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THE IMPACT OF CLIMATE CHANGE ON FARM PRODUCTION

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Abstract: Agricultural production is very sensitive to climate change, due to its natural nature. Farm owners wanting to limit the influence of this impact or to mitigate the effects, have introduced various adaptation measures. The aim of the article is to present the main effects of climate change on plant and animal production on farms and to show the possibilities and barriers to implementing adaptation measures. The article is a review study. The main effects of climate change impact include a reduction in the quantity and quality of production, weakening animal and plant resistance to diseases and pests, and reproduction problems. Adaptation measures are undertaken by farmers, but they can also be initiated by the farm's external environment. The main challenges that farmers are facing include their adaptability problems and the way they perceive climate change and the risks associated with them.

Keywords: crop production, animal production, risk, adaptation, adaptation barriers.

1. Introduction

The increase in size, frequency and spatial distribution of climate change threats makes estimating their effects a growing challenge. Climate change has a very strong impact on agriculture, because of its natural nature. In particular crop production is especially sensitive to changes in climatic factors (Kundzewicz and Kozyra, 2011; Lobell and Gourdji, 2012; Olesen et al., 2011; Schlenker and Roberts, 2009). Recently, weather phenomena have become very burdensome for many sectors of the economy. Weather extremes, such as heat waves or low temperatures, drought, excessive or heavy rainfall, and strong winds are experienced in particular by the farmers. However, climate change is also ongoing. According to the IPCC report

(2014), the observed climate changes in recent decades were caused by human activity and were the result of an increase in the concentration of greenhouse gases in the atmosphere. Continued gas emissions at current levels will cause further warming and a change in the entire ecosystem on Earth. However, the effects of this process may be positive or negative, depending on the geographical area under consideration. For example, forecasts for Poland predict that the effects of climate change will be both positive and negative, with the dominance of the latter (Ministerstwo Środowiska, 2013). The expected increase in the average temperature will probably extend the growing season (it will enable the cultivation of new plant species, but the risk of plant damage caused by spring frosts will also increase), change the state of biodiversity and increase evaporation in winter. Changing the distribution of precipitation will result in an increase in the frequency of drought, the desertification of areas and the occurrence of extreme precipitation (Ministerstwo Środowiska, 2019).

The above conditions constitute only the basic group of the climatic factors affecting production directly and indirectly. Farmers have no influence on the evolution of these factors, so their volatility is a challenge for farms as it increases the risk of not achieving their production and financial goals. In order to reduce the climate impact, farmers use different methods of managing weather risk on the farm, wishing to avoid, reduce, transfer or retain risk (Soliwoda, 2016). Reducing the impact of climate change should focus on the long-term strategies of sustainable development and reducing the negative impact of agricultural production on the environment, which according to recent studies is responsible for 25-33% of greenhouse gas emissions (Clark and Tilman, 2017).

Adaptation to climate change is crucial for the development of agriculture. Limiting or mitigating the impact of climate change is not an objective pursued only by farms, as all agricultural sector entities are involved in these activities. Research indicates that agricultural practices and adaptability to climate change are primarily influenced by farmers' beliefs, their perceptions of risk, and market conditions. Nevertheless, initiative from decision makers is necessary to create the right environment in which farmers can adapt (Reidsma, Ewert, Lansink, and Leemans, 2010). In particular, the burdens of finance and economic risk that many farmers face limit their ability to undertake long-term adjustment measures (Takahashi, Burnham, Terracina-Hartman, Sopchak, and Selfa, 2016).

The aim of the article is to present the main effects of climate change on farm production on the basis of a literature review. Additional objectives include 1) a presentation of farm adaptation activities to climate change, 2) a review of barriers in the implementation of adaptation activities.

2. Impact of climate change on plant and animal production on farms

Climate change, understood as rising temperature trends, CO₂ concentrations in the atmosphere, precipitation (decreasing and increasing), as well as their variability are the subject of many studies that constantly provide new evidence that this impact is significant. The main effects of these interactions in plant production are shown in Figure 1.

