THE ECONOMIC IMPACT OF CLIMATE CHANGE ON CROPS

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Abstract. *In this article, we investigate the influence of climate change in terms of the specific internal process in agriculture and we identify the general measures of adaptation to this context. According to the researchers conducted by the experts in the field, it can be argued thorough that agriculture is strongly affected by climate change. The consequences of this situation consist of reduced production, changed organoleptic qualities of agricultural products, decreased time of harvest etc. For all this, but also, to prevent accentuation of some undesirable repercussions, we must operationalize the appropriate measures for a reasonable adjustment to climate change disruptors of the existing natural environment. Analysing the results of other studies, we observe that these are very different. They vary especially because they are based on different methods of investigation and data processing, namely, mathematical models and scenarios made under specific conditions, requirements and statistical analysis, etc. Thus, the research methodologies started either from various economic analyzes based on the evaluation of the cost-benefit analysis or investigation of data and meteorological information. The approach we propose consists of combining both theoretical, purely economic data and the database and meteorological information in Romania.*

Keywords: *agriculture; economic analysis; climate change; adaptation measures; cost-benefit analysis; climate risks; adaptation measures.*

Introduction

The climate change has the ability to change, even radically, meteorological conditions considered to be normal. As such, it may lead to significant biophysical effects on the entire agricultural sector. In the opinion of producers and consumers, in equal measure, the general assessment of the repercussions generated by this state of affairs must be preceded by detailed assessments starting from the impact of climate change on the main activities which form the specific internal process from agriculture.

So, the climate change can have a negative impact on all crops, regardless of the production cycle with direct effect in terms of productivity, quality of products and their related costs. Traditionally, agriculture is one which provides the necessary grains, vegetables, fruits etc.

As a consequence, this sector is an important source of revenue for local and national economies by which it determines a whole "trophic chain" upstream and downstream, in the sense that there is a higher demand for scientific research, investment, employment, transport, etc. Given all this and taking into account the expected evolution of climate change, future activities of the agricultural sector, so that they can provide the necessary production and to fit into acceptable economic parameters, requires considerable scientific support, adequate forecasting and performance management.

According to Lobell, in these conditions, the focus is on ”adapting to climate change in order to reduce the impact as it can lead to negative effects on crop productivity and economic viability in the agricultural sector.” (Lobell, 2014). In practice, however, as a result of everyday approaches, which do not take into account climatic changes, "in many existing projects, the impact of climate change and its adaptation is not taken into account." (White et al., 2011). On the other hand, the estimates made until this moment on the economic impact of climate change have been dominated by fluctuations and inconsistencies, in large part, of methodological approaches, which also leads to a notable challenge regarding their utility and credibility. So, for the assumption that applicable technologies and agricultural crops will not adapt to climate change, has even reached significant overestimations of probable conceits, leading them, finally, at abandoning scenarios built on premise unrealistic.

Recently, the Intergovernmental Panel on Climate Change (IPCC, 2007) argued that forecasts and regional/global models predicted that temperatures would increase during the summer and will lead to drought in soil have come true as previously stated. (Kovats et al., 2014). Of course, such a scenario such as the one mentioned above indicates a high risk for the condition of the vegetation of agricultural crops in the next five years. Another notable report on climate change is convincing for ”... identifying the usefulness of systemic approaches to address the complexity of climate change and the challenges facing society today, namely, population growth and consumption, the use of resources at the maximum level, demographic change, excessive exploitation of the environment and the provision of ecosystem services. " (Ison, 2010). In connection with the increasing vulnerability of ecosystems, researchers have recently said that the term ”can be compared to a means of crossing the link between the physical effects of the climate on the adaptations of the socio-ecological systems." (Malone & Engle, 2011).

Among other things, the IPCC proposes a definition for vulnerability to climate change, taking into account the degree to which a system may be susceptible and, so, it is unable to counteract the foreseeable adverse effects. Thus, it may be envisaged, inclusive, the „variability of extreme meteorological phenomena, (IPCC, 2007)”. Usually, until this moment, the vulnerability was considered to be closely related to the relationship between the geographical and temporal proximity of a hazard and the trend of exposure, this relationship may lead to unwanted negative effects for the population, society and the environment; as such, exposure/susceptibility to such a vulnerability can be kept under control through an optimal system to adapt to the phenomenon that generates the effect, in this case, climate change. Some researchers add to this definition a subjective nuance (the degree of sensitivity or, in other words, the ability to accept risks), namely, that an important role in the emergence of the vulnerability phenomenon represents... cultural dimension, such as, the perception of

risk in relation to personal experience and trust in authority (Wachinger et al., 2012). As an illustrative element, we mention that some relatively recent research confirms that climate change may have a negative effect on corn, and wheat confirms the positive effects predicted in previous studies (Asseng et al., 2013).

