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THE STABILITY OF FRUIT PRODUCTION UNDER THE IMPACT OF CLIMATE FACTORS – SCIENTIFIC LITERATURE-BASED APPROACHES

ABSTRACT

By the identification of relevant scientific works that investigate fruit production variability, the present paper provides a relevant framework for understanding the scientific concerns in this field and the important factors affecting the stability/instability of the fruit production system.

Key words: fruit, production, stability, climate.

JEL Classification: Q 00, Q10.

1. INTRODUCTION

The successive major system changes in Romania’s agriculture have generated instability, and, what is mostly critical, the absence of continuity, stability, durability and sustainability of the national agricultural system.

The insight into the factors responsible for obtaining stable productions is of great importance to understand both the nature of food and nutrition security and the conditions in which the activities on the agricultural markets take place, as the production fluctuations have a significant impact upon prices (both producer and consumer prices) as well as upon the commitments on future investment actions.

2. STATE OF KNOWLEDGE

Production stability has a multidimensional character. The productivity of agricultural systems is closely strictly linked to the economic, social and environmental conditions. Stable yields can be obtained when a dynamic equilibrium exists between the environmental and the management factors. One of the sustainable agriculture objectives is to obtain stable yields on the long term. In this context, measuring and predicting the impact of climate change upon agricultural production represents a concern for the scientific community.

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The literature provides different ways to analyze the relation between agricultural production stability and different disturbing factors. In the specialty studies, agricultural production stability is investigated from the perspective of the relation with the climate factors (rainfall, temperature variations), with the economic factors (e.g. price fluctuations) and of the relation between the agricultural production stability and the technological factors (irrigation, fertilization, periodical pest and disease infestation). There are different agricultural protocols for optimizing the profitability of fruit production: through conventional production, by obeying certain norms regarding sustainability (through the ecological production) or through intermediary systems, the so-called integrated production systems (Cerutti A, 2011).

3. MATERIAL AND METHOD

A range of specialist studies were consulted in which agricultural production stability is analyzed from the perspective of the relation with the climate factors. The approached problems and the conclusions of these studies were briefly presented.

The debates on the increase of yield variability and of agricultural production implicitly in relation to climate changes in recent years are presented in many specialty studies. The relation between agriculture and climate change is two-way: on the one hand, agriculture has contributed to climate change in many ways, for instance through the conversion of forestland into agricultural land and release of greenhouse gases; on the other hand, the climate changes threaten to irreversibly deteriorate certain natural resources and eco-systems (UN, 2007). Most of the discussions on climate change focus upon the possible effects on yields, but there are relatively few discussions on the possible impact upon yield variability.

4. RESULTS AND DISCUSSIONS

One of the sustainable agriculture objectives is to obtain yields stabilization on the long term. In this context, measuring and predicting the climate change impact upon agricultural production represents a subject of concern for the scientific community.

The climate factors have a particular impact upon the physiological and phenological processes, playing an important and decisive role both in terms of crops productivity and of their geographical distribution. In the case when any environmental factor is below the ideal level, this will become a growth and productivity limiting factor. The three important environmental factors affecting the growth and productivity of crops are the following: temperature (each species has a certain temperature interval represented by a minimum, maximum and optimum level), water (rainfall) and light.

Among the weather phenomena with direct negative effects upon agriculture we can mention the following: changes in the rainfall regime, average global temperature increase and the increase in the frequency and intensity of extreme phenomena. The impact of climate changes upon agriculture and food safety can be first felt in the changes of crop yields, water availability, disease and pest infestation, animal health and other biophysical factors (FAO, 2012). More concretely, the impact of climate changes upon agriculture is materialized into the diminution of the crop growth period (Sarr B, 2012), in significant variations of yields at regional level (Ray D.K., 2013), increase of arid areas (Adel El-Beltagy, 2012), spread of pests and invasive species (Burgiel, S. W, 2010**)**, loss of biodiversity (C Bellard, 2012), which besides food production, fulfils various ecological services, including the recycling of nutrients, regulation of the microclimate and local hydrological processes, elimination of unwanted organisms and harmful chemical substances (Altieri M, 1999).

In many approaches to agricultural production stability, the biodiversity of agro-ecosystems plays an essential role in the attenuation of shocks produced by climate changes, for instance the agro-ecosystem's resistance to rainfall shock. Crop biodiversity has a stronger positive contribution when the rainfall level is lower. The results of research works reveal that high crop biodiversity helps maintaining the agro-ecosystem productivity when the limitation of a physical factor becomes significant (Di Falco S., 2008).

