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Opinion

Food Production in the Context of Global Developmental Challenges

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Abstract: The article presents a synthetic analysis of the most pressing challenges associated with food security in the context of changes induced by global development and the generated problems. The study demonstrated that a more effective model of food production and management is needed to counteract anthropogenic pressure on the natural environment and excessive exploitation of limited resources caused by rapid population growth. Policies aiming to increase the efficiency of production and conversion of raw materials into finished food products of plant and animal origin (including feed conversion into high-energy and high-protein foods), promote the use of novel protein sources for feed and food production, and prevent excessive food consumption and waste are needed. At present and in the future, demographic, social, environmental, and geopolitical factors as well as the availability of natural resources should be taken into account by world leaders who should act together, with solidarity, to provide food to countries suffering from food shortage. Adequate food availability, including both physical and financial access to food, cannot be guaranteed without a holistic approach to global food security.

Keywords: food; production; global developmental challenges

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1. Demographic Factors and Demand for Food

Sustainable development has been always determined by the availability of water, energy, and food, and these factors are likely to play an increasingly important role in the near future [1]. Due to the globalization of social systems and structures, the availability of these resources should be also analyzed at the global level. It should be noted that globalization and resource availability are closely correlated [2]. Numerous relationships are observed between the acquisition, production, and distribution of raw materials and food products in the context of food demand [3].

The global food markets' ability to meet the demand of a rapidly growing population will be one of the greatest developmental challenges in the coming years. The human population is expected to exceed 9 billion by 2050 [4] and peak at 9.73 billion in 2064 [5]. According to the United Nations, the global population will reach 9.4–10.1 billion in 2050, and it will increase to 9.4–12.7 billion by 2100 [6] (p. 5). The accuracy of these estimates will be determined by numerous factors, such as the fertility rate of a population, policies that influence fertility rates, level of development, cultural factors, and mortality rates [5]. China is a good example of the above. Despite being one of the most populous countries in the world, China's fertility rate decreased to just 1.3 in 2020 (the global average is 2.3), and it presently ranks behind many countries in this respect [7]. This decrease resulted from the "one child policy" that had been introduced nationwide by the Chinese government. In turn, limited birth control, early marriage, or even forced marriage has resulted in the highest fertility rates in many African countries (Niger—7.0, Somalia—6.9, Chad—6.4, Mali—6.3, Democratic Republic of the Congo—6.2) [7]. It should be noted that variations in the present and predicted fertility rates will lead to differences in population growth rates around the world. According to the United Nations [6] (p. 12), only nine countries will generate more than 50% of the global population growth by 2050 (Democratic Republic of the Congo, Egypt, Ethiopia, India, Indonesia, Nigeria, Pakistan, United Republic of Tanzania, USA). The population of Sub-Saharan Africa is expected to triple in the 21st century (from around 1.03 billion in 2017 to 3.07 billion in 2100). In turn, the population of many Asian and Central-Eastern European countries is projected to decline [5].

According to Van Dijk et al. [8], global food production will have to increase by 70% to meet the projected population growth by 2050. However, global population growth is not the only factor that increases the demand for food. Rising affluence in developing countries will also drive the demand for food [9,10]. In these countries, most protein is derived from plants, but these sources will be gradually replaced by animal-based protein, similarly to the trends observed in developed countries [11]. The global per capita consumption of fresh dairy products is expected to increase at an annual rate of 1.2% by 2030, whereas the projected increase in global meat consumption will reach 14%, and it can be as high as 30% in Africa, 18% in the Asia-Pacific region, 12% in Latin America, 9% in North America, and 0.4% in Europe [12] (p. 171).

