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Agriculture vs. Alleviating the Climate Change

Rolnictwo a łagodzenie zmian klimatu

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Abstract
Climate changes related to the greenhouse gas emissions (GHG) are seen as one of the major threats to sustainable human development. The agricultural sector is responsible for about 13.7% of global greenhouse gas emissions, therefore the action must be undertaken, which would have to reduce the GHG emissions from agriculture and/or adaptation of agricultural production to the new conditions, so that the productivity of the sector, i.e. agriculture, is not diminished.
The *Climate-Smart Agriculture* is a viable alternative. This term should be understood as targeting the agricultural practices to reduce its negative impact on the environment, and consequently also on the climate. Two strategies are used in the process of climate-friendly agriculture management, noting that agricultural practices can mitigate the climate changes (reduction of GHG emissions), or adapting agriculture to the already noticeable changes (development of soil and water quality, sustainable agronomy, animal breeding, or crop rotation).

Key words: agriculture, climate, Climate-Smart Agriculture, greenhouse gases

Streszczenie
Zmiany klimatu, związane z emisją gazów cieplarnianych (GHG), są postrzegane jako jedno z najważniejszych zagrożeń dla zrównoważonego rozwoju ludzkości. Sektor rolny odpowiedzialny jest za około 13,7 % światowej emisji gazów cieplarnianych, dlatego należy podjąć działania, które miałyby na celu ograniczenie emisji GHG z rolnictwa i/lub dostosowanie produkcji rolniczej do nowych warunków, tak aby produktywność sektora, jakim jest rolnictwo nie zmniejszała się.
Realną alternatywę stanowi rolnictwo przyjazne klimatowi (Climate-Smart Agriculture). Przez to pojęcie rozumie się ukierunkowanie praktyk rolniczych na zmniejszenie jego negatywnego wpływu na środowisko, a w konsekwencji także na klimat. W sposobie zarządzania rolnictwa przyjaznego klimatowi wykorzystuje się dwie strategie działania, zauważając, że praktyki rolnicze mogą łagodzić zmiany klimatu (zmniejszenie emisji GHG), lub dostosować rolnictwo do już zauważalnych zmian (kształtowanie jakości gleb i wód, zrównoważona agrotechnika i hodowla zwierząt czy zmianowanie upraw).

Słowa kluczowe: rolnictwo, klimat, rolnictwo przyjazne klimatowi, gazy cieplarniane

Introduction

The concept of sustainable development assumes postulate of the necessity to meet the basic needs of both current and future generations. Therefore, we should definitely care more about the environment, using the raw materials more economically (Gawłowski et al., 2010). In addition, a major challenge is to ensure the access to food, without which the human population is not able to develop.

One of the available options is an intensive industrial agriculture based on monoculture crops as well as the use of artificial fertilizers and chemical plant protection means. Seemingly, it is consistent with the concept of sustainable development, as it is able to deliver large amounts of food at very reasonable prices. Unfortunately, this happens at the expense of quality (which may pose a risk to human health), as well as the expense of crowding out smaller farms, which produce even better food, they cannot compete with the giants in terms of prices. Moreover, industrial agriculture is growing at the expense of unacceptably high levels of environmental degradation: decline in soil fertility, destruction of ecosystems, and biodiversity loss (Sobczyk et al., 2012). As a result, crops are much less resistant to extreme climate conditions, which occur more frequently and are becoming increasingly violent (Bogdański, 2012; Nelson, 2009; Panagiotis, 2004). Ability of plants for adaptation to a changing climate is also reduced.

Solution to the climate crisis requires replacing the model of industrial agriculture with an alternative that respects the natural limits of the agricultural production space potential and utilizes its regenerative abilities.

