BOOK OF PROCEEDINGS

3rd International and 15th National Congress

Publisher

Serbian Society of Soil Science

Editors

Prof. Dr Boško Gajić
Assist. Prof. Dr Ljubomir Životić
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Each contribution included in the Book of Proceedings was positively reviewed by international referees.

Organized by:

Serbian Society of Soil Science
University of Belgrade, Faculty of Agriculture

Supported by:

Ministry of Education, Science and Technological Development of the Republic of Serbia
Maize Research Institute "Zemun polje", Belgrade, Serbia
Semenarna d.o.o., Niš, Serbia
Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia – Directorate for Agricultural Land
Terra Optima d.o.o., Topola, Serbia
Best Seed Producer d.o.o., Feketić, Mali Iđoš, Serbia

Printed by:

Štamparija Nikitović, Užice, Serbia, 2021

Published in 130 copies

ISBN-978-86-912877-5-7

CLIMATE CHANGE AS THE DRIVING FORCE BEHIND THE INTENSIFICATION OF ACRICULTURAL LAND USE

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Abstract

Climate change in Europe will lead to new precipitation patterns over the next few years and the annual temperature will increase significantly. These changes in climate variables and the resulting effects on agricultural productivity must be differentiated regionally. Plant production depends on sufficient rainfall in summer and, in some regions, on the amount of rainfall in winter. In Central Europe, the amount of precipitation in summer will decrease in the coming decades due to climate change, in some regions the amount of winter precipitation will increase significantly. Agricultural production can suffer severely as a result of rising summer temperatures and low water retention capacities in the soil. The effects of climate change were examined and described 15 years ago. They were examined on the basis of scenarios using plant simulation models. The effects of reduced summer precipitation and increased air temperatures are partially offset by the expected increased CO_2 concentration. Therefore, the effects of changed climatic conditions on crop production are sometimes less drastic on crop yields. The greatest impact of climate change on land use is expected from increasing evapotranspiration and lower amounts of precipitation in the production of leachate. In addition to the expected mean changes, the occurrence of extreme weather conditions is decisive. Here, periods of drought in the growing season and heavy flooding as a result of extreme rainfall are to be expected. However, these events are very difficult or impossible to predict! In addition to the effects of climate change on regional crop production, global changes will have a strong impact on world markets for agricultural products. Another consequence of climate change and population growth is a higher demand for agricultural products on world markets. This will lead to dramatic local land use changes and intensification of agriculture that will

transform existing crop production systems. The intensification caused by rising land and lease prices will primarily affect the maximization of the use of fertilizers and pesticides.

Keywords: climate change, crop production, intensification of land use, water balance, global agricultural production, sustainability, population growth

INTRODUCTION

Regional changes in precipitation and air humidity are associated with global climate change. As a result of the rise in temperature, the annual evaporation requirement of the atmosphere will increase. This results in an acceleration of the hydrological cycle of evaporation and precipitation. The temperature-dependent increase in the water vapor storage capacity of the atmosphere leads to an increase in latent energy in the troposphere. This also results in a worldwide increase in the number of extreme climatic events, such as storms, droughts and heavy precipitation with subsequent flooding. The main problem with these extreme events is that they cannot be predicted by any currently available climate models and that their occurrence as a result of climate change is becoming more and more frequent. In addition, the principles developed by humans, rules of conduct in everyday life, but also the production methods of agricultural land use are geared to typical, mean weather situations. Planning and reacting under such uncertain framework conditions is very difficult and in most of our economic and social areas not well or not yet developed. In addition to changes in the economy, population aging and migration, climate change is the central element of "global change". The expected changes in the climate in the coming decades will not be underestimated in terms of productivity (e.g. due to water shortage or excess), but also in the landscape-ecological functionality of land use systems (e.g. habitat function for species, new groundwater formation). It can already be foreseen today that the direct effects of climate change on the productivity of land use systems will in the short and medium term, influence the world markets for agricultural products and thus also energy supply to a considerable extent. For this reason, the investigation and assessment of the production and landscape ecological consequences of climate change on agriculture must be subdivided into the three areas of impact of climate change:

- Impact of climate change on the production function of land use systems
- Impact of climate change on the ecological functionality of land use systems and
- Effect of climate change on the world markets for agricultural products with the expected feedback effects on agriculture.