2. Surplus Food Distribution

The presented demographic data clearly indicate that while the global demand for food will increase, food will not be distributed equally across geographic regions. This is because high population growth in the least developed and developing countries is not accompanied by a proportional increase in food supply. The above leads to a deficit of both plant- and animal-based foods. According to OECD-FAO [12] (pp. 274–275), by 2021, wheat consumption will exceed wheat production in developing countries by 128 million tons. In the same year, developed countries reported surplus wheat production reaching 138 million tons. Based on FAO, IFAD, UNICEF, WFP, and WHO estimates [13] (p. 8), between 720 and 811 million people in the world faced hunger in 2020, and nearly one in three people (2.37 billion) did not have access to adequate food despite the fact that current food production is sufficient to meet global needs. The causes of hunger differ around the world (military conflicts, natural disasters, climate change, unfavorable soil, and environmental conditions for agricultural production), which does not change the fact that global distribution of surplus food remains an unresolved problem. Until this issue is addressed, hunger will persist in some regions, whereas crop surpluses will be reported in other regions. Therefore, systemic solutions are needed to permanently control and stabilize food distribution chains. Humanitarian food assistance programs are temporary measures that are not sufficient to feed the world.

3. Consumption and Meeting Food Demand

The fact that current food production is not effectively distributed and fails to meet the global food demand can be analyzed in the context of excessive consumption. The average daily energy requirement of adult women and men is estimated at 2000 and 2500 kcal, respectively [14]. In turn, the recommended dietary allowance for protein in persons aged <65 is 0.8 g per kilogram of body weight, which equates to 47–48 g for women and 55–57 g for men [15]. In practice, protein intake considerably exceeds the recommended values without a rational cause (such as physical labor, sports, convalescence, pregnancy, lactation, or rapid growth). According to the Food and Agriculture Organization of the United Nations (FAO) [16], in 2018, daily energy intake per capita was 3456 kcal in the European Union (EU), but it was nearly twice lower (1786 kcal) in the Central African Republic. In many countries, daily protein intake is 50–60% higher than the recommended value [9]. In 2018, the average daily protein intake in the EU was 107 g (146 g in Iceland, 117 g in Denmark, 108 g in France) [17]. These numbers clearly indicate that rational nutrition would deliver health benefits for many consumers and contribute to sustainable global food demand. In 2021, the World Health Organization (WHO) published a report on the health status of the global population [18] which revealed that the number of overweight persons nearly tripled since 1975. The report demonstrated that more than

1.9 billion of adults aged ≥18 (39%) were overweight and more than 650 million (13%) were obese. The majority of the world's population resides in countries where overweight and obesity kill more people than malnutrition. According to Kleinert and Horton [19], obesity caused 4.7 million deaths in 2017 and decreased global life expectancy by a total of 148 million years.

4. Food Waste

Food waste is a very important problem in the context of meeting global food demand. According to FAO estimates [20] (p. 8), around 14% of all food is lost between harvest and retail. The Food Waste Index Report 2021 of the UN Environment Program [21] (p. 8) revealed that around 931 million tons of food waste was generated globally in 2019, of which 61% came from households, 26% from the food service, and 13% from retail. Food loss and food waste are problems that should be examined in a broader context, including the loss of key resources (water and energy) in food production and its contribution to climate change. According to FAO estimates [22] (p. 26), around 38% of the energy used in the global food system is lost or wasted. Food waste is responsible for 8–10% of global greenhouse gas emissions [21] (p. 20). Therefore, food waste is a multifaceted issue that exacerbates current problems by contributing to ineffective food management, wasteful water and energy consumption, and climate change.

5. Global Demand for Agricultural Land (Food Production)

Growing food demand will drive the demand for farmland and pastures used for the production of food and feed. According to estimates, agricultural land area should double by 2050 to keep up with population growth and qualitative changes in the human diet [23] (p. 5). This is an immense challenge because nearly half of the Earth's land surface is already used for agriculture [24]. Therefore, the availability of high-quality land for agricultural production is limited. The global arable land area has increased in recent decades, but the annual rate of cropland expansion decreased from 0.24% in 1961–2010 to 0.04% in 1995–2010 [25]. The above can be attributed to the decrease in farmland availability resulting from climate change, environmental degradation, and urban expansion. According to estimates [26], between 2000 and 2030, urban expansion alone will decrease farmland availability by as much as 15,000 km^2 per year worldwide. Policies aiming to improve the productivity and rational use of the existing agricultural land are thus sorely needed. Mauser et al. [27] have argued that global crop yields on the existing farmland can be more than doubled, whereas Folberth et al. [28] suggested that optimization of agricultural production could induce a nearly 50% decrease in the cropland area required to maintain present production volumes.