In general, adapting to climate change means, in fact, "a high capacity of society to mitigate the negative consequences that may arise due to extreme weather phenomena by developing strategies and measures together with stakeholders to support the expected actions. This adaptive capacity includes various key factors, namely, ...the availability of a viable technology option for crop adaptation, the efficiency of research and development institutions, but also the availability of financial and human resources, including population awareness actions on optimal adaptation methods" (Hallegatte et al., 2011).

From the point of view of adapting to climate change, socio-economic challenges are defined as social or environmental conditions which when the adaptation process is difficult leads to "increased risks arising from the combination of several types of climatic risks (increased sea level, temperature and precipitation changes, extreme weather events) and adverse effects of a geographic, socio-economic or any other nature" (Rothman et al., 2013).

Methodological precisions

According to the suggestions of the US Global Change Research Program, climatic factors can negatively affect food safety in any agricultural system - before, during and after harvest, as well as during transport, storage, preparation, and consumption of cereals, fruits, vegetables, etc. "These factors (temperature, rainfall, and extreme weather conditions) can lead to the emergence of pathogens, food contamination and food illness and changes in the level of exposure to contaminants and chemical residues for crops" (USGCRP, 2014).

In principle, there are two economic problems which may undermine the validity of the use of the relationship between short-term variations of time and agricultural crop profits to deduce the effects of climate change. The projected climate changes will be able to achieve a statistical and economic character that is impacting on the yields of specific crops. Firstly, the econometric model is based on an increasingly more complex approach applied differently from one country to another, because it is necessary to adjust the actors involved and to take measures according to the country and area of origin. Secondly, another potential issue with the validity of this approach is that the farmers cannot adopt the full range of adaptation measures in one year. Specifically, permanent climate change could cause them to modify their activities on their own agricultural land.

Understanding the impact of climate change is based on the analysis of the effects of climate change on different levels. It varied depending on the specific environmental and economic conditions, which have specific difficulties in being accurately quantified. We mention that, we emphasize the conditions of occurrence and manifestation of climate change in the specific regional context of Romania, on the

three fundamental axes of the interaction of the impact of climate change: physical / environmental, economic and social impacts.

Provisions concerning development of climate change in the next years

Using models and simulations leads to a major step towards developing a more effective climate change assessment. Therefore, the application of specialized software in correlation with information and data from the operational program provides a quantitative side for establishing weather forecasts.

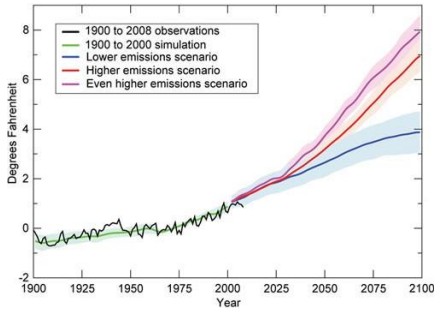

Figure 1. Evolution of temperatures (Fahrenheit) from 1900 to 2100 (https://www.google.ro/search?q=Forecasts+on+climate+change&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjUs_u3w4rUAhUFChoKHX5fCbAQ_AUIBigB&biw=1017&bih=1038#imgrc=aVBkidmo1YkA-M:)

Globally, according to researchers in the field of climate change, it is stated that heating is likely to occur from one century to another, and this hypothesis is based on how climate conditions are manifested, but also on climate models and simulations. In this sense, it is estimated that "the average temperature could be higher, with values that can reach up to 5.4 ° C to 2100", figure 1.

