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GMOs AND GLOBAL FOOD SECURITY

Key words: genetically modified organisms (GMOs), biotech-crops, Global Food Security Index (GFSI), food security, agricultural biotechnology

ABSTRACT. The main aim of the paper was an analysis of the present status and changes of commercially grown genetically modified crops and food security from 2012 to 2018, based on the Global Food Security Index by countries. The work used a descriptive approach with elements of inductive reasoning and meta-analysis based on secondary data, derived from Briefs of The International Service for the Acquisition of Agri-biotech Applications, FAOSTAT and the GFSI, developed and calculated by The Economist Intelligence Unit. The study showed the highest increase in biotech crops was observed in Brazil and the USA, i.e. in countries with a relatively high level of GFSI. Accordingly, the highest positive change in GFSI was achieved in several countries both with quite a high level of GFSI (Chile, Uruguay and Argentina) and with a very low GFSI (Burkina Faso and Myanmar). A slightly positive Pearson correlation coefficient for the area of biotech crops and GFSI indicated that, in the analysed period, when an increase in GM crop area was observed, the value of the GFSI increased as well. However, the value of the Pearson correlation means that the biotech crop area can be considered one of the many factors influencing the food security of the studied countries. The results show that biotech crops cannot only be analysed in the context of food security at a country level, but also at a household level. GM crops could contribute to food production increases and higher food availability, however not necessarily to food security, especially at a country level.

INTRODUCTION

Commercial uses of genetically modified organisms (GMOs), understood as organisms whose genetic material has been changed using genetic engineering techniques or "any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology" [Beardmore, Porter 2003, compare: The Cartagena Protocol on Biosafety in 2000][1], has developed very quickly since 1996 to date. Since

[1] The Cartagena Protocol on Biosafety is an international agreement and a legally binding supplementary protocol to the Convention on Biological Diversity (CBD) adopted on 29.01.2000. The protocol addresses the assurance of the safe transfer, handling and use of living modified organisms (LMOs) created through modern biotechnology and the potential negative effects of them. Up until March 2015, 170 countries have ratified the Protocol [ISAAA 2015, p. 186]. The Protocol defines GMOs as "any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology (…). LMOs are considered to be synonymous with GMOs and other similar terms" [Sendashonga et al. 2005]. The most of the GMOs definitions underline that they "do not occur naturally by mating and/or natural recombination" [WHO 2015].

1996, the first year of commercial planting of biotech crops, more than 60 countries have either planted or imported biotech crops [ISAAA 2017]. Soybeans are still the major biotech crop in the world, followed by maize, cotton and Canola. GM crops are currently commercially grown in 26 countries around the world (Table 1), including 21 developing countries growing 54% of the global biotech crop area and 5 industrial countries growing 46% of the global GM crop area. The situation in cultivation has been changing dynamically during recent years, especially between 2013 and 2015, when a majority of European Union countries decided to stop planting GM crops within their borders [ISAA 2015]. Also, other countries decided to ban both cultivation and imports (e.g. Russia in 2016). Some other states developed and introduced special policies to guide a comprehensive national policy to the research, development and commercialization of GM products (e.g. Kenya) [ISAAA 2015]. Before a GM crop is approved for commercial use, it has to pass rigorous safety and risk assessment procedures [ISAAA 2015], but states introducing and developing the cultivation or import of GM products must take control over their safety and security. However, GM crops can mitigate several current challenges in commercial agriculture [Raman 2017], the questions of biotech food security and safety have constantly been repeated in different contexts, including national and global food security, but still the role of biotech crops for food security is the subject of much controversy [Qaim, Khouser 2013, Dibden et al. 2013, Trivedi et al. 2016]. Some people think that biotech crops will reduce world hunger, while others consider it a technology that risks food security [Trivedi et al. 2016]. Food security is a complex, multifaceted issue influenced by culture, the environment and geographic location. In 1996, the final report of the World Food Summit defined food security as the situation "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" [FAO 1996]. In the publications of the International Service for the Acquisition of Agri-biotech Applications (ISAAA)[2] one can read that "farmers worldwide have adopted GM crops because of the realized economic benefits" [ISAAA 2014], which allowed them to increase family income and reduce food insecurity [Qaim, Khouser 2013]. The future expansion of main biotech crops may come with increasing domestic and global demand for protein for food, animal feed, biofuel production, and raw cotton materials [ISAAA 2017].