The need for rational management of farmland is also justified by the low efficiency of livestock production. Despite the fact that the livestock industry utilizes 77% of global farmland and that nearly half (41%) of the global cereal output is used for the production of animal feed (food—48%, biofuel—11%), it produces only 18% of the world's calories and 37% of total protein [29] (p. 1130). Around 164 m^2 of land is required to produce 100 g of beef-based protein, whereas the production of wheat-based protein requires 50 times less land (3.2 m^2) [30]. An increase in the consumption of plant-based products at the expense of animal-based products (a decrease in livestock production) would reduce farmland area required to produce animal feed (pastures and arable land) [31]. The agricultural land freed from livestock production could be used to grow crops for human consumption. In theory, if only beef and mutton were eliminated from the human diet, the area of pastures and land used to grow crops for animal feed could be reduced by around 50% [30].

In the future, the proportions of plant- and animal-based foods in the human diet will be determined not only by an increase in food production efficiency, but also by the postulates made by environmental activists and dieticians. Livestock rearing, in particular the production of ruminants for meat and milk [32], contributes to greenhouse gas emissions. According to Grossi et al. [33], livestock production accounts for 14.5%

of total anthropogenic greenhouse gas emissions. In turn, nutrition research indicates that red meat exerts negative effects on human health and its consumption should be decreased [34]. The consumption of saturated fatty acids (SFAs) from animal-based foods as well as processed meat should also be reduced. According to the Dietary Guidelines for Americans 2020–2025 [35] (p. 18), the intake of SFAs should be reduced to less than 10% of daily energy intake. Research indicates that daily consumption of 50 g of processed meat increases the risk of colorectal cancer by 18%; it also increases the risk of breast, prostate, and pancreatic cancer, as well as the overall cancer mortality rate [36]. Critics have argued that the reports on the adverse health effects of red meat are not accurate and do not apply to lean meat, which is a source of essential nutrients such as protein, Fe, Zn, Se, and B group vitamins [37,38]. Despite the above, the popularity of vegetarian and vegan diets is on the rise. According to Lemken [39], the Western European market of textured vegetable protein (meat substitute) has been growing at an annual rate of around 10% since 2014.

Agricultural production is affected by occupational and social groups, including radical animal rights activists who have long postulated that intensive livestock farming should be curtailed. In their opinion, animal production raises ethical and moral concerns. Activists argue that husbandry practices do not improve animal welfare but are a source of physical and psychological suffering. Although these views are largely subjective, emotional, and not always fully based on fact, they exert a considerable influence on public opinion.

6. Problems Associated with Intensive Agricultural (Food) Production

Intensive farming and increased food supply carry both global and local risks. On a global scale, intensive agricultural (food) production contributes to greenhouse gas emissions which increase temperatures and lead to climate change. In 2019, the global food chain (agri-food systems) was responsible for 30.6% of greenhouse emissions (in CO_2 equivalents), including 21.35% of CO_2, 78.03% of N_2O, and 53.21% of CH_4 emissions [40]. On the local scale (which could evolve to the regional or global scale), intensive farming leads to environmental degradation by [41] (pp. 15–21):

- **contributing to soil degradation** (damage to soil structure, soil erosion, decrease in soil fertility, increase in soil salinity and acidity, pollution with chemicals, pesticides, and artificial fertilizers)
- **disrupting natural water retention** (due to a higher demand for water, artificial irrigation, drying of natural water bodies, land drainage, elimination of small water bodies in agricultural areas, eutrophication) and **decreasing water quality** (due to leaching of organic and inorganic pollutants to groundwater and surface water);
- **disrupting the genetic and species diversity of organisms, as well as the biodiversity of ecosystems** (due to pesticide use, monoculture, GMOs, and industrial livestock farming).

Over time, intensive farming can decrease agricultural productivity or even cause land to be unsuitable for agriculture. The above will further drive the demand for high-input agriculture or the search for suitable farmland in other regions. The quality and safety of raw materials and foods produced in high-input agricultural systems constitute a separate problem.