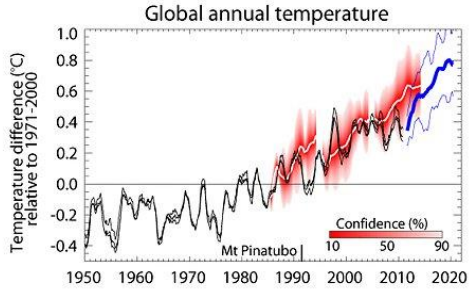

Figure 2. Global annual temperature in the period 1950-2020 (°C) (Climate.gov)

Figure 2 shows an increase in annual global temperatures and temperature differences in the 1950-2020 period. As a result of climate scenarios, it is argued that global warming is differentiated according to geographic location, but at the same time, depends also on climate models.

From the thermal point of view, at the national level, the changes in climatic indicators are on the current global trends and this is due to the fact that it is possible to highlight a temperature increase during the summer. According to the IPCC, in our country it is

estimated an increase in the average annual temperature compared to the 1980-1990 period at European level, there are small differences between the results of the models for the first decades of the 21st century and higher if we refer to the end of the century, so values between "0.5°C and 1.5°C are expected for 2020-2029; between 2.0°C and 5.0°C for 2090-2099, depending on the scenario." (IPCC, 2007). From a pluviometric point of view, over 90% of climate models forecast for the period 2090-2099 droughts pronounced during the summer in the Romanian area, especially in the south and south-east (with negative deviations from the 1980-1990 period by more than 20%). Regarding the amount of rainfall in winter, deviations are lower and the degree of uncertainty is higher.

The impact of climate change on agricultural crops

At the European level

At European level (figure 3), it can be stated that anthropic systems and ecosystems are vulnerable to the major impacts of climate change, such as floods, droughts or landslides. There may also be positive effects, especially in northern Europe due to climate change, but in most European regions we will identify types of negative environmental impact. In particular, a high degree of threat to the agricultural sector in the south and south-east of Europe is expected.

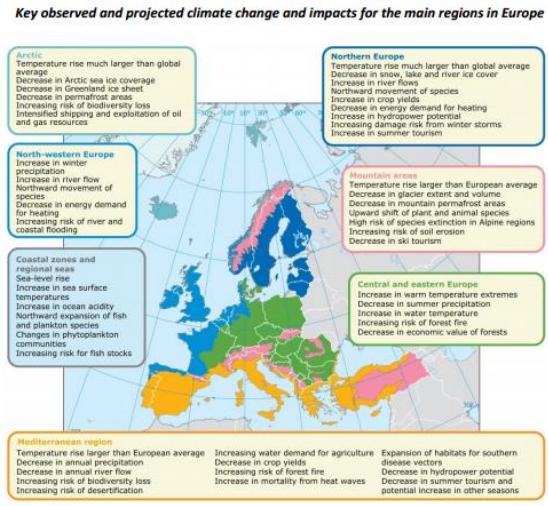

Figure 3. The exposure types according to geographic location at European level (Climate change, impacts, and vulnerability in Europe 2012, An indicator-based report, European Environment Agency)

The term "adaptation" is different from the "reduction" because the reduction refers to minimizing the impact of climate change and adaptation has the role of minimizing the damage caused by these adverse effects for agriculture.

Therefore, it is necessary to correlate the adaptation actions with the reduction ones for a high degree of efficiency and the development of solid societies based on adaptation to climate change. In another train of thoughts, adaptation is a complex

process that refers to the variability of effects according to geographical location, but at the same time, it must be considered exposure, physical vulnerability, socio-economic development, adaptability, health services and disaster response mechanisms / solutions.

Sustainable agriculture in the European Union is based on the tools used to adequately identify responses to climate change challenges through the Common Agricultural Policy. In the agricultural sector, measures are needed to improve environmental performance through more sustainable production methods, also taking into account the conservation of natural resources.

In this regard, it should be noted that agricultural producers, individually, cannot "fight" against climate change. That is why there is the central public authority which, through the policies it adopts, must provide the appropriate support, so that agricultural producers take measures to adapt to climate change and take into account production methods, and through this way continues the necessary flow of services used in rural areas.