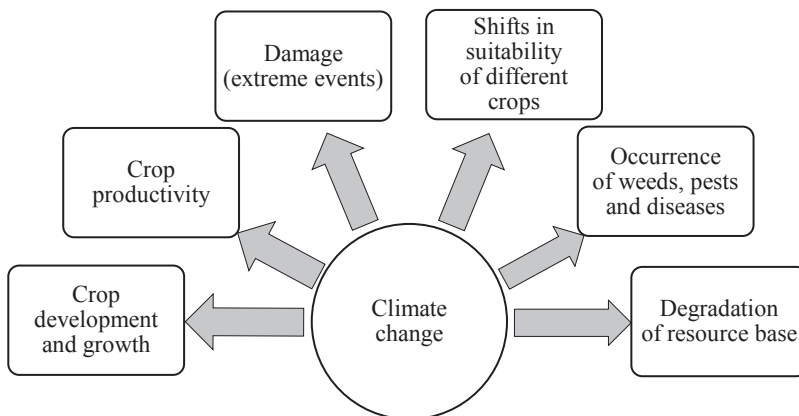


Fig. 1. Impact of climate change on crop production

Source: own study based on the literature cited in the text.

Most of the effects are directly or indirectly related to crop yields and productivity. The plant growth and development phase is of fundamental importance for their cropping and episodic temperature changes exceeding threshold values, e.g. at the plant pollination stage, can be very harmful (Hatfield et al., 2011). On the other hand, maintaining high temperatures can increase the ageing rate of plants, which reduces their ability to effectively produce grains or fruits, reducing their quantity and quality (Hatfield and Prueger, 2015). Another major problem is the change in the dynamics of the development of weeds, insects and diseases in agricultural crops. This problem is additionally related to the adaptation of farming practices of farmers to climate change, e.g. by introducing new varieties and species of plants (Roos, Hopkins, Kvarnheden, and Dixelius, 2011).

The effects of resource degradation are very difficult to quantify. Climate change and, for example, land degradation are interrelated processes. Soil degradation is a direct and indirect effect of human activity as, first of all, it is the result of land use, but indirectly the result of a negative human impact on the climate (soil erosion; deterioration of the physical, chemical and biological condition of the soil; long-term loss of natural vegetation). Land degradation can be aggravated by land use,

management patterns and natural phenomena such as drought, heavy rains and fires (Webb et al., 2017).

The problem of plant productivity as a result of the impact of climate change is of interest to many researchers, especially since the effects may be negative or positive depending on the geographical area analysed. Climate warming for Northern Europe creates more opportunities than threats (Wiréhn, 2018), while countries in the continental climate zone, i.e. Hungary, Serbia, Bulgaria and Romania will face a decline in productivity due to increased heatwaves and droughts, with no possibility of successive crop transfer (Olesen et al., 2011). Similarly in Africa, due to climate change, a reduction in the area of major crops in some countries is expected and their relocation to others, but as a consequence a decrease in productivity in this continent is forecast (Ramirez-Villegas and Thornton, 2015). In turn, research conducted in China does not give unequivocal results. As a result of the relocation of wheat, corn and rice crops, an increase in the production of these plants is expected (Yang et al., 2015), while without taking into account crop displacement, a decrease in corn and soybean yields is forecast (Chen, Chen, and Xu, 2016). From a global perspective it is anticipated that the rate of increase in total crop productivity until 2050 will persist due to technological and agronomic improvements. Even in the most pessimistic scenarios, it is highly unlikely that climate change will cause a net decline in global harvests (Lobell and Gourdjji, 2012).

In animal production, climate change is seen primarily as a threat (Rojas-Downing, Nejadhashemi, Harrigan, and Woznicki, 2017). This is due to the higher probability of occurrence of diseases in farm animals, limited water resources, but also to the decrease in the nutritional value of animal products. The main problems arising in animal production along with climate change are shown in Figure 2.

The most serious effects of climate change in animal production include reduced livestock production. This is due to the occurrence of heat stress in animals resulting from high air temperature and humidity. The period of animal acclimatization to the ambient conditions is characterized by reduced feed intake, higher water consumption and, consequently, a negative energy balance (Nardone, Ronchi, Lacetera, Ranieri, and Bernabucci, 2010). Animal heat stress has a negative impact on both milk production volume (Key, Sneeringer, and Marquardt, 2014; Qi, Bravo-Ureta, and Cabrera, 2015), as well as on weight gain in the production of live pigs, beef and poultry (Baumgard et al., 2017; Kadim et al., 2004). As a result of the occurrence of heat stress and the period of acclimatization of animals to ambient conditions, the reproductive efficiency of farm animals of both sexes also decreases (Rojas-Downing et al., 2017).

Climate change in animal production is often noted by farmers due to limited water resources and problems in producing the right amount and quality of feed. Nardone et al. (2010) estimate that pastoral systems and mixed systems that count on the availability of water and arable crops will suffer most from climate change.