7. Global Warming and Food Production

The average global temperature has increased by 1.2 ± 0.1 °C above pre-industrial levels [42] due to growing CO_2 emissions into the Earth′s atmosphere. By the end of the 21st century (2081–2100), the average temperature is expected to increase by 2.6 to 4.8 °C above the level noted between 1986–2005 under high-emission scenarios [43]. Climate change has multifaceted and already observable effects on agriculture and food production. It decreases the availability of water resources and, consequently, leads to land drought and desertification of large areas. Sterk and Stoorvogel [44] relied on UNCCD data to posit that 12 million hectares of land are lost each year due to desertification and drought, which is equivalent to a loss of 20 million tons of grain. This problem is most pronounced in Africa, Asia, and Latin America, but it also increasingly affects other regions of the world, including Eastern Europe and the Mediterranean countries (Portugal, Spain, Italy, Greece, Albania, Bosnia and Herzegovina, Croatia, Cyprus, France, Malta, Slovenia, Spain, and Turkey) which are at higher risk of soil degradation [45].

Climate change increases the risk of extreme atmospheric phenomena and weather anomalies that lead to natural disasters (drought, flooding, hurricanes, typhoons, cyclones, tornados, windstorms). These events damage crops and decrease yields, but they can also exert long-term effects by contaminating soil during floods and reducing the suitability of land for agriculture in areas that are permanently affected by extreme weather. These anomalies pose a threat to food security. For instance, prolonged drought in 2020 led to a reduction in the crop yield potential and decreased maize yields by 6.0%, winter wheat yields by 3.0%, soybean yields by 5.4%, and rice yields by 1.8% relative to the 1981–2010 average [46].

Coastal areas and inland depressions could be excluded from agricultural production due to flooding caused by rising sea levels, which could further jeopardize global food security. The mean sea level rose at an annual rate of 1.7 ± 0.2 mm between 1900 and 2009, and a further increase to 3.2 ± 0.4 mm per year was noted between 1993 and 2003 [47]. The projections for the rise in sea levels by 2100 are based on various scenarios concerning greenhouse gas emissions and global warming [48] (p. 36). According to two extreme Representative Concentration Pathway (RCP) scenarios (RCP2.6 and RCP8.5), surface temperatures are projected to increase by less than 2 °C (0.3–1.7 °C) and by nearly 5 °C (2.6–4.8 °C), respectively, whereas sea levels can be expected to rise by 24–61 cm and 52–131 cm, respectively [49]. The annual Lancet Countdown report [46] indicates that 569.6 million people currently reside below the altitude of 5 m a.s.l. The rise in sea levels increases the risk of flooding, torrential rain, and excessive water and soil salinity. These events will induce large-scale migration to inland areas where farmland will have to be converted to habitable land to accommodate an expanding population. The example of the Netherlands well illustrates the scale of the problem. According to Haasnoot et al. [50], nearly 60% of the Dutch territory is at risk of coastal and riverine flooding, and 26% of these areas are situated below the current mean sea level. The potential loss of all flood-prone areas coupled with the growing demand for farmland, industrial land and habitable land gives considerable cause for concern. Therefore, many countries have implemented hydraulic engineering projects to protect the most endangered areas against the adverse consequences of rising sea levels.

8. Stability of Food Supply

Stable supplies of raw materials, food products, and agricultural inputs are crucial for food production and food availability. Marine transport drives 80–90% of global trade and moves more than 10 billion tons of containers, solid, and liquid bulk cargo across the world′s oceans [51]. Some routes feature sensitive areas whose throughput affects shipping performance. The Suez Canal, one of the world′s most important shipping lanes, is a good example of the above. The canal was blocked for several days in March 2021. Approximately 30% of the world′s shipping container volume and 12% of total global trade transits through the Suez Canal [52]. Between 23 and 29 March 2021, the canal was blocked by the Ever Given container ship. The canal is a crucial route for transporting oil and gas, and it accounts for 7–10% of the global trade in oil and 8% of the trade in liquefied natural gas. The Suez Canal obstruction demonstrated the extent to which transport networks can also affect food supply, in this case Robusta coffee (the key ingredient in instant coffee). In the group of the world′s leading Robusta producers, only Brazil and the Ivory Coast do not ship their produce to Europe via the Suez Canal. The blockage fueled fears about supply bottlenecks in Europe, which led to an uncontrollable increase in Robusta prices. The same problem can affect all raw materials and foods that are shipped through the Suez Canal, mostly cereals and oilseed crops.

