

**Mariusz Maciejczak\***, **István Takács\*\***, **Katalin Takács-György\*\***

\*Warsaw University of Life Sciences – SGGW, Poland, \*\*Óbuda University, Hungary

## USE OF SMART INNOVATIONS FOR DEVELOPMENT OF CLIMATE SMART AGRICULTURE

*WYKORZYSTANIE INTELIGENTNYCH INNOWACJI W ROZWOJU KONCEPCJI CLIMATE SMART AGRICULTURE*

**Key words:** smart innovations, climate-smart agriculture, technologies, sustainable development, foresight studies

*Słowa kluczowe:* inteligentne innowacje, Climate Smart Agriculture, technologie, zrównoważony rozwój, badania foresight

*JEL codes:* O31, Q19, Q55

**Abstract.** The concept of Climate Smart Agriculture couples climate change and food security through the integration of adaptation and mitigation measures, mostly driven by smart-innovations. The paper is an attempt to present how climate smart agriculture concept could be driven by diffusion of the smart innovations in agriculture, and how these innovations could contribute to reduce vulnerability and hence increase resilience to climate change. The results of foresight studies shows that use of innovative technologies could provide benefits through reducing the asymmetry of information coming from natural production systems and through reducing its vulnerability, as well as reducing the environmental pressure and connected with this risk of increased production failures and negative external effects.

### Introduction

The perception of agriculture, not only by economists, but also by farmers themselves, has led, to shaping its functions through the lens of entrepreneurial rationality, maximization of economic surplus, profitability and development, based on the criteria of effectiveness. It was connected with the approach which equated agricultural activity with industrial activity, thus imposing on agriculture an industrial character [Dethier, Effenberger 2012]. Nowadays, the reassessment of the concept of quantitative development into both quantitative and qualitative issues is taking place. However these changes are driven not only by changing perception of how agriculture should look like, but more often by the increasing environmental problems, especially connected with climate changes [Parry 1992] and limitation in use of non-renewable production sources [Wicki 2017]. These lead to development many concepts, which more address political choices than make theoretical assumptions.

Climate Smart Agriculture aims to sustainably increase agricultural production, increase resilience to climate change and reduce GHG emission, ensure safe food production and food safety [FAO 2013]. In order to meet these objectives there are proposed many practices which are both cost-effective and have a positive climatic impact, such as integrated crop-livestock management, use of renewable energy, use of legumes or cover crops, and practices which increase soil carbon. Nonetheless to ensure long-term sustainable development and appropriately respond to climate changes it is imperative to use also smart innovations based on new technological and organizational solutions applied to agricultural production. Such solutions should enable next generation precision-farms by harnessing modern and emerging technologies such as small satellites, drones, tele-operation, augmented reality, advanced data analytics, sensors, or robotics. Although some of these technologies are already been implemented, the adoption has

been slow and diffusion rates pose a problem [Vanclay et al. 2013, Fogarassy, Nábrádi 2015]. There is thus a need to determinate prospective usefulness of different technologies, already being on high technology and market readiness levels, in order to provide guidelines how they can contribute to the development of climate-smart agriculture.

### **Methods and data sources**

The paper has three objectives. Firstly, the climate smart agriculture concept will be discussed and framed into the paradigm of sustainable development. Secondly, the diffusion of the smart innovations and imitations in agricultural sector will be described. Finally, based on foresight analysis, the smart innovations for agriculture will be assessed against their contribution to climate smart agriculture with regard to resilience to climate change. Having in mind that the concept of CSA can be considered as a novelty in the framework of economic analysis as well as the fact that used for its development technologies are on early diffusion stages, there was applied methods of foresight studies. The rationality behind such choice enables to determinate scenarios for upcoming future actions.

For that purpose the secondary data were collected using literature review of agricultural economics and environmental economics sources. These data were studies by applying Roger's Model of Innovation Diffusion [Rogers 1962] and Gartner Hype Cycle Model [Wolfert et al. 2017]. The primary data were collected using Real Time Delphi Method [Maciejczak 2016]. There were invited 20 experts from 5 countries (Poland, Hungary, Germany, Ukraine and France), whom represent different stakeholders of agriculture and food sector (farmers, processors, traders, consumers, administration). Three sessions under Real Time Delphi methodology were executed in the period January-March 2018. In the first session the prospective technologies for CSA were proposed. The second session aimed to assess possible impact of selected 10 technologies based on advanced technological solutions and 10 technologies based on advanced processes. During the third session, the experts evaluated the probability of cross-impact between selected technologies considered as innovations. Based on the experts' choices the Cross-Impact analysis was performed using approach proposed by Victor Bañuls and Murray Turoff [2011].

