



## ORIGINAL ARTICLE

## Future agriculture and food supply chain - not even doomsday preppers got it right

Štefanić, Ivan<sup>1\*</sup> & Štefanić, Filip<sup>2</sup>

<sup>1</sup>Josip Juraj Strossmayer University of Osijek, Faculty of Agriculture and TERA TEHNOPOLIS Ltd., Osijek, Croatia

<sup>2</sup>LIBERTAS International University, Zagreb, Undergraduate university study program: International Relations / Diplomacy

\*E-mail of the corresponding author: stefanic@tera.hr

**Abstract** - Future agriculture and food supply chain is one of the pillars of human survival and prosperity in the long run. The planet's ecosystem is very fragile and influenced by a large array of very diverse natural and human factors which are frequently interdependent. Regardless of root cause, climate change, pollution and depletion of non-renewable resources and several other unfavorable processes are in place. We can argue that the increase of the average temperature is just a part of a long-term natural cycle and not the consequence of human negligence and pollution, but in the end, it doesn't matter. The ecosystem is changed and agricultural plants might not survive the change and adopt in time. Relevant and fairly reliable indicators are available, but it seems that nobody is paying attention to those staggering numbers and trends. Doomsday preppers are well known to be a rather suspicious and concerned group of people about the reliability of future food supply chain. But even they somehow assume that agricultural production will go on, and the only problems that could occur are short run disruptions in distribution.

The main challenge for future agriculture and food supply chain is to produce more food with considerably less resources in a sustainable manner for a rapidly growing population, preferably even reducing current levels of pollution. Securing future agriculture and food supply chain is a complex task, which requires not only new technologies but also a paradigm shift in the current technological and economic system. Possibly the most important change is the change in current agricultural practices and agricultural education.

Reliability of the food system is heavily dependent on mineral oil and significant amount of transportation. Moreover, global agriculture is extremely centralized and profit oriented. Intense push of GMOs into standard agricultural practice led to severe reduction of biodiversity in agriculture. Once upon a time, countless genotypes of same varieties offered unprecedented genetic variability, which was one of the key factors of survival. Today, large GMO fields are populated with only several genotypes. In occurrence of very harmful effects for that particular genotype, whole fields could be simply wiped out. Additionally, patented genes and the domination of hybrid seeds are major obstacles for farmers' own seeds production and provision of decentralized food production during and after possible capital disturbances of future agriculture and food supply chain. To change that situation it's not possible to implement just partial solutions, but a paradigm shift and systematic solutions are required.

Mankind is only a part of a global system, together with some valuable resources that play a crucial, but not so visible role, in the planet's ecosystem. Forests occupy roughly one third of the earth's land surface. Because of their size, forests play a major role in the functioning of the biosphere and not only a role limited to business. Unprecedented deforestation compensates for loss of arable land, but badly influences the planet's biosphere. It seems rather rational to get to the consensus quickly and replace the management paradigm in a sense that we govern and manage something that belongs to us, with the stewardship paradigm in a sense where we steer and cherish the most important resources, vital for our own survival.

**Keywords** – future agriculture, future food supply chain, food production sustainability, agricultural resources, climate changes, and deforestation

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### Introduction

Ever since humans abandoned hunting and collecting as the main source of food, agriculture is serving mankind well. Agriculture is providing most of the food for the exploding population, currently at more than 7.5 billion [1]. Recently, expectations regarding the food just got higher. Considerable proportion of customers consumes food which travels vast distances to get to their tables: naturally, off-season, and regardless of sustainability. In

spite of such an abundance of food, a lot of those customers are suffering from nutrition related diseases. On the other hand, more than 7.6 million people die every year from hunger [2]. Estimates of the population malnourishment differ a lot and depend on definition of malnourishment. According to UN FAO, approximately one tenth of the population is malnourished, 777 million in 2015 (Figure 1) [3].