As most fruit trees species grow best on deep, well-drained clay soils, with a pH of 6–7, with rare exceptions, climate is one of the strongest determinants of successful fruit tree farming.

In most studies, the climate change impact issue is approached from the perspective of annual average temperature increase. The scientific proofs show that the 30 years with higher temperatures at the end of the 20th century affected the organisms' phenology, the range and distribution of species, as well as the composition and dynamics of the communities (Walther G. R., 2002). The perennial crops are more pregnantly affected by the outrunning of the phenological phases, as the adaptation possibilities by the change of the agricultural activities' calendar are lower than in the case of arable crops.

For the fruit tree species, there are several critical aspects from the temperature perspective. One of these resides in crop tolerance to minimum temperatures. The production level and stability depend on the weather conditions from the flowering time, as the open flowers can safely resist only to a minimum temperature of -1°C up to 2°C. This aspect makes most fruit trees vulnerable to the relatively mild frost in spring. At the same time, pollination is also one of mostly sensitive phenological phases to extreme temperatures.

Winter temperature has a significant role in productivity. Non-achieving the necessary cold period determines the late starting into vegetation of trees, the abnormal flowering, anomalies of flower organs and poor coming into bearing. Satisfying the necessary period of cold weather is a restrictive factor for the expansion of certain fruit trees species from the temperate zone to warmer zones. Thus, the threat of late frosts in spring, combined with more frequent mild winters, represent a challenge even for the resistant species (Burroughs W. J., 2002).

Other factors that can disturb the evolution of the fruit tree biological cycle and could generate high instability of fruit production are the exceptional climatic accidents (outrunning the start into vegetation by 20–25 days simultaneously with the lowering of temperature under the resistance possibilities of the species or variety. Anyhow, the temperature level impacts all the phases of fruit growth and development. During fruit development, when temperatures exceed the optimum interval, we can notice both production losses and changes in fruit quality. The global temperature increase is expected to have a significant impact upon the post-harvest quality, by the modification of the important quality parameters, such as sugar synthesis, organic acids, anti-oxidant compounds, fruit peel colour and fruit firmness (Moretti CL, 2010). For instance, for the apple species, the exposure to temperatures higher than 22°C during reproduction increases the fruit size and the concentration in soluble solid substances but decreases the fruit firmness, which is a quality parameter (Warrington et al., 1999).

Many studies highlight that the distinct air temperature changes in late ’80s led to clear responses in plant phenology, in many parts of the world. Under the impact of global average temperature increase, the plant phenophases fluctuate, and the growing season is prolonged (Romanovskaja D., 2009). Some studies show that in Europe, the average annual growing season was prolonged by 10.8 days as against the early ’60s; these changes can be attributed to the air temperature changes (Menzel A., 1999). In Germany, the phenological phases of the natural vegetation as well as of fruit trees and field crops clearly advanced in the last decade of the 20th century. The strongest change in plant development was produced in the very early spring phases. Until present, the changes in plant development are still moderate, so that no strong impact upon yields could be noticed (Chmielewski et al., 2004).

Besides the phenological changes of crops, the climate changes also impact the phenology of pests. In the last 40 years, the pest and disease management played an important role in doubling the food production, yet the pathogens still affect 10–16% of harvest worldwide.

The scientific observations reveal modifications of the periods in which certain insects emerge in spring or the modification of their geographical area due to climate changes. Among the climate factors involved in this phenomenon, it was noticed that temperature is the most important factor affecting insects ecology, the number of generations per season and insects distribution, while the pathogens of crops are very sensitive to humidity and rainfall, as well as to temperature (Chakraborty, 2011). The importance of pathogens infestation under the influence of climate changes can be seen, for instance, in Butterworth et al., where, combining a simulation pattern of the rapeseed yield with a weather-based epidemiological model, the authors reached the conclusion that under the climate change impact, by the years 2020–2050, yields would increase by 15% in Scotland, while in England yields could decrease by up to 50%.

Fruit production is facing new challenges in relation to pest management, mainly in terms of insecticide use, which left a persistent heritage (lead arseniate, for instance), induced new outbreaks of pests or led to their resistance to pesticides (Granatstein, D., 2008).

In our country, the relation between the climate factor and the infestation with certain pests was also a theme of research. Starting with the year 1996, Chiţu E., Budan C., Butac. M. and Păltineanu Cr. published series of articles in Romania and abroad on phenoclimate simulation models of damages produced by the late frost in plantations and for the estimation of the climatically possible harvest. While the soil rating of agricultural land used the year as time unit, these phenological simulators, by which the possibility of pests emergence through the action of late frost is also calculated, use the hour as time interval for the calculations (Coman M, Chiţu E., 2014).