This is the focus of the present consideration. Only such a complex consideration of the effects of climate change will make it clear in the results of the analyzes that agriculture will be among the winners as well as the losers in terms of socio-economic and landscape-ecological aspects.

MATERIALS, METHODS, RESULTS

Effect of climate change on the production and the land-ecological function of the agricultural landscape

Using the example of two specific study areas with typical land use and similar soils, Eulenstein et al. (2005, 2006) examined how the components of the soil water balance and especially the water availability for agricultural crops could change as a result of the expected climate change. When selecting the study areas, emphasis was placed on the fact that both study areas were dominated by sandy soils with low field capacity. This factor represents the size of the reservoir for water in the soil (corresponds to the area that can be rooted in the depths). In the sandy areas, the agricultural conditions, which are already difficult during the growing season, become even more unfavorable. Between 1961 and 1990 the mean precipitation in Germany determined over many years was 790 mm (1 mm "water column" corresponds to an amount of one liter of water per square meter of soil). For regions in eastern Germany, however, the long-term mean precipitation is only 615 mm, in the Müncheberg area (small town east of Berlin) only 520 mm / year and in the Oderbruch further east it is only 460 mm / year. In addition to the low rainfall, the fact that we are mainly dealing with soils with low water storage capacity in northeast Germany and western Poland is noticeable. The soil value figures determined with the official soil estimate correlate very well with the amount of water that is available for plants and stored in the rooted area of the soil. The soils that dominate the regions are predominantly ground and terminal moraines shaped by the Ice Age, as well as sand areas with relatively low soil values. These sandy soils have a storage capacity of around 100–150 mm down to a depth of one meter. The soils that are considered to be the best in this regard, the black earth soils in Central Germany, on the other hand, can store approx. 240 mm of water at the same depth as available for plants. On warm days in midsummer, approx. 6 mm of water evaporates (corresponds to 6 l / m^2). Under these conditions, a Chernozem would be able to provide the plants with water for 40 days. In purely mathematical terms, a population on sandy soils has reached the end of the water replenishment from the soil after just 17 days. Results from lysimeter and field tests (Roth et al., 1997; Schindler et al., 2001; Müller et al., 2004, Schindler et al., 2007) on with regard to between water consumption, effectiveness of water use and yield formed the basis for deriving the water availability classes. In eastern Germany and western Poland, these problems of poor soil storage capacity and low rainfall accumulate in a way that is unique in Central Europe. It is precisely in these regions that the effects of the expected climate change are likely to be most serious. These location conditions - with water as the most important production factor in shortage - in combination with very little water-storing soils lead to the fact that the production conditions for farms in these regions are to be assessed as problematic, especially during periods of low precipitation within the vegetation periods. In the course of the forecast warming, the decline and the intra-annual redistribution of precipitation from summer to winter half-year (Gerstengabe et al., 2003), this situation may worsen in the future.

Effects on the water balance and the yields of agricultural production systems

The aim of a study by Wiggering et al. (2008) and Eulenstein et al. (2016) was the analysis of the effects of the expected climate change on land use and the landscape water balance of agricultural locations in northeast and central Germany. The first thing to do was to clarify in detail: how the climatic water balance and substance discharges (nitrate and sulphate) under agriculturally used areas as well as the yields of agricultural crops will change under future climatic conditions. An agricultural landscape, located directly at the east of the German capital Berlin was selected for these calculations. It covers 54,000 ha. Exact surveys in the period 1993-2001 on crops, yields and fertilization of a total of 54 farms served as the basis for the calculations. The period from 1993–2001 serves as the reference period for the Gerstengabe et al. (2003) defined climate scenario (Fig. 4.3-3). The scenario calculations are based on a temperature increase of approx. 1.4°K for the period 2001–2055. This trend was determined from the result data of the ECHAM4-OPYC3 model from the Max Planck Institute for Meteorology Hamburg. This model run is based on the IPCC (2001) emissions scenario A1B-CO2, which results in a relatively moderate increase in temperature.