Agriculture is one of the key elements in the struggle against the climate changes, which pose additional challenges for agriculture, especially in developing countries. On the one hand, it is seriously endangered by the consequences of global warming, and on the other, the agriculture itself is a significant source of greenhouse gas emissions. Agriculture lies at the intersection of climate change alleviation and adaptation activities. The agricultural sector is responsible for about 13.7% of global greenhouse gases emissions (GHG) (Tubiello, 2013; Kolasa-Więcek, 2012), and is also a key factor in deforestation, which further contributes to 7-14% of global emissions (Harries, 2012; Hosonuma, 2012). At the same time, climate changes will have significant negative effects on many farming communities, especially small and poor farmers, who have limited capacity of adaptation to climate change, further exacerbating poverty, and food insecurity (Howden, 2007; Morton, 2007). Thus, both mitigation actions aiming at reducing the greenhouse gas emissions and adaptation to maintain current yields, gain the rank of a global importance. Experts agree that, in this situation, mere continuation of current practices is not enough feed the growing population of the world in the upcoming decades (FAO, 2013; Vermeulen, 2012).

Achieving significant progress in adapting and mitigating the effects of climate change in the agricultural sector will contribute to the success of a number of different policy and international initiatives. Mitigating the climate changes is critical to realization of the overall objective of the UN *Framework Convention on Climate Change (*UNFCCC) for stabilizing the greenhouse gases concentrations in the atmosphere, and in particular, in terms of reducing the greenhouse gas emissions from deforestation and the degradation processes (Wollenberg, 2011). Adaptation in agriculture is necessary to achieve the *Millennium Development Goals* established by the Organization of the United Nations, especially the elimination of extreme poverty and hunger (Sanchez, 2005).

As highlighted above, agriculture will be deeply affected by climate change. It is an important sector in terms of greenhouse gas emissions, and therefore it will face the pressure to mitigate the climate changes by reducing the greenhouse gas emissions. It is therefore required to undertake the action for Climate-Smart Agriculture.

The notion *Climate-Smart Agriculture* (CSA), i.e. climate-friendly agriculture, was first used by the Organization of the United Nations on Food and Agriculture Organization (FAO) in 2010. It assumes that at a growing number of world population and increasing needs for food, the agriculture in a form less harmful to the environment and climate can be a solution to many problems. Through the use of appropriate practices, it will help to reduce the greenhouse gas emissions, but at the same time it will provide greater food security and better living conditions in rural areas.

In September 2013, during the UN climate summit in New York, a Global Alliance for Climate-Smart Agriculture was announced, which joined the governments of 20 countries, 30 international organizations and corporations.

The current global system of food production and distribution is responsible for roughly half of greenhouse gas emissions. Its change is critical to inhibit or mitigate the global warming and surviving under conditions of warming climate. From 44 to 57% of all greenhouse gas (GHG) emissions come from the global food system (IPPC, 2001; Smith, 2007).

Because of the prospect of advancing climate change and increasing demand for food by 70% by 2050, the agricultural practices must change to meet these challenges (Bogdanski, 2012). The Climate-Smart Agriculture initiative aims at: achieving the sustainable and equitable growth in agricultural productivity and related income; increasing the resistance of food systems and agricultural livelihoods to the consequences of climate change wherever possible; reducing and/or eliminating the greenhouse gas emissions related to the agriculture.

Acting together, the alliance wants to strive for world food security by adapting the agricultural practices, food systems, and social policies to the climate change and the need for better protection of natural resources.
The Climate-Smart Agriculture is a comprehensive response to the interlinked challenges of food security and climate changes.

Agriculture

It is commonly assumed that farming is the source of 11-15% of all GHG emissions (Scherr, 2012; Smith, 2014). Agricultural activity is a source of greenhouse gases, and at the same time an absorber for carbon dioxide, which in particular is stored in soil organic matter and plant biomass (Uliasz-Bocheńczyk, Mokrzycki, 2015).
The main sources of greenhouse gas emissions in agriculture are (Olecka, Sadowski, 2008):

- Carbon dioxide emissions (CO_2) resulting from the use of fossil fuels in agriculture (fuel, electricity, gas), changes in carbon resources in agricultural soils and the use of fossil fuels during the production of goods intended for agricultural production (fertilizers, animal feed, pesticides, etc.);
- Methane emissions (CH_4) during anaerobic fermentation: enteric fermentation at ruminants, anaerobic digestion during the use and storage of manure and other wastes from livestock production, anaerobic fermentation on flooded rice fields,
- Nitrous oxide emissions (N_2O) associated with the use of mineral and organic fertilizers and the management of manure.