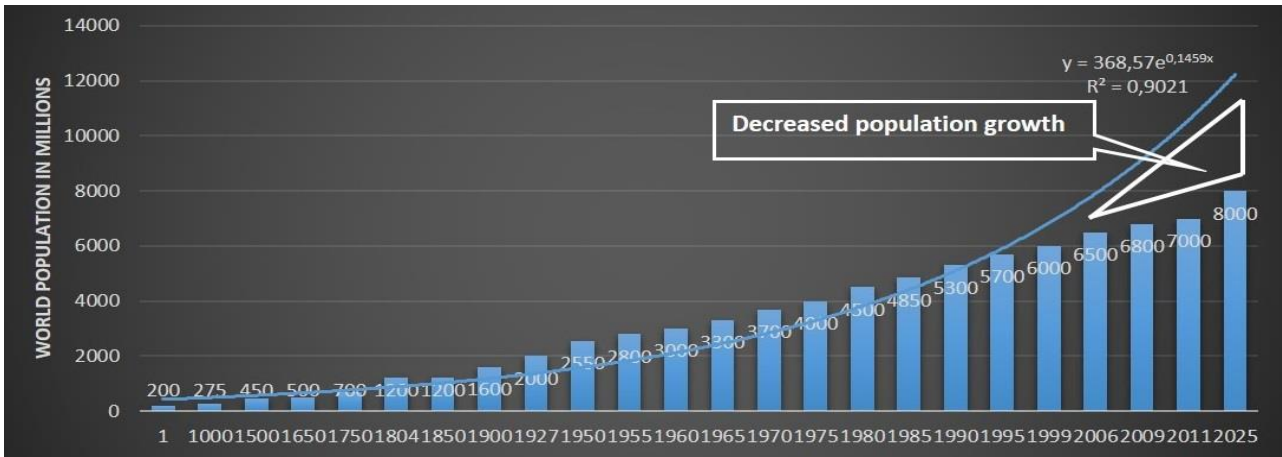


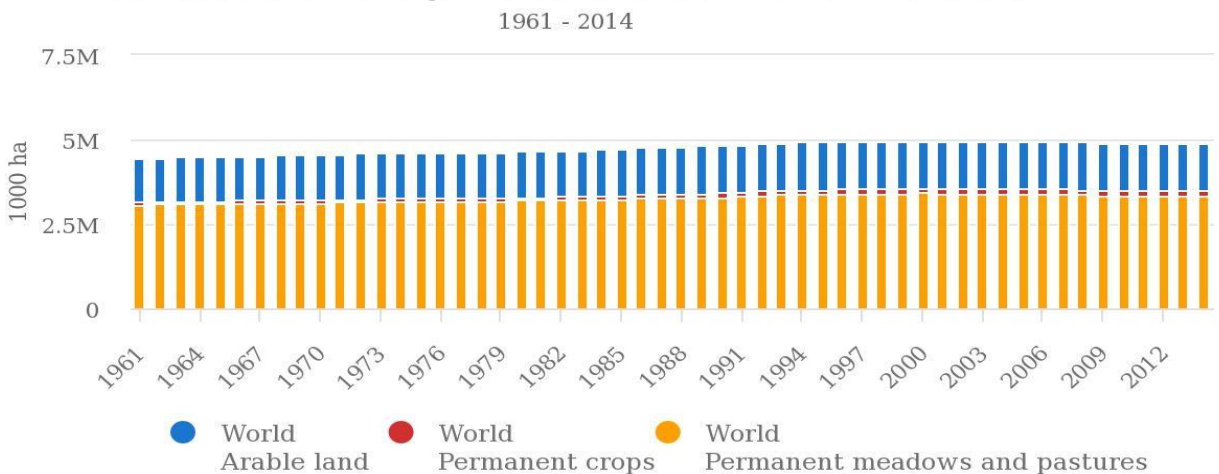
Figure 1. World population and population growth rate Data source: UN population division according to [8].