It should be noted that the Suez Canal is not the only bottleneck in the global marine transport network. The throughput of shipping lines could also be compromised in other regions of the world. The Chatham House report [53] (p. 5) identified the Panama Canal, Strait of Malacca, and the Turkish Straits as the most critical chokepoints due to their share of global trade in specific commodities. According to the report, more than a quarter of global soybean exports transit the Strait of Malacca, mainly to cater to the growing demand for animal feed in China and Southeast Asia. In turn, 20% of internationally traded wheat passes through the Bosphorus Strait and Dardanelles.

Pandemics could also cause serious logistic problems, including in the global trade in raw materials and food products. The COVID-19 pandemic revealed the vulnerability of global supply chains. Border closures, inefficient transport and fluctuating employment in the production sector disrupted physical access to food [54]. These problems have led to a significant increase in the prices of many food products which, combined with the loss of incomes, decreased food affordability. According to the International Labor Organization (ILO) [55] (p. 2), the destabilizing effects of the COVID-19 pandemic led to the loss of 114 million jobs and decreased GDP per capita by 3.3% in 2020 relative to 2019 levels [56].

Geopolitical instability can significantly undermine the stability of food and agricultural material supplies. The Russian invasion of Ukraine is the most recent example of this problem. Russia and Ukraine are among the world's leading cereal producers. In 2020, Russia ranked 1st in global wheat exports (37.27 million tons), 4th in barley exports (4.96 million tons), and 11th in maize exports (2.29 million tons), whereas Ukraine ranked 5th in wheat exports (18.06 million tons), 3rd in barley exports (5.05 million tons) and 4th in maize exports (27.95 million tons) [57]. War damage, decrease in crop sowing area, higher domestic demand after the war in Ukraine, and Russia's potential response to the economic sanctions imposed by the West could decrease global cereal supply and increase cereal prices. Other leading producers (China and India) will be unable to compensate for this deficiency because most of their cereal production caters to domestic consumption [58]. These factors could undermine the stability of the global food and feed markets. Military and political conflict, trade regulations, and market competition can affect the supply of most raw materials and food products. For this reason, the approach to food security will have to be revised in the near future to ensure the stability of the global food supply chain. Greater diversification of food supply sources, promotion of local products, and strategic food reserves are required to achieve this goal.

Diseases affecting crops and livestock can destabilize global food markets at any time. Various preventive, biosecurity, pharmacological, and genetic engineering methods are being implemented with varying degrees of success to prevent or mitigate the consequences of disease. However, the evolution of important animal diseases such as swine flu [59], bird flu [60], African swine fever [61], and Panama disease (Tropical Race 4) [62] that has been decimating banana plantations for several decades is difficult to predict. Entire crop plantations and livestock farms have to be destroyed to prevent these diseases from spreading. In the most pessimistic scenario, if the transmission of pathogens cannot be contained, at least locally, the availability of some products could be compromised, thus increasing food prices and decreasing demand for these products.

The fluctuations in food supply on the global market may be caused not only by plant and animal pathogens (viruses, bacteria, fungi and chromists), but also by pests (mites, roundworms, insects, snails, rodents, and birds) [63]. Between 2001 and 2003, the losses caused by pests in the production of six crop species in 19 regions of the world were estimated at 26–29% for soybeans, wheat, and cotton, and at 31%, 37%, and 40% for maize, rice, and potatoes, respectively [63]. Insect pests pose a particular threat because they cause losses during production as well as storage. According to Jankielsohn [64], herbivorous insect pests are responsible for 18% of the losses in global crop production. It should also be noted that intensive farming (monoculture), climate change, globalization of transport and trade activities facilitate the development and spread of pathogens, pests, and weeds.