To a lesser extent, agriculture also produces small particles in the form of salts that reflect the sunlight in the atmosphere, such as ammonium nitrate (NH_4NO_3) and sulfates.
With regard to the emission absorption, the agriculture and forestry, in contrast to other sectors of economy, are able to bind atmospheric carbon dioxide through photosynthesis and make its sequestration within the soil and biomass. Especially meadows, wetlands, and forests contribute to the absorption of significant quantities of carbon dioxide. However, it may also lead to the loss of these carbon resources, e.g. due to changing in the land use (through deforestation, plowing the grasslands, draining the wetlands, etc.) or exceptional weather conditions (e.g. hurricanes, fires, etc.) leading to rapid release of the stored carbon in a form of CO_2 to the atmosphere (Pawłowski, Cao, 2014). According to FAO, the expansion of industrial agriculture is responsible for 70-90% of the global deforestation, and at least half of that for cultivation of only a few export crops. This means that the contribution of agriculture in deforestation is responsible for 15-18% of global GHG emissions (Scherr, 2012).

The impact of agriculture on greenhouse gas emissions can also be estimated at the level of individual farms, using the balance and taking into account the emissions of greenhouse gases (carbon dioxide CO_2, methane CH_4, and nitrous oxide N_2O), and on the other hand, the CO_2 removal (emissions reduction) as a result of the carbon sequestration within soils and the production of renewable energy and biomaterials. Three main sources of emissions are: animal husbandry, crop production, and manufacture of agricultural production means. Balance *emissions-absorbing* reflects the performance of farms in terms of greenhouse gas emissions (Olecka, Sadowski, 2008).
The emission-absorption of greenhouse gases balance – called the Life Cycle Assessment (LCA) – can also be determined for particular agricultural products (milk, beef, arable crops, biogas, etc.). In the case of farms having a number of production plants, these balances are considered for each of them individually. Thereby, different types of production can be compared in regard of their climate efficiency.

Agri-food industry

Another element of the industrial food system, that contributes significantly to the greenhouse gas emissions, is transport. Transportation of food is the source of a quarter of transport emissions, or 5-6% of the total global GHG emissions.
Another link in the chain of industrial food production is processing. The processing of food into ready-to-eat meals, snacks and beverages requires huge amounts of energy, mostly originating from burning the fossil fuels. Similarly – the packaging. According to the report by Grain: *Processing and packaging allows the food industry for filling the shelves with hundreds of different products, but it also generates huge amounts of greenhouse gases – from 8 to 10% of global emissions* (Grain, 2012).
Refrigeration is a key element of the global supply systems of modern supermarkets and fast food restaurants. Considering the fact that cooling is responsible for 15% of the total global electricity consumption and leakage of chemical freezing media is an important source of GHG emissions, it can be safely assumed that the cooling of foods is responsible for 1-2% of the global emissions. Further 1-2% is the retail sale of food products.
Industrial food system discards up to 50% of the produced food in the course of a long journey from farms to middlemen, processing, shops, and restaurants. A large part of this waste decomposes in landfills to produce significant amounts of greenhouse gases. Up to 3.5-4.5% of global GHG emissions originates from the waste, and the source of 90% of them are materials derived from the food system. Therefore, the wastes from food production and