Physiocrats [4] set the economic system that worked well for agriculture. The model Quesnay created put a lot of emphasis on agriculture, two out of three economic agents: the "proprietary" class consisted only of landowners; the "productive" class consisted of agricultural laborers; were part of economic system. Mercantilists [5] turned everything around and introduced a paradigm, which says that a country's economic wealth could be measured by the amount of gold and silver in its treasury. But even mercantilists claimed that self-sufficiency must be promoted. A country had to use everything it needed within its own borders and not depends on other countries for goods. Agriculture became a polygon to implement great innovations and total food production increased accordingly. However, occasional disruptions were inevitable, and a lot of life was lost and many more were suffered from malnourishment. In his Essay on the Principle of Population, Thomas Robert Malthus [6] argues the principle in which human populations grew exponentially was caused while food production grew at

an arithmetic rate. Thus, humans would have no resources to survive on in the future. Solution to that problem Malthus sees in control on population growth through various factors including disease, war, and famine.

The modern economic paradigm is globalization. In 2000, the International Monetary Fund (IMF) identified four basic aspects of globalization: trade and transactions, capital and investment movements, migration and movement of people, and the dissemination of knowledge. In practice, if you are a business, you shall organize the production of goods in the place where the cost of required resources is the cheapest. If you are a customer, you buy from suppliers with the lowest acquisition costs. It is clear that one of the major drivers of globalization is cheap and reliable transport. Further, globalization besides its impact on business and work organization, economics, socio-cultural resources, causes serious environmental challenges such as global warming, cross-boundary

### Composition of agricultural area World + (Total)



Source: FAOSTAT (Oct 18, 2017)

Figure 2. Composition of World agricultural area 1961 -2014 Source: FAOSTAT, 2017.

water and air pollution, and overfishing of the ocean and similar.

Regional differences in the quality of food supply are significant indicating more troubles in developing countries. But food shortages are occasionally possible in developed countries as well. Post WWII times were troubled with severe food shortages in Europe. Article 39; The Treaty on the Functioning of the European Union (TFEU) sets out the specific objectives of the EU Common Agricultural Policy:

- a) To increase agricultural productivity by promoting technical progress and ensuring the optimum use of the factors of production, in particular labor
- b) To ensure a fair standard of living for farmers
- c) To stabilize the market
- d) To ensure the availability of supplies
- e) To ensure reasonable prices for consumers.

The Common Agricultural Practice in the European Union in time succeeded in achieving all those goals. Not only that: excessive supply and lower food prices caused serious health disorders related to food and nutrition of significant proportions that the population suffers. Obesity, diabetes, high blood pressure and increased cholesterol level, food allergies, various degenerative processes and autoimmune diseases are only examples.

The last decade of the twentieth and the first decade of twenty first century were characterized with several trends that may not be analyzed separately. After the analysis of possible death causes in 2016, smoking and poor diet remain leading risk factors of ill health [7]. With the world's population booming, arable land is decreasing, agriculture is heavily dependent on non-renewable resources, the environment is heavily polluted and agriculture as a profession is assessed as non-attractive with very poor growth potential.

## Materials and methods

Reliability and sustainability of future agriculture and food supply chain is an interdisciplinary topic. Important data from various aspects relevant to the topic are collected from several sources and organized in the form of tables or figures, whichever seems to be more appropriate. Relevant indicators, trends and corresponding equations are calculated where appropriate.

Possible threats are organized in several categories: extra-terrestrial influence, photosynthesis blocking, naturally occurring and caused by human influence. Possible solutions are also organized in several categories as well: Improved existing technologies, new technologies and new paradigms.

## Results

Crucial questions about future agriculture and food supply chain are not related to supply and demand only.

If the question was only “can we feed the current population of more than 7.5 billion?” the answer would be the easy one, because we can.