[2] ISAAA is a non-profit organization with an international network of centers built to "contribute to the alleviation of hunger and poverty by sharing knowledge and crop biotechnology applications". Clive James, former Chairman and Founder of ISAAA, has lived and worked for the past 30 years in the developing countries of Asia, Latin America and Africa, devoting his efforts to agricultural research and development issues with a focus on crop biotechnology and global food security". However, one must remember that ISAAA is sponsored by both public and private donors, including the US Department of Agriculture, CropLife International, FuturaGene, and many others [ISAAA 2019].

MATERIAL AND METHODS

The main content of the paper is a general analysis of the present status and changes of commercially grown biotech crops and food security from 2012 to 2018, based on the Global Food Security Index. The area of genetically modified (GM) crops between 2012 and 2018 and the level of the Global Food Security Index (GFSI) for countries growing GM plants were the main focus of the research. The work uses a descriptive approach with elements of inductive reasoning and meta-analysis based on secondary data derived from Briefs of The International Service for the Acquisition of Agri-biotech Applications, covering information on the area of biotech crops around the world. Due to the nature of the data, analysis is dynamic and covers the period of 2012 to 2018, because of GFSI data availability. Moreover, a comparative analysis was used to examine the changes of the biotech crop area and the GFS Index[3]. "The index is a dynamic quantitative and qualitative benchmarking model, constructed from 28 unique indicators, that measures drivers of food security across both developing and developed countries" [The Economist. 2018]. The GFSI, which examines food security comprehensively and considers the core issues of affordability, availability, quality and safety (core index issue), as well as natural resources and resilience (risk factor) across 113 countries of the world was used in the work. The GFSI was designed, constructed and calculated year by year by the Economist Intelligence Unit. Up till now, GMO has not directly been included as a factor of global food security, however natural resources & resilience factors (e.g. temperature rise, drought, flooding, sea level rise, agricultural water risk, soil erosion, food import dependency etc.) and the quality and safety of food factors (e.g. diet diversification, nutritional standards, micronutrient availability, protein quality etc.) were considered as important in food security. All of them are also important in agricultural biotechnology considered as a factor of food security [Dibden et al. 2013]. The Pearson correlation coefficient was calculated to measure the strength between variables and relationships.

GM CROPS STATUS AROUND THE WORLD

From 2012 to 2018, the area of biotech crops in the world increased by 21.4 million hectares (Table 1), from 170.3 mill hectares in 2012 to 191.7 million hectares in 2018 [ISAAA 2018]. In 2018, up to 17 million farmers were engaged in planting biotech crops and most of them were from developing countries, and some of them were from Low-Income Food-Deficit Countries, including India, Bangladesh, Vietnam (in Asia) and Sudan (in Africa) [James 2017]. In Argentina, Brazil, Uruguay, Paraguay and Eswatini genetically modified crops covered more than half of arable land and in two other countries (Costa Rica and the USA) covered more than 1/3 of arable land.

In 2018, more than 40 different countries, including European Union countries and 18 other countries, imported GM crops for food and feed. The distribution of biotech crops by country and its changes from 2012 to 2018 are shown in Table 1. North America (i.e.

[3] The Economist Intelligence Unit recognizes food security as "a complex, multifaceted issue influenced by culture, the environment and geographic location" [The Economist 2018].