Effects on the water balance of agricultural

It was shown that the plant population already completely deplets the water supply of the soil under today's climatic conditions during the vegetation period. Therefore, the calculated current evapotranspiration during the summer half-year shows no differences between the actual climate and the assumed climate scenario. With the help of the HERMES / SULFONIE models from Kersebaum (1995), a potential evapotranspiration of 510 mm per year was calculated. Taking into account the cultivated crops and the limited water availability in the summer months, the current evapotranspiration is almost 100 mm lower and amounts to 417 mm per year. The leachate donation is around 140 mm per year on average over the years. In the model, the ground water displaced downwards is shown as seepage water, which is displaced deeper than 2 m. The data of the weather patterns of the climate scenario, synthetically generated on the basis of the results of the climate models, show the following picture: the evapotranspiration largely follows the precipitation rates, while the seepage water rate falls to a very low level.

From these calculations (Fig. 1) it can be deduced that under the mean climate changes to be expected in the future, the stress situations for plant populations caused by the water availability could increase. Evaporation, especially in the winter months, due to a rise in temperature, is likely to increase. From the overall extent of the change in evaporation, however, the increase in water shortage for arable crops can be classified as rather moderate.

Therefore, the negative consequences for the generation of income should remain rather manageable under medium conditions. However, the frequency with which extreme weather conditions occur, such as 2018, 2019, 2020 (summer drought) or 2002, 2013, 2021 (precipitation-related floods), is certainly decisive for the economic situation in agriculture. The accumulation of such extreme years could become the real problem for agricultural crop production.

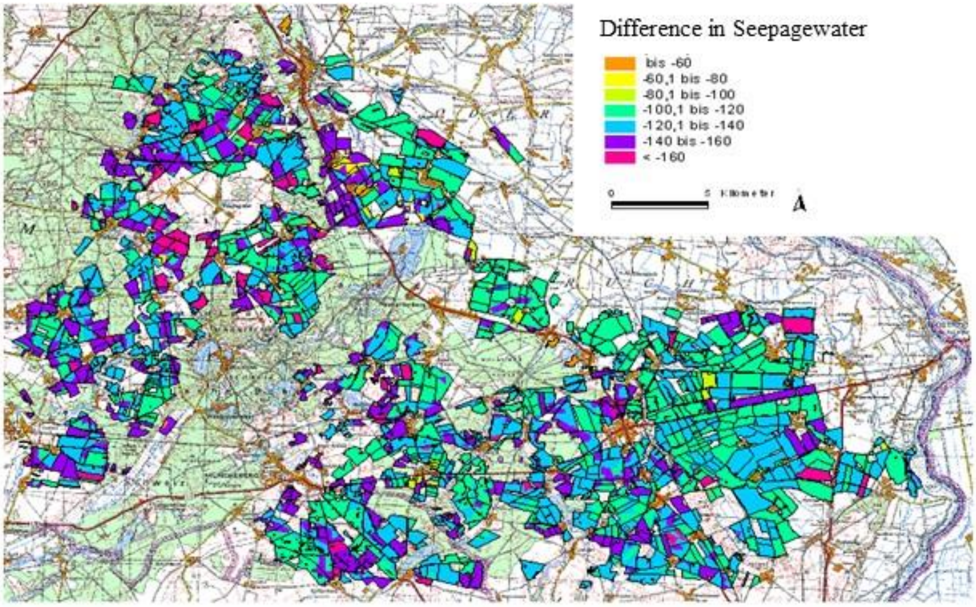

Figure 1. Spatial distribution of percolation water [mm/year] decrease as result of the scenario comparison (Scenario 2050 – Scenario2000)