But question is a little bit more complicated: “Could we sustain the eating habits of those who have the money while feeding the exploding population in developing countries, in a deteriorating environment, dedicating considerable areas to produce energy plants while destroyed arable land is replaced with new one originating from deforested areas, while depleting the planet's non-renewable resources?” and the answer is instantly much less clear. Some of the influencing factors are shown in Table 1.

Table 1. Important trends for future agriculture and food supply chain

Positive	Negative
New technologies in food production and processing Decreased population growth rate (Figure 1)	Population on the brink of the food sustainability Damaged ozone layer Increased concentration of greenhouse gases Increased average temperatures Increased pollution Intense loss of arable land Decreased quality of arable soil Heavy dependence on non-renewable resources Intense deforestation Lack of consensus regarding future agriculture and food security Severe reduction of biodiversity in agricultural GMOs Mankind is counting on future but yet non-existing technologies

According to the study prepared by the University of Sheffield's Grantham Centre for Sustainable Futures, the world has lost a third of its arable land due to erosion or pollution in the last 40 years. In practice, this is an annual loss of arable land equal to the size of a state like Bulgaria or Benin. [9]. But official statistics shows no such trend. Long term data series compiled by FAO indicates that World arable land in 1965 was 1,314,999,730 ha, and in 2014 it was 1,417,152,640 ha, so we are cultivating 100,000,000 ha more than 50 years ago.

The answer to this paradox is rather simple, lost arable land is replaced with newly deforested land. But deforestation is not the appropriate solution. In the short run it will compensate for lost arable land and it will prevent the food shortages caused by decreased production capacity. However, the role of forests is much more important in global eco-cycles of the planet and as such rapid deforestation (Figure 3.), if continued, will lead to irreparable changes. In 2006 Earth Policy Institute prepared the report on forests based on UN FAO Global Forest Resources Assessment. It was clear that 125 million hectares of forests were lost in 20 years. Six years later, EPI the report was updated based on UN

FAO Global Forest Resources Assessment 2012. The time period was the very same (1990-2010), but initial estimates were corrected. Good news was that area under forests was underestimated. Unfortunately, deforestation was underestimated as well, totaling 135 million hectares of lost forests [10] [11].



Figure 3. Principal causes of soil degradation. Data source: Earth Policy Institute.

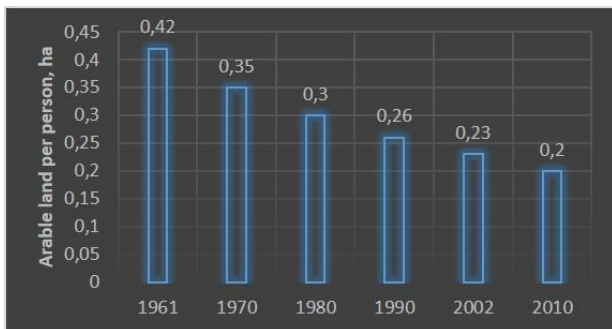


Figure 4. Arable land per person. Data source: World Resources Institute and the World Bank.

Previously we established that the world population is booming, but with decreased pace. We are losing arable land rapidly and this land lost to erosion and pollution cannot be remedied in the short run. We compensate that loss of arable land with deforested land and by doing that

we are causing even bigger and more difficult damages to the planet's ecosystem. By integrating all of those factors, we can calculate very appropriate indicators, Amount of arable land per person, to assess the quality of future agriculture and food supply chain.

Over the period of 50 years, available arable land per person has shrunk in half (Figure 4). It is clear that regional differences are significant, not only in terms of available money for food, but also in terms of nutritional habits and food availability.