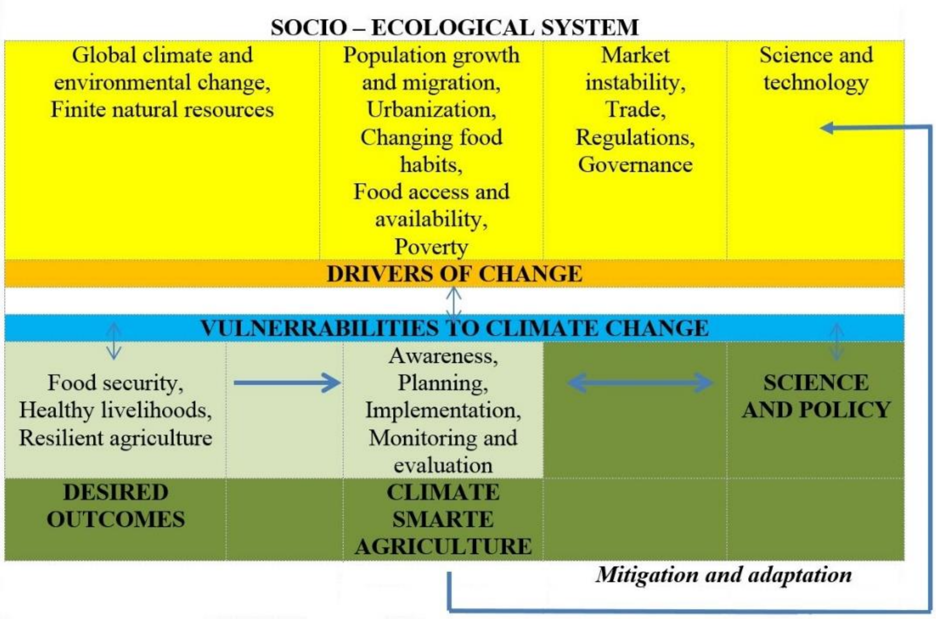

Figure 1. Diagram illustrating how climate-smart agriculture can be utilised as an agent for developing resilience, mitigation and adaptation within the socio ecological system.

Table 1. Technological innovations relevant to CSA categorised according to climate change objective (CSA Booster, 2014).

Climate variability risk	Multiple – constraint mitigation	Resource management optimization	Smart spatial allocation
• information systems (local data-agronomic models), • insurance options, • alert systems for extreme events, • preventive infrastructure, • new varieties and protection practices, • institutional changes i.e. regulation in food markets.	• life – cycle assessment (LCA), • logistic optimization, • information and control system (e.g. for inputs and manure handling).	• combined farming systems and food processing, • irrigation systems and water management optimization tools, • sustainable land management practices, • tools to model links between resources and agricultural and non – agricultural use, • participatory approaches for resource management.	• shifts to other land use, • sourcing practices and strategies of retailers, firms (e.g. in agricultural cooperatives), • simulation tools for spatial distribution of land use at different scales, integrating agriculture with other activities.

distribution are responsible for 3 to 4% of the global greenhouse gas emissions.

Climate-Smart Agriculture

Global demand for agricultural products, both food, fiber and fuel, is constantly linked with population growth and changes in diet. As a result, there is an increase in *per capita* income and – where there are no additional land for agricultural purposes – the need for alternative energy sources. Thus, agriculture needs to produce more in the same area of land, while adapting to a changing climate and has to be more resistant to threats from extreme weather events such as droughts and floods (Smith, 2007).

During the World Science Conference held in 2013 on Climate-Smart Agriculture (Davis, CA, USA), the participants analyzed the status of the global science and best practices on climate and agriculture around the world. They reiterated the consensus reached at the World Science Conference in 2011 on Climate-Smart Agriculture (Wageningen, the Netherlands), agreeing with a broad strategy based on a science and policy in order to strengthen the food security, climate change alleviation, and adaptation of changes (Wageningen Statement, 2011). Existing and promising works within the CSA were identified and programs for interdisciplinary research and science-based activities supporting CSA were formulated.

The term *Climate-Smart Agriculture* (CSA) has been adopted to represent the strategies that can contribute to meet above challenges by increasing the resistance to weather conditions, adaptation to climate changes, and reduction of greenhouse gas (GHG) emissions from agriculture, which contribute to the global warming (Figure 1) (WB, 2011, 2013; FAO 2013).

Technological innovations have been highlighted as playing a key role in transitions to sustainable practices in the future, including the context of Climate-Smart Agriculture. Innovations within Climate-Smart Agriculture are shown in Table 1 (SA Booster, 2014).

The importance of agriculture for climate protection depends on both the size of the area, on which the production is carried out, as well as the specifics of the sector – this is the range of human activities, which can affect a wide range of conditions and shape the natural processes.

A considerable share of, especially methane and nitrous oxide in emissions, shows that undertaking the action in the agricultural sector is an important issue. There are three main lines of action in agriculture, which can contribute to more effective climate protection (Karaczun, 2006, Smith et al., 2007):

- Reducing the greenhouse gas emissions into the atmosphere,
- Increasing the amount of carbon bound in the biosphere,
- Avoiding greenhouse gas emissions.