Effects on the yields of arable crops

The ZALF (Leibniz Center for Agricultural Landscape Research eV, Müncheberg; www.zalf.de) has developed a model approach for regional yield estimation and, through integration into the Spatial Analysis and Modeling Tool (SAMT) (Wieland et al. 2004), has developed a spatial simulation tool expanded. The yield models developed with the help of this tool make it possible to examine the influence of changing weather patterns on the yield. Calculations made with these models for the study area result in a yield depression of between 14% for potatoes and approx. 5% for the main grain types barley, wheat, rye and triticale. Taking into account the effects of increased CO_2 concentrations known from other studies (such as the so-called FACE experiments: free-air concentration enrichment), the estimated yield decreases for all crops are less than 10% and especially marginal for the cereals that are dominant in terms of cultivation. This means that ultimately the emission-related increase in the CO_2 content in the atmosphere promotes plant growth and more efficient utilization of the water supply and can help to compensate for the drop in yield. With regard to the effect of the CO_2 concentration in the atmosphere on many cultivated plants, numerous experiments and valuable data on the relationships between the CO_2 concentration and the temperature-dependent reaction of the cultivated plants have recently been obtained. This was done experimentally in sunlit, controlled chambers, “open top chambers”, free-air CO_2 enrichment (FACE) studies and to a limited extent, phytotron studies. (Boats et al., 2011; Hatfield et al., 2011; Jones et al., 2011). The spatial distribution of the climate-related decline in yields at the climate level 2050 compared to the climate level 2000 shows clear differences on a small scale. In the study area in the areas of influence of the Oderbruch, the lowest yield losses can be expected, which can be explained by the better groundwater supply in this floodplain area. The yield losses there are mostly only in the range of up to 5%. On the other hand, on the fields of sandy soils, the losses are higher and are usually more than 5% and sometimes more than 10–15%.

The effects of the climate to be expected locally for the climate level 2050 (PIK climate scenarios) on the yield of agricultural crops are shown in Table 1 in comparison to the yield of the climatic level 2000 on the considered representative fields for the most important fruit species cultivated in the study area summarized. Taking into account the CO_2 effect, the yield losses caused by changes in temperature and precipitation are compensated for in the cultivated cereals.

Table 1 Simulated impact of climate change (Scenario 2050 vs. Scenario 2000) on crop yields for the study area (two CO_2 levels)

Crop	Cropping rate (%)	Mean crop yield change (%)	
		at 370 ppmv CO_2	at 465 ppmv CO_2 *)
Winter rye	17	- 6	- 0.3
Winter wheat	16	- 5	0.5
Silo corn	9	- 8	- 3
Winter rape	9	- 11	- 6
Winter barley	6	- 5	0.5
Triticale	6	- 4	0.1
Sugar beets	2	- 9	- 4
Alfalfa	3	- 12	- 7
Spring barley	2	- 5	0.3
Spring rape	< 1	- 7	- 2
Spring wheat	< 1	- 4	0.9
Clover gras	1	- 13	- 8
Oat	1	- 5	0.2
Potatoes	1	- 14	- 9

***) Basis: CO_2 fertilization effects obtained in the FACE-experiment of the Federal Research Centre for Agriculture Brunswick, Germany (at 550 ppmv → 10.7 % yield increase in average)**

However, this is not the case with root crops, silage maize, rapeseed, alfalfa and grass clover and yield losses are likely. Effect of climate change on the ecological function of the agricultural landscape The impact of the decline in groundwater recharge on the feeding of the ecologically valuable wetlands is likely to be much more serious than on agricultural yields. Unlike the forestry alternative, agricultural land use currently leads to significant new groundwater formation rates (Eulenstein et al. 2005b). From the seepage and its lateral runoff, it supplies the numerous ecological wetlands occurring in Brandenburg (lakes, brooks, moors and other lowland areas). Should the leachate donation from the agricultural land actually develop as the scenario suggests, then the ecological functionality of these ecosystems will have to be questioned. According to the climate scenarios, a lower nitrogen discharge is initially forecasted. This is mainly explained by the fact that, as a result of lower seepage water rates, nitrogen and sulfur are not shifted into the subsoil as quickly and thus ultimately the supply of these substances initially accumulates in the upper, 2 m deep soil layer. The modeling for the fields recorded and accounted for in the study area was carried out using the HERMES / SULFONIE models by Kersebaum (1995). In Fig. 4.3-5 and -6, in addition to the components of the water balance, the sulphate and nitrate discharges from the rooted zone and their concentrations in the seepage water are shown. With the exception of the peak, nitrogen discharges vary between 25 and 100 kg/ha per year.