Table 1. Distribution of biotech crops by country from 2012 to 2018

Countries	Total area of biotech crops [mln ha]							Share in agricul-tural land in 2018 [%]	Change 2012-2018 (2012 = 100.0)
	2012	2013	2014	2015	2016	2017	2018		
Argentina	23.9	24.4	24.3	24.5	23.8	23.6	23.9	61.0	100.0
Australia	0.7	0.6	0.5	0.7	0.9	0.9	0.8	1.7	114.3
Bangladesh*	-	-	<0.05	<0.1	<0.1	<0.1	<0.1	<1.3	-
Bolivia	1,0	1,0	1,0	1.1	1.2	1.3	1.3	30.7	130.0
Brazil	36.6	40.3	42.2	44.2	49.1	50.2	51.3	63.4	140.2
Burkina Faso*	0.3	-	-	-	-	-	-	-	0.0
Canada	11.6	10.8	11.6	11,0	11.1	13.1	12.7	29.0	109.5
Chile	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	<0.1	<7.8	100.0
China	4,0	4.2	3.9	3.7	2.8	2.8	2.9	2.4	72.5
Colombia	<0.1	0.1	0.1	0.1	0.1	0.1	0.1	5.6	100.0
Costa Rica	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	<0.1	39.9	100.0
Czech Republic	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	-	-	0.0
Eswatini (Swaziland)	-	-	-	-	-	-	<0.1	57.1	-
Honduras	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	<0.1	9.8	100.0
India*	10.8	11,0	11.6	11.6	10.8	11.4	11.6	<7.4	107.4
Indonesia	-	-	-	-	-	-	<0.1	0.4	-
Mexico	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.8	100.0
Myanmar	0.3	0.3	0.3	0.3	0.3	0.3	0.3	2.7	100.0
Pakistan	2.8	2.8	2.9	2.9	2.9	3.0	2.8	9.0	100.0
Paraguay	3.4	3.6	3.9	3.6	3.6	3.0	3.8	78.1	111.8
Philippines	0.8	0.8	0.8	0.7	0.8	0.6	0.6	10.7	75.0
Portugal	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	<0.1	<10.6	100.0
Slovakia	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	-	-	0.0
South Africa	2.9	2.9	2.7	2.3	2.7	2.7	2.7	22.5	93.1
Spain	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.8	100.0
Sudan*	<0.1	0.1	0.1	0.1	0.1	0.2	0.2	1.0	200.0
Uruguay	1.4	1.5	1.6	1.4	1.3	1.1	1.3	53.5	92.9
USA	69.5	70.1	73.1	70.9	72.9	75.0	75.0	47.5	107.9
Vietnam*	-	-	-	<0.1	<0.1	<0.1	<0.1	<1.4	-
World	170.3	175.2	181.5	179.7	185.1	189.8	191.7	13.8	112.6

* Low-Income Food-Deficit Countries (LIFDCs) [FAOSTAT 2019]

Source: [James 2012, 2013, 2014, 2016, 2017, 2018, FAOSTAT 2019] the USA and Canada) followed by Latin America, represented by Brazil and Argentina, has the largest percentage of biotech crops grown in 2018 and the whole analysed period. The expansion of biotech crop areas can be observed in Asia, especially India. However, in some countries one can observe a decrease in the area of GM crops (e.g. in Burkina Faso, China, and Philippines). The four major GM crops, i.e. soybeans, maize, cotton, and canola, despite decreasing in area, were the most adopted biotech crops by 26 countries and biotech soybeans covered 50% of global biotech crops [James 2018].

According to ISAAA, in total, 70 countries of the world have adopted biotech crops, however most countries in the world prohibit GMO cultivation, especially in 2015, when a majority of European Union nations decided to stop the cultivation of GM crops due to consumer resistance and the influence of EU regulations [Dibden et al. 2013]. Nevertheless, many countries still allow GMO products, particularly animal feed, to be imported, e.g. European countries import about 14 mill tonnes of soya beans per year as a source of protein to feed animals, including chickens, pigs and cattle, as well as for milk production [EC 2019] and 28 mill tons of soya bean meal [de Visser et al. 2014]. Many other countries, e.g. China, Japan and Canada, restricted GMO products, but only until they pass regulatory standards.

Clive James claims that "three domains merit consideration for the future to achieve food security and alleviate poverty and hunger around the world (…), i.e. significant potential for the adoption of selected GM products such as biotech maize in new countries, more than 85 potential new products being field tested prior to approval, e.g. drought tolerant maize in Africa and Golden Rice in Asia and finally, genome-edited crops which may be the most important scientific development, offering significant advantage over conventional and GM crops" [James 2015].

THE GLOBAL FOOD SECURITY INDEX OF COUNTRIES WITH GM CROPS

According to the GFSI framework, the USA, Australia and Canada rank top of the index for 2018 for countries with GM crop production, followed by Portugal, Spain, Chile, Uruguay and Slovakia (Table 2). It must be noted that the United States GFSI rating dropped several times during the analysed period and the Canadian GFSI has almost remained at the same level. Sudan, Burkina Faso, Bangladesh and Myanmar rank bottom of the index, while India and Mexico have declined the furthest in the rankings over the studied years (2012-2018). Nevertheless, Myanmar followed by Uruguay, Colombia and Argentina have made the most progress in food security measured by GFI (Table 2).

The Economist underlined that despite the 2018 GFSI improvements in food availability and affordability, the overall food quality and safety score declined during recent years, due to reduced diet diversification and lower protein quality and their "findings show countries can continue to do more to ensure the safety and health of food" [The Economist 2018].