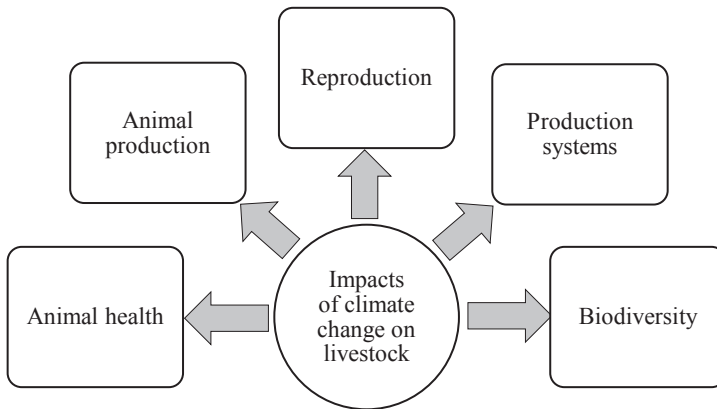


Fig. 2. Impact of climate change on animal production

Source: own study based on the literature cited in the text.

On the other hand, grasslands are well suited to buffering negative climate impacts, e.g. in Europe, the former Soviet Union countries, North America, and especially in South Asia. Increasing the production of concentrated feed, especially when it is necessary to irrigate crops, will be difficult due to falling groundwater levels and soil fertility, as well as limiting biodiversity (Weindl et al., 2015).

The relationship between animal health and climate change is not widely studied. Researchers suggest, however, that zoonoses and outbreaks of infectious diseases are more likely to occur with global warming (Sachan and Singh, 2010). It is estimated that an increase in temperature between 1 and 5°C can cause high cattle mortality (Howden, Crimp, and Stokes, 2008). Higher temperatures as well as weather extremes increase the susceptibility of animals to disease and the possibility of their transmission by pathogens (Bett et al., 2017).

As a result of climate change a diversity of livestock breeds are threatened. Data show that intensive animal production, based on a small number of selected animal breeds, poses a far greater threat to biodiversity than extensive production (FAO, 2009). The expansion of intensive animal production and the export of entire production systems have led to a reduction in diversity by replacing large-scale local breeds with a small number of successful breeds around the world. Thornton, van de Steeg, Notenbaert, and Herrero (2009), state that the effects of the impoverishment of genetic diversity are irreversible and the damage difficult to quantify. In the author's opinion, reducing the number of livestock breeds can lead to the loss of resistance genes to many diseases and pests, and problems with environmental adaptation.

3. Adaptation of farms to climate change

Adaptation can be understood as an adjustment in response to observed or expected changes in order to mitigate damages, or use as opportunities (Kundzewicz, 2017). In the farming system, Smit and Skinner (2002) consider changes in some features of this system as an adaptation (of the agricultural sector or farms belonging to it) directly related to limiting vulnerability to climate change.

Although farmers decide on the implementation of adaptation measures, the initiative may come from entities from the farm environment, public or private, then they are directed to a wider group of farms (Figure 3). Actions at the farm level are taken in the farmer's decision-making process. In the actions presented in Figure 3, their interdependence is important, e.g. research and development of plant varieties more resistant to diseases can be carried out in enterprises in the field of agri-business, partly financed from the state budget, and used on farms will impact the change of the performance of agrotechnical operations in them.

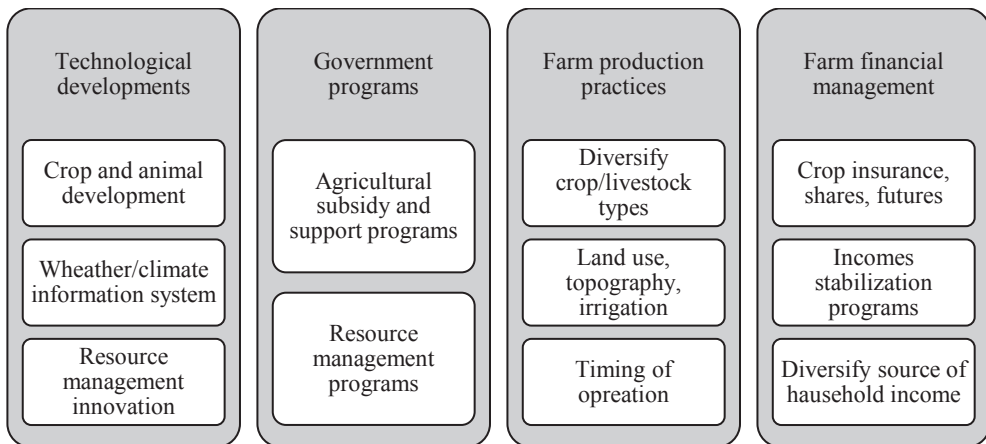


Fig. 3. Types of climate change adoptions in agriculture (with selected examples)

Source: own visualization based on considerations of (Smit and Skinner, 2002).