DISCUSSION AND CONCLUSION

Effects on the world markets for agricultural products and the expected feedback on agriculture

The previously known and generally applicable influences on agriculture will change considerably over the next few years. In addition to a predicted climate change, the economic framework conditions in particular have a major influence on how farmers make strategic long-term, but also short-term decisions for their farms and production. In addition to technical progress and new markets, this decision-making behavior is primarily shaped by agricultural policy and social requirements. In addition to the significantly increasing importance of market mechanisms, these include:

- Decrease in agricultural trade policy or market and price policy
- Increasing environmental, animal welfare and consumer policies at the same time
- Intensification of production processes as a result of increasing demand and prices worldwide.

If one looks at the global climatic changes that are emerging, it becomes clear that other previously intensively used agricultural regions will be more severely affected by climate change than Europe due to rising temperatures and falling amounts of precipitation. For this reason, it will not be possible to significantly expand the range of agricultural products from the regions affected, such as Australia and the Midwest of the USA. On the other hand, as recent studies show, there are certainly favorable locations such as in southern Brazil. Using yield simulations for maize and soybeans, Lana (2013) was able to show that with the right choice of varieties, no significant yield losses are to be expected under the conditions of future climate change. In contrast to Australia, the same applies to New Zealand. With increasing demand and constant or decreasing supply, prices will rise and with them farmers' incomes. The previous income situation of the farms is often quite inadequate, sometimes ruinous. The prospects for higher prices for the farmers' products are therefore fundamentally positive from the point of view of maintaining the farms. As a result of the supply shortage and increases in energy prices, animal feed, fertilizers and fuels are also becoming more expensive and thus the costs of agricultural production are higher. Rising revenues due to rising market prices for agricultural products are thus partially offset by the increasing cost pressure.

Increasing variability in the climate leads to higher uncertainties in production, which will result in greater risks / failures and therefore higher costs.

Nevertheless, due to the high productivity of the agricultural locations in Central Europe and the often very good, flexible management of the farms, it is to be expected that the vast majority of agricultural areas in Central Europe will continue to be used for agriculture in the future, with the exception of a few border locations. If one then also takes into account that the world population will increase from currently over 6 billion to over 9 billion by the mid-2030s, one can imagine the increase in demand for agricultural products. The FAO anticipates an increase in annual demand of one billion tons of plant products by the mid-2030s (Fig. 2).