Although it was noticed that in certain areas moderate warming can easily increase the productivity of crops, climate variability can have a deeper effect upon yields and associated risks than the changes in the average temperature (Semenov M.A., 1995).

In the specialist studies, climate variability is evaluated in terms of the combined effects of the most important environmental factors involved in the growing and productivity of crops. The conclusions of studies show that the impact of the climate variables modifications on average yields is different by species and region, so that it is still difficult to understand the influences of annual inter-climate variations in relation to yields. Anyhow, unlike the impact of average global temperature increase, climate variability is one of the most important factors influencing crop production from year to year, even in the high-yield and high-tech agricultural areas (Yinhong K, 2009). The climate changes have determined a decrease of wheat and maize production worldwide, while the soybean and rice productions remained stable. The climate trends were high enough in certain countries to offset a significant part of average yield increases resulting from technology, fertilization and from other factors (Lobell DB *et. all*, 2011).

Certain studies, conducted at extended geographic scale, show that the climate variability did not have a statistically significant influence upon yields, in all the crop growing regions. On average, at global level, 32–39% of the variability of maize, rice and soybean yields from year to year are explained by climate variability (Ray D, 2015).

As the variability of climate factors can produce serious damages in orchards, generating high production volatility, the investments on fruit trees orchards must always be based on zoning studies of fruit tree species, on the basis of climate information, as well as on information on the pedological, biotic and economic factors.

The zoning of fruit trees species is a real support for putting into value the biological, ecological, agro-technical and production particularities of fruit trees, and on this basis, for the elaboration of modern technologies, differentiated by species, varieties, ecological zones, in order to obtain stable quality harvests, under high economic efficiency conditions. A stable agricultural eco-system can better face the stress factors induced by climate changes. For this purpose, the identification of sectoral vulnerabilities is a first important step towards the development of adaptation plans to climate changes.

In the year 2014, in Romania, the agro-climatic and soil potential of fruit tree species was evaluated within an inter-disciplinary working group. The study represents the first nationwide approach to zoning the main species of fruit trees, fruit shrubs and strawberries, establishing the spatial distribution of these species favourability degree. For favourability degree interpretation, scores from 0 to 4 were assigned for each climate and pedological factor in part. The results show that there are few cases in which the qualification less favorable (1.5–2.5) was given, and for most cases the scores are in the moderately favorable interval (2.5–3.5) for the fruit trees crops. In very few situations the scores exceed 3.5 (very favorable), out of different reasons, and in all cases the potentiation of the low level of environmental factors through technological measures was needed, irrigation being one of the most important measures (Coman M, Chiţu E., 2014).

5. CONCLUSIONS

Climate is one of the strongest determinants of the successful growing of fruit trees. In most studies, the impact of climate changes is approached from the perspective of annual average temperature increase.

For the fruit tree species, there are several critical aspects in relation to temperature: a) crop tolerance to minimum temperature; b) vulnerability to relatively slight frosts in spring; c) sensitivity to extreme temperatures during pollination; d) the significant role of winter temperature in productivity. The exceptional climatic accidents may also disturb the development of the fruit tree biological cycle, generating high instability of fruit production.

Under the impact of average global temperature increase, the plants phenophases fluctuate, and the growing season is prolonged. The research results show that, until present, the impact of average global temperature increase on plants development is still moderate, as no strong impact upon yields could be noticed.

Fruit production is facing new challenges related to pest management, due to changing the intervals of occurrence of certain insects in spring, or the change of their geographical area, under the background of climate change.

Production stability has a multidimensional character. The productivity of agricultural systems is closely linked to the economic, social and environmental conditions. When a dynamic equilibrium exists between the environmental and management factors, stable yields can be obtained.

As the variability of climate factors can produce serious damages in orchards, generating high production volatility, the investments on fruit tree orchards must always be based on zoning studies of fruit tree species, on the basis of climate information and on information regarding the pedological, biotic and economic factors.