Common agricultural policies have specific elements that could facilitate adaptation to climate change. Thus, opportunities can be offered to agricultural producers, namely to facilitate access to risk management tools such as access to insurance, if appear losses from natural disasters caused by climate change. Rural development policies offer chances to offset the adverse effects that climate change can cause to agricultural producers and rural economies, for example, providing support for investments in more efficient irrigation equipment. The agricultural and environmental programs to encourage better management of soil and water resources by agricultural producers are also important for adaptation. The general objectives of the Common Agricultural Policy are the following, and these, in turn, have several subordinate objectives: (i) viable production of food, contributing to agricultural income and limiting agricultural income variability to increase competitiveness in the agricultural sector and to increase its share of value in the food chain, compensating for production difficulties in areas with specific natural constraints, as there may be a major risk of land abandonment; (ii) sustainable management of natural resources and climate action to guarantee production practices, ensuring the improvement of the provision of public environmental goods, fostering green growth through innovative methods, pursuing mitigation and adaptation actions to climate change; (iii) balanced territorial development to support employment in rural areas and maintaining the social structure of rural areas, improving the rural economy and promoting diversification to allow for structural diversity in agricultural systems, improving conditions for small farmers and developing local markets.

The climate change is also a real concern for the EU agriculture. Agriculture will face many challenges in the coming decades, such as i) increasing international competition, (ii) liberalization of trade policy (iii) Decrease in the alert rhythm of the rural population. The effects of climate change can be beneficial for agriculture in some regions of Europe, especially in northern areas, but often can lead to unexpected/bad events, especially in regions already under socio-economic pressure and other environmental factors. This unequal effect of global warming amplifies the economic differences between rural areas of the European Union, and at the same time, the produces a higher risk of land abandonment and regional marginalization.

At the national level

The Central Competent Authority in Romania in the area of adaptation to climate change is represented by the Ministry of Environment through the General Directorate for Green Energy, Climate Change, and Sustainable Development. The climate change affects different economic sectors, and agriculture is one of the most exposed because agricultural activities depend directly on climatic factors. This is important for the European area because 90% of this area is composed of agricultural land and forests. Adaptation is a critical challenge for agriculture and rural areas.

According to statistics, in Romania, "crop production is reduced by at least 30-50% due to the expansion and intensity of extreme meteorological phenomena, and for the sustainable conservation of natural resources in the agricultural field, measures must be taken to scientifically substantiate actions and measures to prevent/mitigate adverse consequences." (ICPA, 2014). In general terms, drought represents the natural phenomenon determined by the precipitations below the normal values, the degree of supply varying significantly depending on the stage of growth and development of agricultural plants.

During the period 2005-2007, the "First National Strategy on Climate Change" was debated, which started in 2005 and was approved by Government Decision No. 645/2005. In 2008, the central competent authority elaborated the "Adaptation to Climate Change Guide" approved by the Minister's Order (No 1170/2008), this was due to the fact that the EU Green Paper needed to outline measures and strategies for "Adapting to climate change in Europe - options for EU action".

By Government Decision no. 529/2013, in 2013, the Romanian Government adopted the "National Strategy on Climate Change (2013-2020)" (according to Ministry of Environment). Through this document wanted to highlight specific post-Kyoto targets/actions for mitigation and adaptation to climate change. In this regard, adapting to climate change 2013-2020 was proposed to develop a framework for action and vision in accordance with the principles of national strategy to develop an individual action plan for each sector.

Thus, the Government of Romania, in close association with the World Bank, has developed a program for two years to provide advisory services on climate change through the implementation of the National Climate Change Strategy. Meanwhile, improvements to the strategy were called for and revised in the final version in 2015, accompanied by a plan of actions, deadlines, and indicators. In Romania, the "Adaptation to Climate Effects Guide" was implemented, taking into account the actions implemented at the international and European level, and this is reflected in the following documents adopted in 2005, namely the National Strategy and the National Action Plan on Climate Change. Thus, in order to develop and promote this guide, it was necessary to set up an inter-ministerial working group on adaptation to climate change involving different representatives from several areas vulnerable to the effects of climate change.

Consequences, trends and strategic options

In all areas of activity and regions, there are different opportunities for planning and implementing climate change adaptation measures, but taking into account agricultural potential and context-based approaches. In the context of the actions on the development strategies of the European states, the emphasis is on reducing or eliminating the negative effects of climate change in the agricultural sector.

Also, the global approach in terms of the interdisciplinary nature of actions refers to identifying and linking development and implementation activities of intra- and inter-sectoral measures with responses to the effects of climate change. However, we can highlight the fact that agricultural production varies from year to year, which is influenced by changes in climatic conditions and the emergence / producing extreme weather events. In other news, climate variability can influence the Romanian economy and the agricultural sector remains vulnerable to extreme weather phenomena, so the impact on agriculture is higher due to the fact that climatic variability is more pronounced. Thus, the effects of climate change on the agricultural sector led to the need for decision-making processes to reduce the risk of high crop production, proper harvest standardization, and sustainable agriculture promotion.