## **Results and Discussion**

### **Sustainability of Climate Smart Agriculture**

Being aware of the fact that the vulnerability of the agricultural sector to climate change is influenced by environmental and socio-economic factors the CSA, as a global development goal, was introduced by FAO [2013] to guide the transformation of agricultural system under the paradigm of sustainability. The concept of CSA couples climate change and food security through the integration of adaptation (short term) and mitigation (long term) measures. It aims to reduce vulnerability by improving the adaptive capacity of agricultural systems to climate stress and, hence, securing the provision of food, while reducing GHG-emissions from agricultural practices and land uses contributing to climate change [Brandt et al. 2017]. It should be taken into consideration the effects of the new solutions on land use and land prices. Judit Oláh et al. [2017] concluded, that due to the increasing biofuel output less land goes to animal feed production, so land use implications including GHG emission savings will change, that will appear in price volatility [Oláh et al. 2017].

Elwyn Grainger-Jones [2012] stresses out that the concept of CSA can't be considered as another view of the 'Green Revolution'. To the contrary, CSA fits into the sustainable agricultural approaches. This means that addressing climate change does not require to discard or reinvent everything that has been learned about agriculture in recent decades. In fact, CSA is built upon a technical foundation that largely already exists and a range of sustainable agricultural approaches – such as sustainable agriculture, sustainable intensification and conservation agriculture – are the cornerstones of implementing CSA in practice.

However as stressed by Caroline Mwongera et al. [2017] approaches that aim to identify and prioritize locally appropriate CSA technologies will need to address especially the context-specific multi-dimensional complexity in agricultural systems. As argued by Mariusz Maciejczak [2017] agriculture should be recognized as a complex adaptive system, which faces also new challenges resulted from the introduction of bioeconomy or circularity approach in the production activities.

In contrast to conventional agriculture management, CSA is an effort to ensure planning around climate change and agriculture in holistic way that is maximizing multiple outcomes and minimizing tradeoffs in management of food systems [Sain et al. 2017].

The technologies used for that purposes are not always in place and the promise of their usefulness not always meets real needs of the adapting system [Maciejczak, Faltmann 2017]. The major barriers experienced by providers of technological solutions were identified as difficulty in demonstrating value, access to investment, an ‘unsympathetic’ regulatory landscape and difficulty reaching customers. By contrast, users identified lack of awareness, high costs, long return on investment periods, lack of verified impact and regulatory issues [Verschuuren 2017]. The greater engagement with users early on in the design process (‘co-creation’) the better alleviation of both problems. Despite the wide endorsement of sustainable, climate smart farming practices and technologies by the scientific community, it seems unlikely that the entire agricultural sector across the world will convert from conventional to climate smart agriculture anytime soon. Therefore, the broad adoption of climate smart agriculture now has primarily become a governance issue.

### **Innovative smart technologies for sustainable agriculture**

Technical development is a continuous process in everyday agriculture. Competitiveness, technical and economic efficiency depends on the technical-development factors. Technical development of agriculture is based on four main pillars due the definition of European Association of Agricultural Economists [Takacs 2008]. These four pillars are the following: biological, chemical, technical and human. Technical pillar includes engineerable, architectural development, too [Husti 2003]. The expansion of the factors of agricultural technical development is closely related to general social development. Here should be mentioned the ‘de-growth’ theory, by Serge Latouche [2007, 2011]. Due to the limitation here only the need of reevaluation of resource use, consumption, question of localization, role of cooperation, share of access are mentioned here as one potential direction of future’s innovation.

Innovation has wider meaning: production or adoption, assimilation, and exploitation of a value-added novelty in economic and social spheres; renewal and enlargement of products, services, and markets; development of new methods of production; and establishment of new management systems. It is both a process and an outcome, but should be highlighted the role of human factor in it. Agriculture is a very complex system. The production is carried out in an ecological environment (soil, climate, certain agro-eco potential for yields), mainly based on and with biological organism, on and in the land, using natural and artificial resources, technical equipment, etc. During the last decades – as the importance of knowledge has higher significance and the complexity of the technologies, equipment got more complicated – the human factor and organizational innovation got importance in the process of “implementation” of the innovation results in practice. When a new technology is implemented into a such complex system, hard is to reach economic efficiency. Efficiency has a technical meaning: yield efficiency for the given land, soil and climatic conditions. The responsibility of the farmers means to find the appropriate species, technologies from the point of view of agro-eco potential. Role of human factor increased in last decades in technical development: To adopt those technologies that are either newly invented or are being utilized in new ways means task for farmers to think, to work, to manage the so complex ‘system’, their farm in another way that they used to. Higher is