REFERENCES

1. Adel El-Beltagy, Magdy Madkour, (2012), *Impact of climate change on arid lands agriculture*, Agriculture & Food Security, Volume 1, Number 1
2. Altieri, M., (1999), *The ecological role of biodiversity in agroecosystems*, Original Research Article, Agriculture, Ecosystems & Environment, Volume 74, Issues 1–3, June 1999, Pages 19–31
3. Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W., & Courchamp, F., (2012), *Impacts of climate change on the future of biodiversity*, Ecology Letters,15(4), 365–377. http://doi.org/10.1111/j.1461-0248.2011.01736.x
4. Burgiel, S.W. and. Muir A.A., (2010), *Invasive Species, Climate Change and Ecosystem Based Adaptation: Addressing Multiple Drivers of Global Change*, Global Invasive Species Programme (GISP), Washington, DC, US, and Nairobi, Kenya
5. Butterworth, M. H., Semenov, M. A., Barnes, A., Moran, D., West, J. S., & Fitt, B. D., (2009), *North–South divide: contrasting impacts of climate change on crop yields in Scotland and England*, Journal of the Royal Society Interface, rsif20090111.
6. Chakraborty S. and. Newtonb A. C., (2011), *Climate change, plant diseases and food security: an overview*, Plant Pathology 60, 2–14
7. Cerutti A. K, Bruunb,S, Gabriele L. Beccaro, Bounousa G, (2011), *A review of studies applying environmental impact assessment methods on fruit production systems*, Journal of Environmental Management, Volume 92, Issue 10, Pages 2277–2286
8. Chmielewski, F.M., Müller, A., Bruns, E., (2004), *Climate changes and trends in phenology of fruit trees and field crops in Germany, 1961–2000*, Agric. For. Meteorol., 121, pp. 69–78
9. Coman Mihail, Chiţu Emil coord, Zonarea speciilor pomicole în funcţie de condiţiile pedoclimatice şi socio-economice ale României, editura Nivel Multimedia, ISBN 978-973-1886-93-0,
10. Di Falco, S., Chavas, J.P., (2008), *Rainfall Shocks, Resilience and the Dynamic Effects of Crop Biodiversity on the Productivity of Agroecosystems*, Land Economics, 84(1):83–96.
11. Granatstein, D. and Kupferman, E., (2008), *Sustainable horticulture in fruit production,* Acta Hort. (ISHS) 767:295–308,
12. http://www.fao.org/docrep/016/i2856e/i2856e.pdf
13. http://www.grida.no/publications/rr/food-crisis/page/3571.aspx
14. Moretti CL, Mattose LM, Calbo AG, Sargent SA., (2010), *Climate changes and potential impacts on postharvest quality of fruit and vegetable crops, A review,* Food Research International 43: 1824–1832.
15. ONU, (2007), *Devastating For The World's Poor: Climate Change Threatens the Development Gains Already Achieved*, The Magazine of the United Nations, Vol. XLIV No. 2 16. Ray, D.K., Mueller N.D., West P.C, and Foley J.A., (2013), *Yield trends are insufficient to double global food production by 2050*, PLOS One 8: E66428. doi:10.1371
16. Ray, D.K., Gerber James S., MacDonald, Graham K., West, Paul C., (2015), *Climate variation explains a third of global crop yield variability*, JA – Nature Communications, PY-2015/01/22/online
17. Romanovskaja, D. E. Baksiene, (2011), The influence of climate change on the beginning of spring season and apple tree (*Malus domestica* Borkh) phenology in Lithuania during the period 1971–2000, Journal of Food, Agriculture & Environment Vol.9 (2): 735–739
18. Sarr, B., (2012), *Present and future climate change in the semi-arid region of West Africa: a crucial input for practical adaptation in agriculture*. Atmos. Sci. Lett 2012, 13, 108–112
19. Semenov M.A., Porter J.R., (1995), Climatic variability and the modelling of crop yields, Agricultural and Forest Meteorology, Volume 73, Issues 3–4, Pages 265–283
20. W. J. Burroughs, (2002), *Gardening and climate change, Weather*, Volume 57, Issue 5, Pages 151–157

21. Walther, G.R., Post, E., Convey, P., Menze, 1, A., Parmesan, C., Beebee, T.J.C., Fromentin, J.M., Hoegh-Guldberg, O. & Bairlein, F., (2002), *Ecological responses to recent climate change*, Nature, 416, 389–395.
22. Yinhong Kang, Shahbaz Khan, Xiaoyi Ma, Climate change impacts on crop yield, crop water productivity and food security – A review, Progress in Natural Science: Materials International, Volume 19, Issue 12, Pages *1665–1674*, 2009
23. Lobell D., Schlenker W., Costa-Roberts J., (2011), *Climate Trends and Global Crop Production Since 1980, SCIENCE*, 29 JUL 2011: 616–620
24. Menzel, A., & Fabian, P., (1999), Growing season extended in Europe. Nature,397(6721), 659–659
25. Warrington I.J.,. Fulton T.A,. Halligan E.A, de Silva H.N., (1999), Apple fruit growth and maturity are affected by early season temperatures, J. Am. Soc. Hortic. Sci., 124, pp. 468–477