The most important activities in agriculture in order to protect the climate should include (Karczun, 2008):

Some changes in agricultural techniques:

- Measures to increase efficiency in the use of nitrogen fertilizers. This can be achieved, for example, through the use of improved technology for nitrogen application, matching the nitrogen supply to the needs of plants, appropriate systems to maximize the use of animal manure in crop production, leaving the plant residues containing nitrogen in the field, and finally reducing the use of nitrogen fertilizers. It is extremely important to keep fertilization based on the plans and on the basis of crop's fertilization needs;
- Observance of the proper crop rotation and the introduction of intercrops, which increase the carbon binding in the biosphere and may reduce the need of soil for mineral nitrogen fertilizers;
- The use of plowless tillage techniques, which reduces the carbon loss from the soil and reduces emissions of N_2O;
- Improving the efficiency of irrigation techniques. About 18% of the cultivated areas in the world is artificially irrigated often in an inefficient way leading to a loss of energy and may increase the emission of nitrous oxide from those areas;
- Increasing the carbon binding by biomass, for example, by a greater amount of humus contained in the soils of arable lands, support for perennial crops (orchards, nurseries of ornamental species). A special role will be played by activities for the introduction of new and preservation of existing woodlots, ecological areas, and permanent grasslands.

Changes in animal husbandry:

- Improvement of animal feeding. This can be accomplished, for example, by better balancing the rations ensuring better use of feed, including the elimination of unnecessary amounts of amino acids and adding the formulation binding nitrogen compounds, which are the source of N_2O emissions;
- Improving the livestock maintenance systems. This can be done by adding the biotechnological preparations reducing N_2O emissions, into the manure and litter, reducing evaporation surface of droppings in lairs and litter;
- Reducing CH_4 emissions from the stored manure and liquid manure through the lowering of temperature of stored excrement by means of recovery and accumulation of heat energy or the construction of installations for the biogas recovery from liquid manure fermentation.

Support for bioenergy and energy utilization:

- Promoting the use of renewable energy sources (RES). Agriculture can be a source of renewable raw materials for energy production (energy crops, biofuels); there is also the possibility of using RES as a source of energy used in agricultural production;
- The use of incentives to implement the energy-saving investments in agriculture. Activities in this field are typical works of a double benefit – allow not only the reduction of emissions, but give the benefit to people undertaking them. Although agriculture is not a very energy-consuming sector of the economy, there are many opportunities to improve the efficiency of energy use, including animal husbandry, cultivation under cover, or at cultivation works.

The above examples of activities do not exhaust all possible ways to protect the climate in agriculture, however, they point to a wide range of possible actions, the implementation of which can contribute to an effective climate protection.

Adapting agriculture to climate changes

There are various definitions of the adaptation of agriculture to climate changes. Riebsame et al. (1995) argue that it is *any action aimed at the reduction of negative, or at the increase of positive impacts of climate change*. The adaptation can also be planned or spontaneous, that is carried out in advance or *ad hoc*. An example of planned adaptation is breeding of varieties resistant to drought and temperature changes, while spontaneous adaptation consists in adapting the date of sowing/planting crops to changing climatic conditions (Table 2).

Table 2. The potential consequences of climate change depending on stimulating factor

Phenomenon and trend of changes	Potential consequences for agriculture
Warming, Decrease in number of cold/freeze day/night, Increase in number of hot days	Increased yields in colder regions, Decreased yields in warmer regions, Increased incidence of pest infestation
Increase in frequency of hot periods and heat waves	Decrease in yields in warmer regions due to heat stress
Increase in the incidence of frosts in late spring and early autumn, Increase in the frequency of heavy rainfall	Destruction of crops, soil erosion, inability of tillage due to wet ground
Increase in the frequency of droughts	Soil degradation, lower crop yields, destruction of crops, increased mortality of livestock
Increased incidence of extremely high sea level	Salinity of irrigation water and delta areas

The adaptive options include a wide set of methods aimed at reducing the vulnerability and increasing the adaptability of farming systems in relation to climate change. These options include technical solutions that relate to the risks associated with climate changes, stress factors in the environment, development of early warning systems, and creating systems of crop insurance. They also include a number of farm practices (such as the protection of soil and water, crop diversification, and improving the growing conditions), which would make that agricultural systems to become more resilient to climate changes, diversify the livelihoods of farmers and ensure the continuity of services supply from ecosystems (Howden, 2007).