the invested capital value in the farm, higher level of knowledge, managerial skills are needed, farming risk is increasing so higher the loss can be due to inadequately work. All innovative solutions in agriculture should serve sustainable agriculture. The term “sustainable development” goes further on the future: it includes the current and long-run sustainable production and the controversies of environmental protection that assurance the right quality of life, and hard-preventable, but rather tolerated conflicts. Here appears the role of innovation named as smart for sustainable development [Caffey et al. 2001, Mensah, Castro 2004, Behnassi et al. 2011, Popp et al. 2018]. Also should be highlighted the relationship between economic growth and sustainable development [Jámbor, Leitato 2017].

### **Climate Smart Agriculture driven by Smart innovations’ diffusion**

Based on Rogers’ typology of the diffusion of innovations the use of an agricultural innovation can be explained, including some of the reasons for the level of its uptake in practice [Takács-György et al. 2013, Lencsés et al. 2014]. The motivation factors of users play key role in the adaptation of the technology. Aversion to the novelty, to new technologies is a real barrier of the wider spreading besides the lack of financial sources to renew the equipment. Following the initial phase, the role of interpersonal communication channels increases (e.g. discussions between experts), the farmer shows also can help to increase the farmers’ knowledge on new technology [Maciejczak 2012, Csizmadia 2009]. As the important factors can be mention also the IT skills, the role of extension services and communications and other usefulness of novelty in the diffusion of technology. The causes of the slow spreading process also include lack of education and expertise. High is the role of positive attitude to the new technology, environment conscious thinking besides the economic expectations in the success of individual decisions. The biggest problem with the application of a new technology is that its possible advantages and disadvantages highly depend on the professional knowledge and attitude of the manager and the staff. Some of the benefits can be observed directly (material saving, improved cost-effectiveness, yield growth), similarly to extra costs and investments. However, its indirect impacts, such as the reduction of the environmental load and increased food safety, are less obvious. As long as the positive impacts of the new technology are not obvious and measurable for farmers, and the perceived risk of its introduction is high, the technology will diffuse slowly, even when the financial background is sufficient.

The results of the foresight study presented on the figure 1 indicates that out of 10 selected technologies, which principally based on advanced technical discoveries only 4 can be considered as prospected to support CSA. On one hand these are technologies that delivers new solutions, never used before, such as sensors or drones. They common characteristic is that they deliver more precise and accurate information needed to optimize agricultural production. Similarly the second group of technologies, namely special data and network management are used to collect, process and utilize information. These technologies main benefit comes from reducing the asymmetry of information coming from natural production systems and through reducing its vulnerability. The second group of analyzed technologies are farming processes oriented and out of 10 selected for foresight study also 4 has been recognized by experts as having strong impact on CSA. These technologies aim to reduce the environmental pressure and connected with this risk of increased production failures (low yields) and negative external effects (pollution). Two of technologies, namely cover crop and green manuring increase the productive function of the land for arable production, while fodder management ensures long term benefits for animal production.

However the spreading of the smart innovations in agriculture can be described also through the co-dependence of a used technology with another emerging technologies being the results of development in the IT sector, machinery and chemistry, plant breeding, biotechnology. The collective diffusion and the cross-impact one technology has on the another is one of key factors deciding on the successful intake and practical utilization.