Farm-level adaptation strategies can be divided into two basic types: climate mitigation strategies and impact transfer strategies. Production diversification is one of the basic adaptations used on farms. The diversity of species as well as livestock breeds and crop varieties can increase drought tolerance, high temperatures, and can also increase animal production. In addition, the diversity of crops and livestock reduces disease and pests due to climate change. Diversification can also be understood more broadly as the diversity of farm production systems. Particularly noteworthy are mixed production systems (plant-animal, agricultural-forestry), which can lead to increased production efficiency on farms by producing more food

on a smaller area using smaller resources, such as water (FAO, 2017; Rojas-Downing et al., 2017). Changes in agricultural practices influence the reduction of the impact of climate change on production results. This applies to both the implementation of various agrotechnical operations in plant production, including the schedule for their implementation (Olesen et al., 2011; Wiréhn, 2018), as well as decisions related to the management of animal herd farms (e.g. adopting breeding strategies that can increase animal tolerance for heat stress and diseases and improve their reproduction and development (Rojas-Downing et al., 2017)). Strategies for financial adaptation are associated with mitigating the effects of climate change due to the increased risk of a decline or loss of farm income. Financial adjustments include decisions on crop insurance, derivative financial instruments, income stabilization programs, and the diversification of household income sources.

The nature of climate change influences the choice of farm adaptation strategies. In the case of continuous changes (e.g. related to changes in the rainfall distribution throughout the year), farmers limit their impact by changing the production structure, switching to types of productions less sensitive to weather changes, diversifying production or investing in field irrigation systems. However, in the case of extreme phenomena that cause catastrophic damage (drought, frost, etc.), they try to share the risk by insuring themselves against the consequences of such events (Musshoff, Odening, and Xu, 2011).

Government (public) support and incentive programs have a large impact on the type of adaptation strategies implemented on farms. An example can be activities related to the so-called greening as part of the CAP reform in 2013, which supported practices related to crop diversification, maintenance of permanent grassland and environmentally friendly areas (to preserve biodiversity). Mutual insurance funds (Lipińska, 2016) mitigating the effects of climate change are also a popular instrument supported by government programmes.

4. Barriers in the adaptation of farms to climate change

The implementation of climate change adaptation measures on farms is limited by their adaptability and the readiness of their owners to implement new strategies (Figure 4) (Kragt, Mugeru, and Kolikow, 2013). Adaptive capacity is associated with the possibilities of reorganizing farms, i.e. having sufficient resources (human, financial, information, etc.). In turn, the readiness of a farmer to undertake adaptation activities is conditioned by the cognitive factors, values and goals of the farmer, his/her insights on the costs, benefits and risks associated with changes. If a farmer does not see the benefits of adaptation, he/she will not adapt to climate change.

On farms, direct restrictions on adaptation to climate change are related to biophysical and technological factors. Biophysical factors can constitute absolute restrictions because they refer to agro-climatic conditions and the physiological

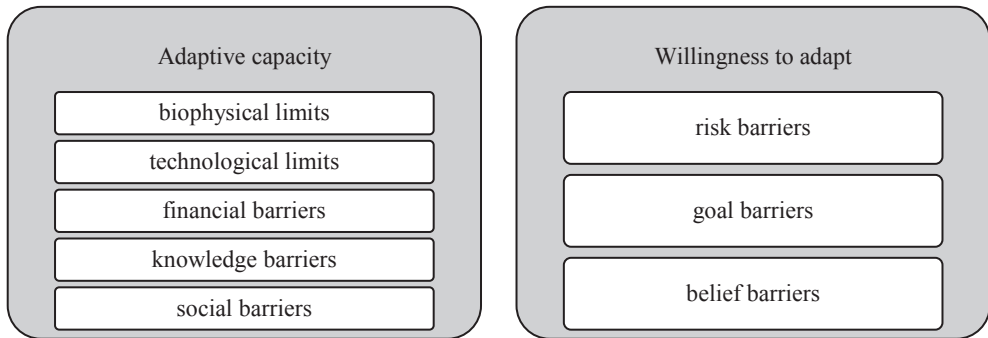


Fig. 4. Limits and barriers to adapting to agricultural climate change

Source: own adaptation on base of interdisciplinary framework defined by (Kragt et al., 2013).