No doubts that agriculture is a wonderful and important profession. However, it's not very appreciated among students and future professionals. According to [12] farmer as a profession, who plans, directs, or coordinates the management or operation of farms or other agricultural establishments is ranked 164 out of 200 professions. Additionally, farmer's work environment is assessed very poor (180/199), stress level high (140/199) and projected growth very poor (165/199). Apparently, being a farmer is less attractive than animal care and service worker who feeds, grooms, bathes, and exercises pets and other nonfarm animals (ranked 150). Only agriculture and food related professions ranked higher than a farmer are agricultural scientist, ranked 93/199 with projected growth assessed as poor and butcher (156/199). Professional chefs are even worse (182/199). Attractiveness of agriculture as a profession is not substantially different in other similar rankings.

The earlier mentioned study prepared by the University of Sheffield's Grantham Centre for Sustainable Futures describes the trend of losing arable land very close to being irretrievable without major changes to agricultural practices, it is difficult. A major reason for that is continual ploughing of fields, combined with heavy use of fertilizers, which can be described as inappropriate agricultural practices (Figure 5). And those inappropriate agricultural practices are degrading soils across the

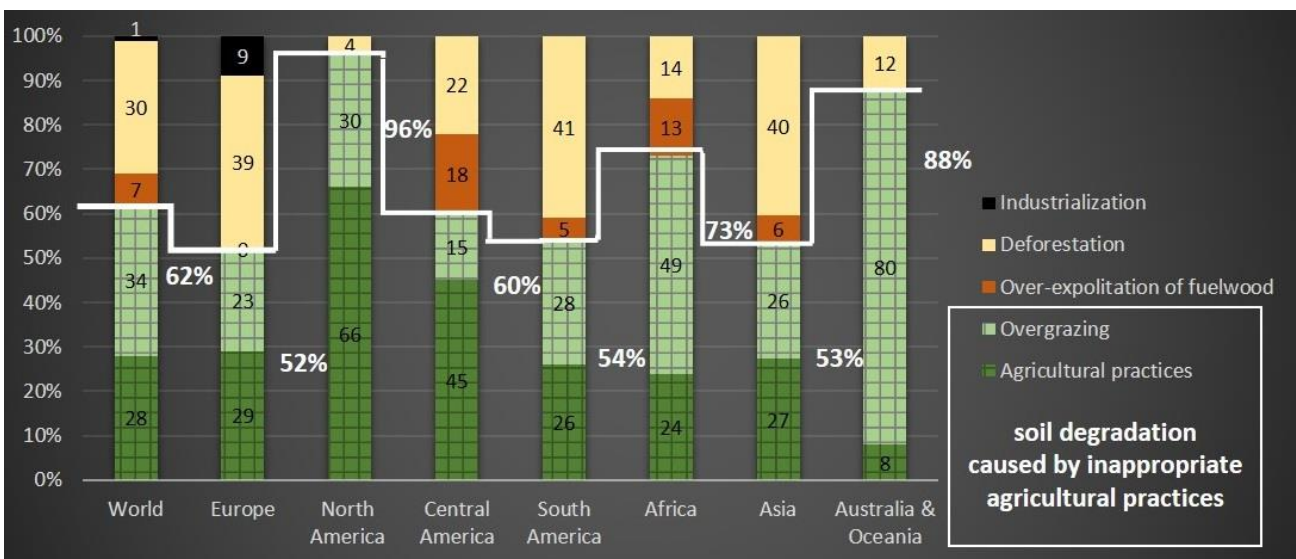


Figure 5. Principal causes of soil degradation. Data source: International Soil Reference and Information Centre.

world with erosion occurring at a pace of up to 100 times greater than the rate of soil formation. How quick and efficient humans could be in deforestation is well known, but it takes around 500 years for just 2.5cm of topsoil to be created amid unimpeded ecological changes [9].

Intense loss of arable land is caused by several, very different reasons: soil pollution, repurposing of agricultural land and losses caused by construction of roads, railways and buildings is not the only problem. Inappropriate agricultural practices are reducing the quality of the arable land, which is still in use. Lesser quality soils combined with water shortages and unfavorable precipitation distribution could lead to the significant disruption in agriculture and food supply chain. However, low supplies of the food stuffs are not only result of natural causes like low- or destroyed yields by volatile climatic changes (thunderstorm winds, droughts, etc.). Occasional economic and market disruptions like yields not harvested or lost during the transport, storage, processing and distribution are also a frequent problem.