Table 2. The Global Food Security Index in countries with GM crops from 2012 to 2018

Countries	GFSI*							
	2012	2013	2014	2015	2016	2017	2018	change 2012-2018 (2012 = 100.0)
Argentina	62.9	62.1	62.2	66.4	68.4	67.4	69.2	110.0
Australia	82.1	81.5	81.1	83.0	83.8	83.5	83.7	101.9
Bangladesh	42.6	42.7	44.4	42.0	42.8	42.0	43.3	101.6
Bolivia	50.5	50.8	51.6	52.5	52.7	51.5	50.7	100.4
Brazil	65.8	66.9	66.8	67.7	68.4	67.9	68.4	104.0
Burkina Faso	33.2	32.2	31.4	35.3	35.0	34.2	37.9	114.2
Canada	82.8	81.6	82.0	82.7	83.2	82.5	83.2	100.5
Chile	71.0	71.2	72.9	73.6	75.0	74.7	75.1	105.8
China	62.5	62.5	64.2	65.2	66.4	64.2	65.1	104.2
Colombia	57.3	57.2	58.7	57.5	59.8	60.7	63.7	111.2
Costa Rica	67.5	67.3	67.5	67.9	69.1	69.4	69.3	102.7
Czech Republic	73.6	74.6	74.2	74.1	75.3	75.9	76.1	103.4
Eswatini (Swaziland)	-	-	-	-	-	-	-	0.0
Honduras	49.7	48.9	49.3	47.9	51.4	49.2	50.7	102.0
India	51.6	50.6	50.3	51.5	52.0	50.9	50.1	97.1
Indonesia	50.3	50.3	49.2	50.7	53.6	53.2	54.8	108.9
Mexico	67.5	66.6	66.4	68.0	66.1	66.4	66.4	98.4
Myanmar	39.3	40.2	41.1	44.2	46.9	45.6	45.7	116.3
Pakistan	46.6	45.5	48.5	49.3	49.7	49.4	49.1	105.4
Paraguay	52.7	52.8	52.6	54.0	54.9	56.7	57.2	108.5
Philippines	51.8	48.9	49.2	50.9	50.4	49.0	51.5	99.4
Portugal	79.1	78.7	79.1	79.0	80.4	79.0	79.3	100.3
Slovakia	68.9	68.5	68.1	68.8	69.6	70.0	70.3	102.0
South Africa	61.5	61.6	63.4	63.2	65.1	65.2	65.5	106.5
Spain	78.7	78.1	78.9	78.0	79.1	78.2	78.0	99.1
Sudan	34.4	33.7	36.7	37.0	37.7	36.2	36.4	105.8
Uruguay	64.3	65.9	68.6	69.2	70.7	69.7	71.3	110.9
The USA	85.6	85.2	85.5	84.6	85.5	84.9	85.0	99.3
Vietnam	52.7	53.4	54.5	54.3	56.9	55.3	56.0	106.3
World	56.9	56.6	57.3	58.2	58.7	57.9	58.4	102.6

* Global Food Security Index

Source: [The Economist 2018]

BIOTECH CROPS AND THE GLOBAL FOOD SECURITY INDEX

The level of changes of the area of biotech crops and the Global Food Security Index by countries with GM crop production from 2012 to 2018 is shown in Table 3. While the highest increase in biotech crops has been observed in Brazil and the USA, the biggest positive change in GFSI was achieved in some other countries, including countries with

Table 3. Changes of area of biotech crops and the Global Food Security Index in countries of the world from 2012 to 2018

Countries	Relative change 2012-2018					
	the area of biotech crops			GFSI		
	increase	decrease	no change	increase	decrease	no change
Argentina			+	++		
Australia	++			+		
Bangladesh				+		
Bolivia	+++					+
Brazil	+++			+		
Burkina Faso		+		++		
Canada	+					+
Chile			+	+		
China		+++		+		
Colombia			+	++		
Costa Rica			+	+		
Czech Republic			+	+		
Eswatini (Swaziland)				.	.	.
Honduras			+	+		
India	+				+	
Indonesia				+		
Mexico			+		+	
Myanmar			+	++		
Pakistan			+	+		
Paraguay	++			+		
Philippines		+++			+	
Portugal			+			+
Slovakia			+	+		
South Africa		+		+		
Spain			+		+	
Sudan	+++			+		
Uruguay		+		++		
USA	+				+	
Vietnam				+		
World	++			+		

*Increase or decrease: ≥ 1.0-9.9% +, 10.0-19,9% ++, ≥ 20.0% +++

Source: own elaboration based on data of Table 1 and 2 quite a high level of GFSI (Chile, Uruguay and Argentina) and in some countries with a very low GFSI (Burkina Faso and Myanmar). It is quite interesting that in most of the mentioned countries there was no change of GM crop area from 2012 to 2018 and, at the same time, the GFSI has increased. The different situation was observed in Australia, Brazil, Paraguay and Sudan where both values increased at the same time or in the Philippines where both values decreased between 2012 and 2018.

