http://ocs.macsur.eu/public/conferences/2/schedConfs/2/program-en_US.pdf)

Research was made within the framework of the FACCE JPI – MACSUR project titled: 'A detailed climate change risk assessment for European agriculture and food security, in collaboration with international projects' - Contract no. FACCE JPI/04/2012; a portion of the P100 PARTNER (UTP) project is financed by NCBiR.

3 The VALUE Model, *Iddo Kan*[3]

3.1 Introduction

A main sub-task with respect to crops is to statistically estimate with statistical methods predictions of expected crop-yield contingent on climate, soil and production cost for use in existing trade models, or refined versions thereof. The work is closely related to C2.5 (Empirical data analysis), and benefits of cooperation are expected in terms of methodology and model structures.

For the assessment of future climate change impacts on land use patterns and agricultural markets, the Agricultural Model Inter-comparison and Improvement Project (AgMIP; agmip.org; Rosenzweig et al., 2013) together with MACSUR project and the Inter-Sectoral Impact Model Inter-comparison Project (ISI-MIP; isi-mip.org) has conducted multi-model simulations with harmonized data on future yield changes. These scenarios are designed to assess the upper end of climate change impacts, therefore addressing only a high-emission scenario, RCP8.5 (Moss et al., 2010; Riahi et al., 2011), and without considering possible growth enhancing effects of higher atmospheric carbon dioxide concentrations ([CO2]), which are subject to large uncertainties (Long et al., 2006; Tubiello et al., 2007) and require adjustments in management (Ainsworth and Long, 2005). The two crop models employed (DSSAT as a widely used field scale model and LPJmL as a widely used ecosystem-based model) represent the two different groups of gridded global crop models.

3.2 The VALUE Model

VALUE (Vegetative Agricultural Land Use Economic) is a regional scale model, which analyzes the impact of changes in various exogenous factors on agricultural use of land and other inputs. This is a Positive Mathematical Programming (PMP) model, which was developed by Kan, and applied for the analysis of a range of agricultural issues, including

[3] Edited parts of the author's original paper are included in this report.

climate change (Kan et al., 2007; Palatnik et al., 2012), rural landscape (Kan et al., 2009), agricultural recycling of organic wastes (Kan et al., 2010) and irrigation water management (Kan and Rapaport-Rom, 2012), which is the main issue studied using the VALUE model.

Among the well known programming models of agricultural water use are the SWAP (Statewide Water and Agricultural Production), which is integrated into CALVIN (CALifornia Value Integrated Network) (Lund et al., 2003), and AGSM (Agricultural SUbmodel), which has been developed as a sub-model to WAS (Water Allocation System) and applied to Israel (Fisher et al., 2005). Other models have been developed for the case of Israel by Becker, Zeitouni and Shechter (1996) and Yehoshua and Shechter (2003). Most of these agro-economic models are based on an assumed water demand function of the vegetative agricultural sector, which is estimated by the use of aggregated data, observed during a base period. Such an estimated function, however, may not accurately represent responses to large shocks, which shift water demands away from the range of consumptions included in the estimation dataset. Alternatively, extrapolations may be rely on production functions, which are estimated based on outputs of agronomic models and calibrated for a base period. Examples for this method include Letey and Dinar (1986), Plesner and Feinerman (1995) and Kan (2003). The VALUE model applies this meta-analysis approach. In this process we apply the crop-production model developed by Shani and coworkers (Shani et al., 2007), in which soil parameters of hydraulic conductivity affect yields through their impact on water uptake under plant-soil-atmosphere equilibrium conditions. The model also captures the effect of salinity on yields. This crop model produces outputs based on which non-linear production functions are estimated and used to describe yield responses to water quantity and quality (e.g., Kan, Schwabe and Knapp, 2002).

VALUE is based on a two-stage mathematical programming procedure: in the first stage it is calibrated so as to reproduce observed base-period's regional land and water allocations among 45 crops; in the following stage, changes in various parameters are introduced and optimal land and water applications are calculated. Internalization of land allocation among crops is based on a positive mathematical programming calibration approach (Howitt 2005); thereby, the model assesses impacts on optimal agricultural management, where adaptation to changes is considered endogenously with respect to both the extensive (land allocation among crops) and intensive (field level water application) margins.

The model has been developed and calibrated for the case of Israel. Applications of the model include the analysis of policies to internalize external agricultural benefits, and examination of the effects of expected trends in the water economy, mainly the projected changes in the availability of various water sources and prices.

Nevertheless, VALUE has been primarily developed for the assessment of climate-change impacts; in particular the effects of the associated changes in water availability. Changes in precipitations affect both levels: in the field level they directly contribute to crops' water availability through rainfall during the growing season, while in the regional scale they affect the constrained amount of various types of irrigation-water sources. Since the production functions capture the impacts of both water quantity and salinity, the model accounts for the adverse effects of irrigation by brackish waters and treated wastewaters, which are largely used as substitutes of freshwater in Israel.