Table 2. Possible treats and solutions for future agriculture and food supply chain

THREATS	POSSIBLE SOLUTIONS
<b>Extraterrestrial influence</b>	<b>Improved existing technologies</b>
Asteroid, comet, meteor strikes, solar winds and solar flares and consequent geomagnetic storms	Genetic modifications of plant and animal species to adopt faster to radical environmental changes
<b>Naturally occurring</b>	Urban agriculture
Volcano eruptions (ash and lahars/mudflows), earthquakes, floods and flesh floods, tsunamis, rise of ocean level	Hydroponics, Aeroponics, Aquaponics
Harsh and long term droughts	Saprophytes
<b>Photosynthesis blocking</b>	Yeasts
Stratospheric aerosol including volcanic ash and ash from other sources	Enzymes
Global warming or new ice age	<b>New technologies</b>
<b>Human influence</b>	Food printing
Global pollution including nuclear disasters	<b>New paradigms</b>
Heavy dependence of the agriculture on mineral oil	Circular economy
War (conventional and nuclear)	Existing but not used food sources like insects, weeds, etc.
Unreasonable push toward farmer's profitability causing production of lesser quality food or even harmful food	Change in food habits including more sustainable food (Less beef)
	Space colonization (decreased population)

Intense push of GMOs into standard agricultural practice led to severe reduction of biodiversity in agriculture. Once upon a time, countless genotypes of same varieties offered unprecedented genetic variability, which was one of the key factors of survival. Today, large GMO fields

are populated with only several genotypes. In case of occurrence of very harmful effect for that particular genotype, whole fields could be simply wiped out. Additionally, patented genes and domination of hybrid seeds are major obstacle for farmers own seeds production and provision of decentralized food production during and after capital disturbances of future agriculture and food supply chain like unavailability of certified seeds due to the failure of transportation system.

In the analysis of possible threats to future agriculture and food supply chain (Table 2.) we have to distinguish causes that appear on the regular basis like solar winds, those which appear periodically like solar flares in approximate 11 years cycles and those which appear occasionally if ever, like asteroids, comets or meteor strikes. Another level of analysis relates to the impact of those causes. In many cases the very same cause could have direct and indirect impact. An asteroid strike would physically destroy crops or food processing facilities in the immediate surrounding of its impact, but indirect effects could be much more devastating and long term, like considerable amount of stratospheric aerosol which blocks photosynthesis.

It is important to emphasize that different sources of treat could have the very same indirect mechanisms of impact.

For example, aerosols could be delivered to the stratosphere due to the meteor strike, volcano eruption or detonation of a nuclear bomb. Although stratospheric aerosol would block the photosynthesis regardless of the source of ash, some causes could have additional effects as well (like radioactive contamination after nuclear detonation). There are threats, which might impact agriculture and food supply chains considerably but only indirectly. Geomagnetic storms caused by solar winds could interfere with the infrastructure vital for the sector, like the GIS satellite network, power grids and water supply infrastructure and global transportation system.

Probably the most important step in securing future food supply for the growing population in a closed system (like the 'Planet Earth') is an accurate and reliable assessment of the current situation. However, viewpoints are ranging from 'everything is just fine', those changes are just a part of a natural long term climate cycle, to seriously concerned people who are aware that the planet's eco-system is severely polluted on the brink of irreversible and unfavorable changes. There is a large group of people who are seriously concerned with current situation and development trends. Some of them are seriously worried saying, "it's critical, but the alarm did not turn off for some strange reason". Many institutions are publishing their reports regularly pointing out how low planet food supplies until next harvest are going. Every captain of the space ship 'The planet Earth' shall be concerned if not scared. Especially, when taking



into consideration that some of the promising attempts to improve the situation also have serious side effects. Production of energy plants could be our great hope to reduce the dependence on mineral oil. We did successfully create a whole new industry, partially due to the intense rise of crude oil prices. Consequently, production of energy plants competed with food production for the same fields and contributed to the increase of food prices. Obviously, limited production resources available now are the bottleneck in the food supply chain for the growing world population. Probably the most tragic scenario is going in the right direction but not fast enough.