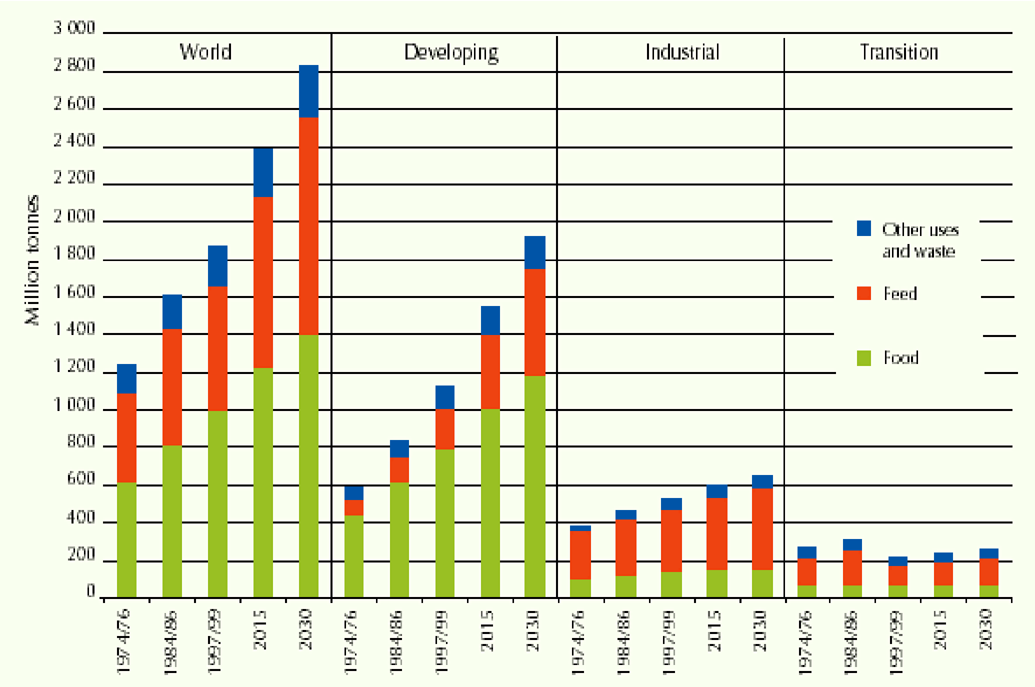

Figure 2. Aggregate consumption of cereals, by category of use. from: World Agriculture: Towards 2015/2030. An FAO perspective.

The 32% increase in world population by 2050 will be a powerful factor in food distribution. In addition, the daily energy intake will increase from the current 2831 kcal (FAOSTAT, 2013) to 3130 kcal in 2050. The competition for land for the agricultural production of biomass for nutritional purposes, as animal feed, for industrial raw materials and as an energy source, as well as for available water resources (with water retention in the landscape for ecological functions, for irrigation, etc.) will therefore increase. The following graphic (Figure 3) already illustrates the trend towards price increases for agricultural land in Germany.

This trend is particularly evident where agricultural land is traded on the market. The intensification caused by rising land and lease prices will primarily affect the maximization of the use of fertilizers and pesticides.

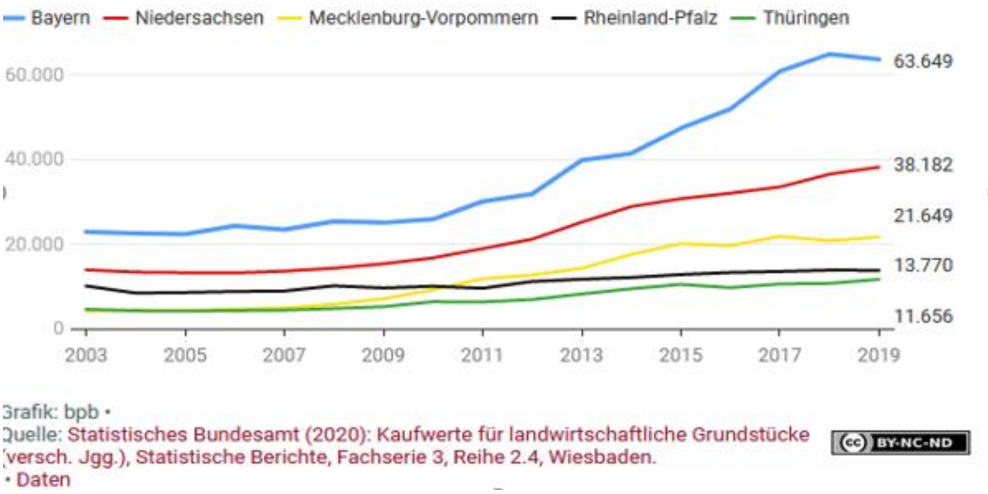

Figure 3. Trend towards price increases for agricultural land in in some regions in Germany

REFERENCES

Boats, K. J., Allen, L. H., Prasa, P. V. V. & Jones, J. W. 2011. Testing effects of climate hange in crop models. In Handbook of Climate Change and Agroecosystems (Eds. D. Hillel and C. Rosenzweig). London: Imperial College Press.

Eulenstein, F., J. Olejnik, M. Willms B. H. Chojnicki, S. L. Schlindwein, U. Schindler & L. Müller 2005. Possible effects of climate changes on land use in North Central Europe and consequences for land use planning. Eisforia 3 (1): 16-32.

Eulenstein, F., J. Olejnik, M. Willms B. H. Chojnicki, U. Schindler, B. H. Chojnicki. & R. Meissner 2006. Mögliche Auswirkungen der Klimaveränderungen auf den Wasserhaushalt von Agrarlandschaften in Nord-Mitteleuropa. Wasserwirtschaft 96 (9): 32-36.

