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A safe space of rural areas in the context of the occurrence of extreme weather events—A case study covering a part of the Euroregion Baltic

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ABSTRACT

Ongoing climate change was first noticed by the public a few decades ago. The factual occurrence of such a change and its impact on the space were confirmed by both results of scientific research and economic assessments carried out for a variety of economic purposes. The economic sectors whose activities are based on natural weather conditions are most vulnerable to the effects of ongoing climate change. An increase in the number of extreme events, and primarily of their effects, are deeply felt by, primarily, the agricultural community. The study focused on the agricultural sector involved in crop cultivation within a part of the Euroregion Baltic. For analyses, statements on financial losses in agriculture, suffered in the years 2010–2014 and caused by extreme weather events (*inter alia* rainstorm, hail, cyclones, lightning strike, flood, spring frost, drought, the negative effects of over-wintering of crops), were used. By applying the theory of scale-free networks, a network of relationships was constructed, which allowed the authors to indicate sensitive places vulnerable to financial consequences of such events in rural areas.

The European Union policy which also embraces the fragment of the part of the Euroregion Baltic under study aims at broadening the range of policy instruments which are to affect changes to land use patterns in order to find the balance between the outcomes of agricultural production and the adverse effects brought about by this production to natural ecosystems. This direction of activities is also aimed at preventing the effects of climate change. The constructed *scale-free* network model indicated that not all agricultural areas are equally affected by the financial effects of the occurrence of extreme events. An analysis enabled the indication of the most vulnerable (sensitive) locations, the so-called *hubs*, while the investigated topology of the system leads to the conclusion that financial losses in the current sensitive locations may increase to an unimaginable level. Knowledge of the nature of the system, however, allows one to affect its evolution. Targeting of the European Union policy instruments toward the areas most affected by the consequences of extreme weather events will make agricultural producers less vulnerable to them and strengthen the farmer community's trust in the expected financial results of the farm work.

1. Introduction

Climate change is currently one of the key environmental, social, economic and political problems in numerous countries. The effects of this change, occurring over the last few decades, intensify, and therefore have become an object of interest to governments and the international community.

The climate of the Earth has changed many times due to the fluctuations in solar radiation, changes to the parameters of the Earth's orbit around the Sun, changes to the composition of the Earth's atmosphere, and the properties of the Earth's surface (Kundzewicz and Juda-Rezler, 2010). According to the report of the *Intergovernmental Panel on Climate Change*, climate warming over the recent decades is clear because the atmosphere and the ocean are heated, the amount of snow and ice has decreased, and both the sea level and the greenhouse gases concentration have risen (IPCC, 2013). This fact is also confirmed by scientific research involving the observation of the elements of atmosphere using the latest methods (Rahman, 2016; Li et al., 2015; Van Malderen et al., 2014; Guerova et al., 2016; Khodayar et al., 2016). Humans also actively participate in the climate change through population growth as well as economic, socio-political, cultural, religious, scientific and technological factors which bring about changes in ecosystems (Nelson et al., 2006; Martinez-Harms et al., 2017).

The existence of humans is determined by a variety of ecosystems (agroecosystems, forest, aquatic, and natural ecosystems, etc.) yet humans systematically change them with their existence, leading to their

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degradation. In every region of the world, plants, animals, and ecosystems are adapted to the prevailing climatic conditions. When these conditions change, the plants and animals present will be impacted, some will become less productive, or even disappear (Gordon et al., 2010; Harrison et al., 2010; FAO, 2016). Changes in ecosystems occur due to the complex interaction between mutual relationships between people and their surroundings, when they try to satisfy their basic needs and improve their well-being (Nelson et al., 2006). Agricultural ecosystems may also act to the detriment of natural ecosystems (e.g. plant diseases, crop pests, water use, soil impoverishment, spread of undesirable species), reducing their efficiency or increasing production and management costs (Zhang et al., 2007). Certain changes in ecosystems are difficult to predict e.g. the effect of a certain climatic change on a whole ecosystem, because each element will react differently and interact with the other. The absence of internal mechanisms controlling the relationships between the costs borne by the environment and the land use and management (Bryan, 2013; Lant et al., 2008) is the main cause of the changes occurring in natural ecosystems. The concept of ecosystem service includes a range of provisioning (e.g., food, fresh water, and bioenergy), regulating (e.g., climate, erosion, and pests), supporting (e.g., biogeochemical cycling, biodiversity/habitat), and cultural (e.g., recreation and education) services (Power, 2010; Bryan, 2013). However, ecosystem service does not remedy the adverse effects of agricultural production which influence the balance between the supplies of different ecosystem goods and services (Wiggering et al., 2016). This creates additional hazards to agricultural productions, resulting from climate change, which directly translate into hazards to food security and feeding people. This particularly concerns social groups directly dependent on agriculture in terms of livelihood. Such hazards may also affect food security and feeding remote populations through the volatility of prices and the distortion of trade. According to the *Food and Agriculture Organization of the United Nations* (FAO, 2016), climate change affect rural areas and the agricultural production in many aspects (Fig. 1). A range of physical, biological and biophysical impacts bear on ecosystems and agroecosystems, translating into impacts on agricultural production. This has quantity, quality and price effects, with impacts on the income of farm households and on purchasing power of non-farm households. All four dimensions of food security and nutrition are impacted by these effects *(*FAO, 2016*)*.