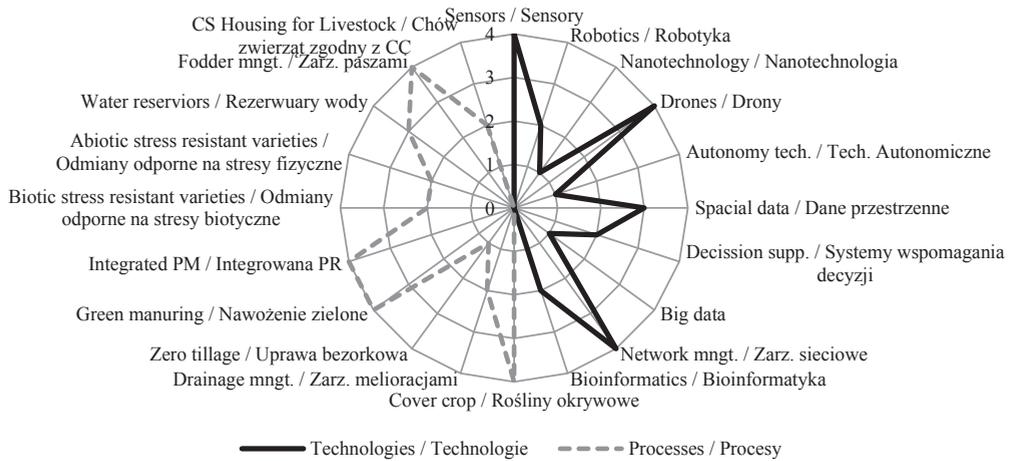


Figure 1. The prospective impact of selected technologies and processes on the development of CSA  
 Rysunek 1. Przewidywany wpływ wybranych technologii i procesów na rozwój CSA  
 Source: own elaboration based on Delphi survey

Źródło: opracowanie własne na podstawie badania metodą Delficką

When a new technology appears, often is considered as an obligate solution for the given problem and the expectation of a rapid, wide spreading is big. The so-called Amara's law can be applied: "We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run" [Fenn, Raskino 2008]. The appearance of a new technology is generally of great interest, the so-called 'new technology fun' farmers try the application, invest into the new equipment – and very often without the proper knowledge, skills – they implement it into their farming. After the first experiments – if they have not got good yield and economic results – many of them gave the new technology up, or did not continue the introduction and extension of the new items. They search for alternative solutions as their excessive expectations do not match with the reality. After the interest peak, there is almost a temporary disillusionment. After the refinement of the technology, its applicability improves, instead of the risks, the benefits come to the fore, leading to its spread in production. As explained by the Gartner's hype cycle model the technologies are verified not only against their practical usefulness but also against alternative solutions. These solutions cross-impact their mutual application.

The executed cross-impact analysis based on the Delphi survey is presented in the figure 2. There were identified most active and passive technologies that would have different impact on each other. As most critical technologies impacting the spread of other ones and similarly impacted by other have been recognized those which delivers added value from enhancement of biological processes (biotic stress resistance, cover crop, integrated pest management) as well as reduce the risks of vulnerability of biological processes through their efficient supervision (robotics) or delivering advance information (sensors). Similar group, however with less impact are technologies categorized as active. They however are less influenced by other technologies, mostly due to their construction or application characteristic. In the executed survey these are i.e. drones or drainage. As reactive technologies has been recognized two: autonomy technologies and zero tillage. These technologies are highly influenced by other technologies serving often as complementarity is a system application. As buffering technologies, which so far are rather isolated have been recognized a.a. big data or bioinformatics. Into this group also network management was categorized. The experts argue that this is only one from selected technologies that requires collaborative actions of several agents, not only farmers, but also advisors or technology providers. Because of this characteristic the cross impact on other technologies is rather small.