3.3 References

Becker, N., Zeitouni, N. And Shechter, M. 1996. "Reallocating Water Resources in the Middle East through Market Mechanisms." *Water Resources Development,* 12(1):pp. 17-32.

Feinerman, E., J. Letey, and H. J. Vaux, Jr. “The Economics of Irrigation with Nonuniform Infiltration.” *Water Resources Research* 16, no. 6 (1983):1410-1414.

Fisher, F.M., Huber-Lee, A., Amir, I., Arlosoroff, S., Eckstein, Z., Haddadin, M., Hamati, S.G., Jarrar, A., Jayyousi, A., Shamir, U. and Wesseling. H. 2005. "*Liquid Assets: An Economic Approach for Water Management and Conflict Resolution in the Middle East and Beyond*." Resources for the Future press, Washington, D.C.

Howitt, R.E. 2005. "Agricultural and Environmental Policy Models: Calibration, Estimation and Optimization." **http://www.agecon.ucdavis.edu/aredepart/facultydocs/howitt/master.pdf**

Kan, I. 2003. "Effects of drainage-salinity evolution on irrigation management." *Water Resources Research*, 39(12):pp. 1377-1388.

Kan, I., Ayalon, O., Federman, R., 2010. On the efficiency of composting organic wastes. Agricultural Economics 41, 151-163.

Kan, I., Haim, D., Rapaport-Rom, M., Shechter, M., 2009. Environmental amenities and optimal agricultural land use: The case of Israel. Ecological Economics 68, 1893-1898.

Kan, I., Rapaport-Rom, M., 2012. Regional blending of fresh and saline irrigation water: Is it efficient? Water Resources Research 48.

Kan, I., Rapaport-Rom, M., Shechter, M., 2007. Assessing climate change impacts on water, land-use and economic return in agriculture.

Kan, I., Schwabe, K.A. and Knapp, K.C. 2002. “Microeconomics of Irrigation with Saline Water.” *Journal of Agricultural and Resource Economics*, 27(1):pp. 16-39.

Letey, J., and A. Dinar. 1986. “Simulated Crop-Water Production Functions for everal Crops When Irrigated With Saline Waters.” *Hilgardia* 54(1):pp. 1-32.

Lund, J.R., Howitt, R.E., Jenkins, M.W., Zhu, T., Tanaka, S., pulido, M., Tauber, M., Ritzema, R. and Ferriera, I. 2003. "Climate Warming and California’s Water Future." Center for Environmental and Water Resources Engineering Report No. 03-1, Dept. of Civil and Environmental Engineering, University of California, Davis, CA, http://cee.engr.ucdavis.edu/faculty/lund/CALVIN/, 2003.

Palatnik, R.R., Eboli, F., Ghermandi, A., Kan, I., Rapaport-Rom, M., Shechter, M.-. 2012. Integration of general and partial equilibrium agricultural land-use transformation for the analysis of climate-change in the Mediterranean. Climate Change Economics 2, 275-299.

Plessner, Y., Feinerman, E., 1995. "On the economics of irrigation with saline water: A dynamic analysis." Natural Resour. Model. 9: pp. 255-276.

Shani, U., Ben-Gal, A., Tripler, E., Dudley, L.M., 2007. Plant response to the soil environment: An analytical model integrating yield, water, soil type, and salinity. Water Resources Research 43.

Yehoshua, N. and Shechter, M. 2003. "Climate Change and Agriculture: an Israeli Prespective" In Giupponi, C and Shechter, M. (eds.), Climate Change in the Mediterranean: Socio-Economic Perspectives of Impacts, Vulnerability and Adaptation, Edward Elgar Publication.

4 Projecting future crop productivity for global economic modelling, *Christoph Muller, Richard D. Robertson*[4]

Assessments of climate change impacts on agricultural markets and land-use patterns rely on quantification of climate change impacts on the spatial patterns of land productivity. We supply a set of climate impact scenarios on agricultural land productivity derived from two climate models and two biophysical crop growth models to account for some of the uncertainty inherent in climate and impact models. Aggregation in space and time leads to information losses that can determine climate change impacts on agricultural markets and land-use patterns because often aggregation is across steep gradients from low to high impacts or from increases to decreases. The four climate change impact

[4] Parts of the authors' original paper are included in this report.

scenarios supplied here were designed to represent the most significant impacts (high emission scenario only, assumed ineffectiveness of carbon dioxide fertilization on agricultural yields, no adjustments in management) but are consistent with the assumption that changes in agricultural practices are covered in the economic models. Globally, production of individual crops decrease by 10–38% under these climate change scenarios, with large uncertainties in spatial patterns that are determined by both the uncertainty in climate projections and the choice of impact model. This uncertainty in climate impact on crop productivity needs to be considered by economic assessments of climate change.

The details of this study can be found in:

Christoph Muller, C. and Robertson, R. D. (2014). Projecting future crop productivity for global economic modelling, Agricultural Economics 45, 37–50.