Mitigating the climate change

Climate change will have significant and generally negative consequences for agriculture and its development, especially in the lower latitudes. Since 1980, climate change has contributed to a reduction in global yields of corn and wheat, respectively by 3.8% and 5.5% (Lobell, 2011). Increased climate variability over the coming decades will increase the frequency and intensity of occurrence of both floods and droughts, as well as increase the risk of production in relation to crops and livestock, and reduce the ability of farmers to cope with the problems of climate change (Thornton, 2010). Climatic changes are a threat to food access for populations, both on rural and urban areas, by reducing the agricultural production and increasing the risk of market distortion (Varmeulen, 2014). The negative effects can be alleviated through the adaptation of agriculture from relatively small changes in production practices to large transformational changes in the systems of agricultural and food products.

Climate-Smart Agriculture is to focus on diversification (using complementarity between crops, through systems of crops and livestock in the area of risk management). Diversification is a key element in building the adaptability (Bruce, 2014).

The mitigating options for agriculture can be broadly divided into three categories of practices: (1) actions to increase carbon resources above and below ground, (2) activities that reduce emissions directly from agricultural crops (carbon dioxide, methane, nitrous oxides) in any place in the agricultural production cycle; and (3) actions to prevent deforestation and degradation of ecosystems with high carbon content for the establishment of new rural areas (Smith, 2007; Wollenberg, 2012).

Food systems contribute significantly to global warming and are responsible for about 19-29% of global emissions, most of which coming directly from the activities of agricultural production (i.e. N_2O and CH_4) (Vermeulen, 2012).

Because of the need to increase production in many developing countries, greenhouse gas emissions from agriculture are likely to rise, mainly due to continued expansion in livestock production, fertilizer use, and changes in land cover (Bennett, 2014). However, sustainable intensification, with a focus on improving the production efficiency, is necessary to achieve the purpose of mitigation of climate changes: to achieve lower emissions of N_2O and CH_4 per unit of production. Sustainable intensification on existing agricultural lands is also a major potential source of reduction of land cover changes, especially forests abundant in carbon, as well as wetlands (Wollenberg, 2011). Although less intense, lower production efficiency may generate local environmental benefits. This strategy may need to devote to the cultivation lands situated elsewhere to compensate locally lower yields, leading to greater overall environmental benefits (Wyszyński et al., 2008). Globally, the total yields – mainly cereal crops and oil – have increased by 135% in 1961 and 2005, while the area of arable lands has increased by only 27% (Burney, 2010), although the expansion degree of agricultural lands varies significantly between regions. However, increased efficiency, due to the intensification, may increase the incentives for expansion (Rudel, 2009; Ewers, 2009). To achieve the purpose of climate change alleviation, we must go far beyond the simple goals of agriculture intensification. Both concepts, both sustainable intensification of agriculture and Climate-Smart Agriculture recognize this reality.

Summary

To provide the proper functioning of agriculture is a particular challenge for sustainable development of mankind, especially in the context of climate changes.
Adapting of agriculture to climate changes and their mitigation can be generated by various means, for example: increasing the soil quality by improving its buffer properties; moderating the hydrological cycle; improving the soil biodiversity; regulating the cycle of carbon dioxide, oxygen, and plant nutrients; increasing the resistance to drought and floods, as well as carbon sequestration.
There are substantial opportunities to realize the objectives of adaptation and alleviation of climate changes in agriculture and to adopt an integrated approach to the landscape, which contribute to achievement of the objectives in the field of climate change, food security, provision of ecosystem services, and other purposes. Although there is no a single general pattern to capture synergies between adaptation and mitigation of climate change, their combined analysis in landscape planning, research, technical assistance, government policies, and funding mechanisms can significantly help in achieving this objective. A renewed and strengthened commitment to sustainable agriculture, protection of agriculture, agroforestry, and other best management practices in agriculture, as well as increased pressure on the integrated landscape management, can contribute to the development of agricultural and landscape systems, while contributing to the food security, fight against poverty, and conservation of biological diversity in areas particularly affected by the climate change.

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