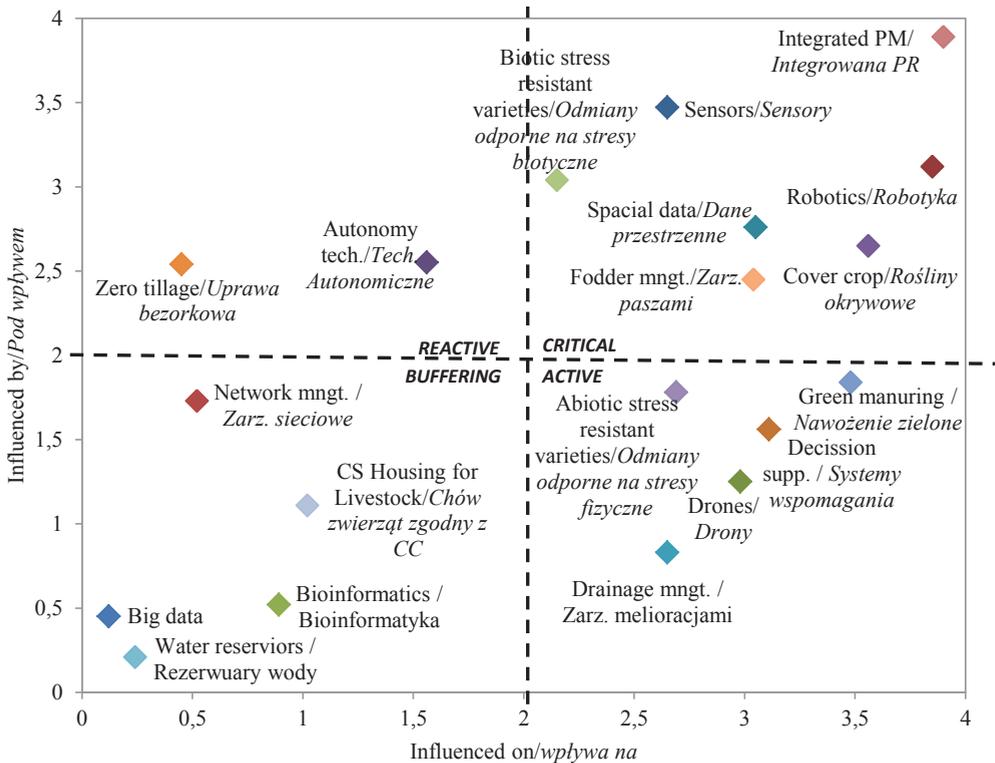


Figure 2. Cross-impact of selected technologies contributing in development of CSA.

Rysunek 2. Analiza wzajemnych oddziaływań wybranych technologii na potrzeby CSA

Source: own elaboration based on Delphi survey

Źródło: opracowanie własne na podstawie badania metodą Delficką

## Conclusions

The concept of Climate Smart Agriculture fits into the growing importance of sustainable development as a practical answer to call for economic viability, social inclusiveness and environmental protection. It couples climate change and food security through the integration of adaptation and mitigation measures. Its main aim is to reduce vulnerability by improving the adaptive capacity of agricultural systems to climate stress and, hence, securing the provision of food. Such aims can be achieved using different smart-technologies being innovative, especially in scope of agricultural production and management, which diffusion largely depends on many factors. These factors can be recognized as internal and external. The internal factors come not only from limited investment opportunities of farmers but largely on their knowledge and skills as well as openness for change. The external factors come from cross-impact of and on other novel technologies. The application of selected technologies for the foresight study under the requirements of the CSA concept could provide several benefits. The main benefit comes from reducing the asymmetry of information coming from natural production systems and through reducing its vulnerability. Their application allows to reduce the environmental pressure and connected with this risk of increased production failures (low yields) and negative external effects (pollution). It needs to be stressed out that the issue of technology driven development of CSA is crucial for implementation of sustainability paradigm in the agriculture. The paper framed some important for this process issues, but further analysis, i.e. about constraints or trade offs are needed.

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### Streszczenie

*Koncepcja Climate Smart Agriculture (CSA) łączy wyzwania związane ze zmianami klimatu i bezpieczeństwem żywnościowym, postulując integrację działań ograniczających i zapobiegających powstającym ryzykom, głównie za sprawą inteligentnych innowacji. Artykuł przedstawia, w jaki sposób CSA może wykorzystać inteligentne innowacje w rolnictwie. W szczególności jak innowacje te mogą przyczynić się do zmniejszenia podatności na zagrożenia systemu rolnego, a tym samym zwiększenia jego odporność na zmiany klimatu. Wyniki badań foresight pokazały, że wykorzystanie innowacyjnych technologii może przynieść korzyści poprzez zmniejszenie asymetrii informacji pochodzących z naturalnych systemów produkcyjnych oraz poprzez ograniczenie szoków i stresów wynikających ze zmian klimatu, a także zmniejszenie presji środowiskowej i związanych z nią ryzyk produkcyjnych i negatywnych skutków zewnętrznych.*

Correspondence address  
Maciejczak Mariusz, PhD  
orcid.org/0000-0002-0630-5628  
Warsaw University of Life Sciences – SGGW  
Nowoursynowska Str. 166, 02-787 Warsaw, Poland  
e-mail: mariusz\_maciejczak@sggw.pl

Prof. dr. István Takács  
orcid.org/0000-0002-0847-3844  
Óbuda University  
1084 Budapest, Tavaszmező utca 17., Hungary  
e-mail: takacs.istvan@kgk.uni-obuda.hu

Prof. dr Takács-György, Katalin  
orcid.org/0000-0002-9129-7481  
Óbuda University  
1084 Budapest, Tavaszmező utca 17., Hungary  
e-mail: takacsnegyorgy.katalin@kgk.uni-obuda.hu