Therefore, variability and climate change must be analyzed in terms of daily agricultural activities, through mitigation strategies and adaptation measures.

In order to establish a cost-benefit analysis, the following elements are required:
The costs related to the purchase and installation of equipment, consultancy services for the proper implementation of the measure, irrigation water supply, the use of fertilizers, etc.

Benefits: decreasing losses, increasing yield, water conservation for irrigation, etc.

AC i,j,k=Ic i,j,k x $\frac{rx(1+r)^T}{(1+r)^T - 1}$, where

I - the adaptation measure; j - culture, k - region
ACi, j, k - the annual capital cost of the measure i for the culture j in the region k (€ / year)
ICi, j, k: The cost of capital for measure i in culture j in region k (€)
R - discount rate (%)
T – time (years)

The annual operating and maintenance costs of adaptation measures include the use of any additional costs, such as water irrigation, application of additional quantities of chemical fertilizers, nitrogen, etc. and other costs, as well as the cost of consulting agronomist farmers on how to properly apply adaptation measures in the agricultural sector to reduce the adverse effects of climate change.

The annual cost equivalent EACi, j, k was defined by the formula:
EAC i,j,k = AC i,j,k + OMC i,j,k = AC i,j,k + CWi,j,k+CFi,j,k+restOMi,j,k
OMCi, j, k - the annual cost of operation and maintenance of measure i for culture j in the region k (€ / year)

CWi, j, k: the annual cost of additional irrigation water as a result of measure i for culture j in the region k (€ / year)
CFi, j, k: The annual cost of nitrogen fertilizers as a result of measure i for culture j in the region k (€ / year)
RestOMi, j, k: additional cost of annual leave due to measure i for harvest j in region k (€ / year).
The annual benefits Bi, j, k from the implementation of each adaptation measure and culture j in the k region are given by:
Bi,j,k=BPi,j,k+BWi,j,k+BFi,j,k = (Yci,j,k-YCNoAj,k) x Pj + (WnoAj,k-Wi,j,k) x PWk + (FnoAj,k-Fi,j,k) x PFN, where
YCi,j,k - crop yield j in region k, when measure i is implemented (kg / ha)
YCNoAj, k -crop yield j in region k in the absence of adaptation (kg / ha)
Pj - The crop production price j (€ / kg)
Wi,j,k - annual irrigation water consumption for culture j in region k, when measure i is implemented (m^3 / ha)
WNoA,j,k - annual irrigation water use for culture j in region k in the absence of adaptation (m^3 / ha)
PWk - the price of irrigation water in the region k (€ / m^3)
Fi,j,k - annual consumption of crop fertilizer j in region k, when measure i is implemented (kgN / ha)
FNoA,j,k - annual consumption of N fertilizer for culture j in region k, without adaptation (kg N / ha)PFN - price of fertilizer N (€ / kg N)

Recommendations for adopting decisions with a preventative role

Below, we will briefly outline the main recommendations and adaptation measures adopted in the agricultural sector, namely: (a) the selection of varieties cultivated by correlating the local environmental conditions with the degree of resistance of the genotypes to the limiting vegetation conditions (drought, excess humidity, high temperatures, cold, etc.); (b) Crop management and rational use of land are mandatory measures to preserve production potential, while maintaining a low impact of agricultural practices on the environment and the climate (c) Cultivating a greater number of varieties / genotypes, namely varieties / hybrids, each agricultural year with a different vegetation period, to better capitalize on climatic conditions, especially the humidity regime and the staging of agricultural works; (d) the choice of genotypes resistant to limiting vegetation conditions with high tolerance to "heat", drought and excess humidity; (e) selection of varieties of plants with natural resistance to specific diseases caused by pathogens.

Conclusion

In conclusion, this approach is based on a description of the cost-benefit analysis that is a commonly used methodology for implementing climate change adaptation plans, as it is necessary to address all aspects with efficiency and effectiveness. Agriculture is an important field of the Romanian production, which is why it is necessary to discuss issues related to the impact of climate change on it. The central competent authorities and other relevant institutions should pay particular attention to adaptation measures

through appropriate solutions, and impact quantification and economic performance analysis help support decision-makers.

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