features of plants and farm animals. Some barriers resulting from biophysical factors can be overcome by the use of appropriate technology, provided that it is available, both in terms of the tool developed (the existence of technology) and the farm's ability to cover the costs of its implementation. Therefore it is important to support farms in implementing specific strategies, e.g. in investments in new technologies limiting the negative effects of climate change (Kahil, Connor, and Albiac, 2015) or in the change of land use (European Court of Auditors, 2017). This support can be of a financial nature, but also a knowledge transfer. Knowledge flowing from various institutions and social interactions, and above all the contradiction of this information, constitutes a serious barrier by changing the perception of climate change and the risk arising from undertaking or not undertaking adaptive actions. Factors such as technology, information, and knowledge are important determinants of farmers' resilience to climate change and their adaptability (Nguyen et al., 2016). An important argument for creating policies to reduce the impact and effects of climate change is that they affect farmers' faith that the climate is actually changing as a result of human activity (including agricultural activity) (Prokopy et al., 2015).

The second group of restrictions is closely related to the personality traits of farmers. The perception of the costs and benefits of introducing changes in farms determines their propensity to adapt. Farmers' decisions are made to maximize benefits. In the context of a changing climate, the unpredictability of the effectiveness of decisions made is increasing. This is mainly due to the parallel impact of many other non-climatic risks on the farm (market, legal, etc.), difficulties in distinguishing permanent trends from episodic climate changes and the impact of the individual situation of the farmer and his/her family on the decisions made (Bradshaw, Dolan, and Smit, 2004).

5. Conclusions

Climate change is an important factor in agricultural production. Scientific research results for the most part show that the effects of climate change on farm production are negative. There is a link between these changes, both in plant and animal production, with a decrease in productivity, a deterioration in resistance to pathogens and an increased process of displacement from the production of less resistant species, leading to a reduction in biodiversity. The positive effects of climate change can only be found in crop production. This has to do with the emergence of opportunities for plant cultivation in regions where climatic conditions have so far prevented such production.

Reducing the impact of climate change on farm production is fundamental in the limitation of production risks, especially in plant production. The most commonly used adaptation strategies on farms include the diversification of production and changes in agricultural practices, which, for example, include the diversification of agricultural practices, that through e.g. appropriate agrotechnical measures, weaken the impact of reduced precipitation (FAO, 2017).

Adapting farms to climate change depends on the adaptability of farms and on farmers' willingness to make changes. Restrictions on the availability of technology, knowledge and financial resources are the main barriers to adaptability, yet they can be eliminated by implementing financial support and knowledge transfer programs as well as legal regulations (Adamowicz, 2012; Biesbroek et al., 2010). The second group of barriers are factors related to the subjective assessment of the impact of climate change on farm production by the farmer. These are also factors related to the belief in the effectiveness of the actions taken, which supported appropriate climate policy can raise the importance of the problem of climate change in assessing the farmer and increase his/her readiness to adapt to it.

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WPLYW ZMIAN KLIMATU NA PRODUKCJĘ W GOSPODARSTWACH ROLNYCH

Streszczenie: Produkcja rolnicza jest bardzo wrażliwa na zmiany klimatu ze względu na swój przyrodniczy charakter. Właściciele gospodarstw, chcąc ograniczyć wpływ tego oddziaływania lub złagodzić skutki, wprowadzają różne działania dostosowawcze. Celem artykułu jest przedstawienie głównych skutków zmian klimatycznych w produkcji roślinnej i zwierzęcej w gospodarstwach oraz prezentacja możliwości i barier wdrażania działań dostosowawczych. Opracowanie stanowi studium przeglądowe. Do głównych skutków oddziaływania zmian klimatu należy zaliczyć obniżenie ilości i jakości produkcji, osłabienie odporności zwierząt i roślin na choroby i szkodniki oraz problemy z rozmnażaniem. Działania adaptacyjne podejmowane są przez rolników, ale mogą być inicjowane przez otoczenie zewnętrzne gospodarstwa. Do głównych wyzwań, przed którymi stoją gospodarstwa, można zaliczyć ich problemy ze zdolnościami adaptacyjnymi oraz sposób postrzegania zmian klimatu i związanego z nimi ryzyka.

Słowa kluczowe: produkcja roślinna, produkcja zwierzęca, ryzyko, adaptacja, bariery adaptacji.