### **Not even doomsday preppers got it right**

Doomsday preppers are survivalists, or "preppers", who are preparing to survive for various circumstances that may cause the end of civilization, including economic collapse, societal collapse, and even electromagnetic pulse [14]. Most of the US preppers consider short-term disruption in the food supply chain as a main problem. The analysis of Google search for 'doomsday prepper checklist' indicates that the top 10 search results advise to store food with extended shelf life, keep the inventory list updated and supply safe and secured. They all somehow assume that agricultural production will go on, regardless of what caused the disruption in food supply chain in the first place. Only one source in top ten search result [15] advises preppers to acquire heirloom seeds, however further instruction is limited to fruit and vegetable seeds and not to seeds of cereals, staple food, energy plants, fodder and other important plants.

People usually consider 'history' as the history of mankind, but history of the planet is somewhat bigger. Ecological cycles are the various self-regulating processes that recycle the earth's limited resources – water, carbon, nitrogen, and other elements - that are essential to sustain life [16]. Understanding how local cycles fit into global cycles is essential to make the best possible management decisions to maintain ecosystem health and productivity for now and the future, especially in agriculture. Mankind, regardless of how mighty it could appear these days, is only a part of a global system, together with some valuable resources, which play a crucial, but not so visible role, in the planet's ecosystem. Forests occupy roughly one third of the earth's land surface. Because of their size, forests play a major role in the functioning of the biosphere and not only a twisted role limited to harvesting, transporting, and converting timber into products.

Having said that, it seems rather rational to replace the management paradigm in a sense that we govern and manage something that belong to us, with the stewardship paradigm in a sense where we steer and cherish the most important resources, vital for our own survival. We can argue that the increase of average temperature is just a part of long-term natural cycle and

not consequence of human negligence and pollution, but in the end, it doesn't matter. The ecosystem is changed and agricultural plants might not survive the change and adapt on time.

### **Conclusion**

Future agriculture and food supply chain is one of the pillars of human survival and prosperity in the long run. The planet's ecosystem is very fragile and influenced by a large array of very diverse natural and human factors which are frequently interdependent. Regardless of root cause, climate change, pollution and depletion of non-renewable resources and several other unfavorable processes are in place and agricultural plants and animals are under tremendous pressure to adjust and they don't adjust fast or without significant setbacks.

The main challenge for the future agriculture and food supply chain is to produce more food with considerably less resources in a sustainable manner for a rapidly growing population, preferably even reducing current levels of pollution. Securing future agriculture and food supply chain is a complex task, which requires not only new technologies but also a paradigm shift in current technological and economic system. Possibly the most important change is the change in current agricultural practices and agricultural education for future agriculture and food supply chain.

To improve the current situation of agriculture and food supply chain it's not enough to implement just partial solutions, a paradigm shift and systematic solutions are required. Decreased dependence on mineral oils and less transportation are a good start. Decentralization and a higher emphasis on environmental sustainability are required. The use of GMOs certainly has its role in future agriculture, but extreme precaution has to be put in place. Finally to achieve all of that the agricultural education has to be revised beforehand. Our results has indicated that overexpression of GST enzymes can play important roles in the detoxification of heavy metals, and tolerance to herbicides. The overexpression of *Zmgsstf4* gene was also found to increase resistance against chloroacetanilide herbicides (Milligan et al. 2001).

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