A Pearson correlation coefficient for the area of biotech crops and Global Food Security Index calculated for the analyzed period was slightly positive (0,1583), meaning that when an increase in GM crop area was observed, the value of the GFSI increased as well, however the correlation was very weak. GM crops cannot only be analysed in the context of food security at a country level, but also at a household level. However, the role of biotech crops for food security is the subject of much controversy. Scientists say such crops are needed to feed the human population which has limited resources [Qaim, Khouser 2013, Dibden et al. 2013, Trivedi et al. 2016]. Obviously GM crops could contribute to food production increases and higher food availability, however not necessarily to food security. There may also be an impact on food quality and nutrient composition. For example, Matin Qaim and Shahzad Khouser [2013] investigated the effects of Bt cotton on farm households in India, proving that its adoption has significantly improved calorie consumption and dietary quality, leading to increased family income, thus reducing food insecurity by 15-20% among cotton-producing households. Other studies, e.g. Pamela Ronald [2011] and Graham Brookes and Peter Barfoot [2008] have emphasized the socio-economic issues of GM crops and food security.

CONCLUSIONS

This paper highlighted the facts and data of GM crops and the Global Food Security Index by country and their changes between 2012 and 2018, considering whether there is any relation in-between them. The study showed the highest increase in biotech crops was observed in Brazil and the USA, i.e. in countries with a relatively high level of GFSI and the highest positive change in GFSI was achieved in several countries both with quite a high level of GFSI (Chile, Uruguay and Argentina) and with a very low GFSI (Burkina Faso and Myanmar). A slightly positive Pearson correlation coefficient for the area of biotech crops and GFSI indicated that the relation between GM crops and GFSI is very weak and there are many factors to be considered that influence the food security of the studied countries. It is also important that there is a difference in food security at a national level and household level and the factors influencing food security at both levels can be different. The results show that biotech crops cannot only be analysed in the context of food security at a country level, but also at a household level. The results of the study show that GM crops could contribute to food production increases and higher food availability, however not necessarily to food security.

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GMO A ŚWIATOWE BEZPIECZEŃSTWO ŻYWNOŚCIOWE

Słowa kluczowe: organizmy modyfikowane genetycznie (GMO), uprawy biotechnologiczne, Globalny Indeks Bezpieczeństwa Żywnościowego (GFSI), bezpieczeństwo żywnościowe, biotechnologia rolnicza

ABSTRAKT

Głównym celem pracy jest analiza obecnego stanu i zmian w uprawach biotechnologicznych oraz bezpieczeństwa żywnościowego na podstawie Globalnego Indeksu Bezpieczeństwa Żywności (GFSI), według krajów. W pracy zastosowano podejście opisowe z elementami wnioskowania indukcyjnego i metaanalizy opartej na danych wtórnych, pochodzących z publikacji Międzynarodowego Instytutu Propagowania Upraw Biotechnologicznych (ISAAA), FAOSTAT i Globalnego Indeksu Bezpieczeństwa Żywnościowego (GFSI), opracowanego i obliczanego przez The Economist Intelligence Unit (the EIU). Badanie wykazało, że w latach 2012-2018 najwiekszy wzrost powierzchni upraw genetycznie modyfikowanych zaobserwowano w Brazylii i USA, tj. w krajach o stosunkowo wysokim poziomie GFSI, a najwyższą pozytywną zmianę GFSI w kilku krajach, zarówno z wysokim poziomem GFSI (Chile, Urugwaj i Argentyna), jak i z bardzo niskim GFSI (Burkina Faso i Myanmar). Nieznacznie dodatni współczynnik korelacji Pearsona dla obszaru upraw biotechnologicznych i GFSI wskazuje, że w analizowanym okresie, wraz ze wzrostem powierzchni upraw GM, wartość GFSI na ogół także zwiększała się. Uprawa roślin genetycznie modyfikowanych może być więc uważana za jeden z wielu czynników wpływających na bezpieczeństwo żywnościowe badanych krajów.

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