Restoring natural ecosystems through changes to the pattern of land use and management is currently the global priority *(*Ehrlich et al., 2012; Foley et al., 2011) as they are able to counteract the effects of human activities (climate change). Recommendations for food production include a recommendation of crop management − this particularly concerns the dates of sowing cereals, the selection of a variety, and a change to the duration of irrigation. According to Müller and Elliott (2015), adaptive changes to crop management are likely to improve the productivity by approx. 7–15%, although these results depend greatly on the region and type of crops. An increase in efficiency of limited water resources is another important aspect of creating the flexibility of agricultural farms in the context of climate change, therefore the management of shortages and surpluses is an important item of adaptation. New cultivation practices enable a reduction in the exposure of the topsoil to the impact of climate, an increase in evaporation, an increase in the characteristics of soil humidity, and a reduction in the sensitivity to drought and heat. Increasing the diversity in production systems is also of importance. This can take various forms, for example: a combination of various types of production, e.g. forestry, crop and animal production; an increase in the number of various species, populations, varieties or breeds; and an increase in the use of a genetically diverse material. Such a strategy aims to minimise risks in the future. Finding ways to combine diversity strategies is one of the main challenges of the future (FAO, 2015). In addition, according to Jones and Thornton (2009), in certain regions, flexible transition between crop and animal production will be of key importance in the adaptation strategy.

Policy-makers, having noticed the problem of imbalance, are also developing market policy instruments (including financial incentives) for the provision of ecosystem service (Bryan and Crossman, 2013). For instance, documents concerning Common Agricultural Policy in force in the EU and in the part of the Euroregion Baltic under study set out the principles of the so-called cross-compliance as well as agri-environment-climate packages in which the amounts of obtained payments are linked with the fulfillment of specific requirements by beneficiaries. These requirements are primarily supposed to counteract soil erosion, limit the degradation of organic matter, to counteract changes to the soil structure, and preserve and protect plant and animal habitats as well as water. Proposed the introduction in rural areas of (1) buffer zones (tree and bush covers) on agricultural land at a distance of 5–20 m from the edge of water courses, drainage ditches, channels, lakes and water reservoirs (with an area of up to 50 ha), water intakes, and the areas of marine coastal waters; (2) field woodlots and shrubs, also along transport (including agricultural transport) routes; (3) woodlot strips conducted along contour lines, and surface woodlots at locations vulnerable to erosion; (4) the maintenance of vegetation cover, stubble fields, forecrop post-harvest remnants, and mulch at 30% of the area of arable land in farms located in areas exposed to water erosion; (5) a ban on the cultivation of plants requiring the maintenance of ridges along the slope in arable land situated on slopes of over 20°; these areas must be used for the cultivation of perennial plants, with a vegetation cover or litter in interrows; (6) a ban on grassland burning (grass, post-harvest remnants, etc.) which will help maintain an appropriate level of organic matter; (7) a ban on trimming hedges and trees in the periods of bird hatching and rearing, and on the destruction of natural monuments and ditches up to 2 m in width, which will ensure the maintenance of agricultural landscape features; (8) the protection and conservation of garden ponds within a farm with a total area of up to 100 m^2; (9) a ban on the destruction of habitats and refuges which are areas of reproduction, rearing, resting, migration and preying of birds under protection within Natura 2000 sites; (10) a ban on the erection of structures, installations and devices without permit within Natura 2000 sites; (11) compliance with the rules of fertilisation on steeply sloping, water-logged, flooded, frozen or snow covered areas; (12) the proper application of plant protection products and biocides; (13) the maintenance of an appropriate level of greenness through the diversification of crops; the maintenance of permanent pasture on an appropriate surface; the maintenance of pro-environmental areas in agricultural farms with an area of over 15 ha of arable land (fallow areas, elements of agricultural landscape, hedges, trees planted in groups, tree strips, field margins, water holes, shrubs along drainage ditches and watercourses, under-sowing of grass in the main crop, or mixtures made of 2 groups of indicated plants (ZWZ, 2014).

Each financial incentive can influence multiple land uses, and each land use can affect multiple ecosystem services (Bryan and Crossman, 2013). According to Bryan (2013), when changing agricultural land use back to natural ecosystems through restoration, trade-offs have been found between achieving salinity and biodiversity objectives (Maron and Cockfield, 2008), and between carbon sequestration and a range of other services including biodiversity (Crossman et al., 2011), food (Nelson et al., 2010; Paterson and Bryan, 2012), and water (Chisholm, 2010).

Previous research addressing the issue of climate change focus on many aspects related to climate change. For example, many studies have explored the local and regional economic impacts of specific events, such as tropical cyclones, floods, earthquakes, heat waves, and wild fires (Pielke, 2007; Zhang et al., 2009; Okuyama and Chang, 2004). Quantitative scenario analysis has been widely applied at multiple scales and has addressed multiple issues (Alcamo et al., 2008; Rothman, 2008; Rounsevell et al., 2014; Nakicenovic et al., 2014; Bryan et al., 2016) some of them are targeted, sector-wise, towards agriculture and land use (Golub et al., 2012; Havlik et al., 2011; Thomson et al., 2010; Van Der Werf and Peterson, 2009). These analyses, containing