Eulenstein, F., Schindler, U., Müller, L., Willms, M., Sheudzhen, A. K., Schlindwein, S. L., Tauschke, M., Behrendt, A., Lana, M. 2016. Climate change affects nitrogen and sulphur load in percolated water from agricultural landscapes. Agriculture and Agricultural Science Procedia 11, 59-64.

FAO 2003. World Agriculture: Towards 2015/2030. An FAO perspective. Jelle Bruinsma (ed.) (ISBN: 9251048355), 444 pp.

FAOSTAT 2013. FAOSTAT. Vol. 2013.

Gerstengabe F.-W., F. Badeck, F. Hattermann, V. Krysanova, W. Lahmer, P. Lasch, M. Stock, F. SUCKOW, F.; WECHSUNG & P. C. WERNER 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. PIK Report No. 83; Potsdam Institut für Klimafolgenforschung. 92 pp.

Hatfield, J. L., Boote, K. J., Kimballi B. A., Ziska, L. H., Izaurralde, R. C., Ort, D., Thomsen, A. M. & Wolfe, D. .2011.. Climate impacts on agriculture: Implications for crop production. Agronomy Journal 103(2): 351-370

Jones, J. W., BartelsARTELS, W. L., FraisseRAISSE, C., Boote, K. J., IngramNGRAM, K. T. & Hoogenboom, G. 2011. Use of Crop Models for Climate-Agricultural Decisions. In Handbook of Climate Change and Agroecosystems: Impacts, Adaptation, and Mitigation (Eds. D. Hillel and C. Rosenzweig). Imperial College Press.

Kersebaum, K. C. 1995. Application of a simple management model to simulate water and nitrogen dynamics. Ecological modelling 81: 145–156.

Lans, M., A. 2013. Regionalization of climate change impacts and adaptation strategies for maize in Santa Catarina State, Brazil. Dissertation zur Erlangung des Doktorgrades Abteilung Acker- und Pflanzenbau der Agrar- und Ernährungswissenschaftlichen Fakultät der Christian-Albrechts-Universität zu Kiel

Müller, L., A. Behrendt, G. Schallitz & U. Schindler 2004. Water Use Efficiency of Crops at Shallow Water Tables in a Temperate Climate. Proceedings of the 8th International Drainage Symposium Sacramento, USA, 409-418.

Roth, D., R. Günther & S. Knoblauch 1997. Wasserbilanz sowie Wasserverbrauch und Bodenwasserausschöpfung landwirtschaftlicher Fruchtarten auf einem tiefgründigen Lößstandort. Agribiol. Res. 50 (3): 271-278.

SchindlerCHINDLER, U., M. Wolff & G. Kühn 2001. Lysimeterstudie zum Einfluss von Düngung und Bewirtschaftung auf die Ertragsbildung, den Wasserhaushalt und die Nährstoffauswaschung im Trockengebiet der Uckermark. Zeitschrift für Pflanzenernährung und Bodenkunde, (164): 697-703.

Schindler, U., J. Steidel, L. Müller, F. Eulenstein & J.Thiere 2007. Drought risk to agricultural land in Northeast and Central Germany. Journal of Plant Nutrition and Soil Science170 (3): 357-362.

Statistisches Bundesamt 2020. Kaufpreise für landwirtschaftliche Grundstücke, Statistische Berichte, Fachserie 3, Reihe 2.4, Wiesbaden.

Wieland, R., W. Mirschel, K.-O. Wenkel & I. Ajibefun 2004. Räumliche Simulation mit SAMT. In: Wittmann, J.; Wieland, R. [Hrsg.]: Simulation in Umwelt- und Geowissenschaften -Workshop Müncheberg 2004, (Berichte aus der Umweltinformatik), Shaker Verlag Aachen, 161-181.

Wiggering, H., Eulenstein, F., Mirschel, W., Willms, M., Dalchow, C., Augustin, J. 2008. The environmental effects of global changes on Northeast Central Europe in the case of non-modified agricultural management. Landscape Online, 4, 1-17.