As a result, they pose an increasingly serious problem not only in their original habitats, but also in areas where they were not previously identified.

Potential problems associated with insufficient supply of food of appropriate quality as well as low resource use efficiency in food production have spurred the search for alternative raw materials for food and feed. The protein sources for the production of meat analogs continue to attract growing attention in the context of food security, climate change and the health consequences of consuming animal-based foods. Alternative proteins are derived from plants, microorganisms, fungi, insects, and algae [65–67]. According to Morach et al. [68], in the baseline scenario, the alternative protein market will grow more than seven times in size in the next 15 years, from 13 million metric tons to 97 million metric tons per year in 2035, which accounts for 11% of the overall protein market. Assuming that average revenues reach USD 3 per kilogram, the entire market will be worth around USD 290 billion. The extent to which alternative proteins will enter the mainstream diet will depend on economic factors (production costs), health and safety considerations, and consumer preferences.

9. Diversification of Food Products to Meet Consumer Expectations

Contemporary food companies implement market segmentation in their strategies to cater to the needs of specific consumer groups. The above has fueled the development of the next-generation food market which can be divided into the following segments [69]:

- **foods with special attributes**, namely foods that meet the needs of specific consumer groups (organic food, kosher food, traditional specialties guaranteed food, vegetarian food);
- **novelty foods** which differ from conventional food products in raw materials and their sources (transgenic food, in vitro meat), provide health benefits beyond meeting basic nutrition needs (functional food), and are ready to eat with minimal or no preparation (convenience food);
- **special purpose foods** which differ from conventional food products in nutritive and assimilative properties and/or method of preparation (diets that address specific health concerns, infant formulas, foods for persons with special nutrition needs, foods prescribed by medical professionals).

Novel foods cater to the needs and expectations of contemporary consumers who are concerned about their physical and mental wellbeing, but often lack the knowledge, time, and means to implement their dietary resolutions [70]. The development, marketing, and promotion of such products can be a part of carefully planned and wide-reaching institutional strategies. For example, the Japanese government has implemented regulatory systems referred to as Food for Specified Health Uses (FOSHU) and New Functional Foods to regulate the functional food market and improve public health [71]. Next-generation novel foods are also introduced to gain a competitive advantage over market rivals.

Food companies also rely on behavioral segmentation to divide markets based on the price that different consumer groups are able and willing to pay for specific products. Each year, various organizations and institutions publish indices that gauge economic inequality by measuring wealth distribution. The World Inequality Lab Report of 2022 [72] (p. 15) compared the incomes and financial assets of households in different countries and divided them into three wealth groups: bottom—50%, middle—40%, and top—10% (including the share of wealth owned by the global top 0.1% and billionaires). The report revealed that the top 1% captured 38% of global wealth growth in the past 25 years. The top 0.01% (around 520,000 adults, including around 2570 billionaires) owns 3% of global wealth, while the bottom 50% possesses only 2% of the total. According to World Bank data [73], global GDP per capita in 2020 amounted to USD 10,918.7 (USD 34,148.90 in the EU), but it was more than 23 times lower in Somalia (USD 438.3), Mozambique (USD 448.8), and Sudan (USD 486.4). Immense differences in purchasing power parity on the global and local scale will prompt producers, including food companies, to diversify their product base to meet the needs of less and more affluent customers.

10. Conclusions

The presented list of developmental factors that influence global food production is by no means exhaustive. Nonetheless, based on the described processes, the following major trends can be identified on the contemporary food market:

- the quantity and availability of food has to be increased to feed a growing world population;
- the quality of food has to be improved to cater to the consumers′ rapidly evolving needs and expectations;
- the quality of food raw materials has to be improved to meet the demands of the food processing industry.

The undertaken measures have to ensure that limited resources (water, energy, soil) are utilized rationally and efficiently, and that they exert a minimum impact on the environment (reducing greenhouse gas emissions and soil degradation, preserving the biodiversity of natural ecosystems). Systemic solutions aiming to reduce food waste (with particular emphasis on households) promote the principles of rational nutrition (to prevent excessive food consumption), fully utilize the potential of alternative nutrient sources (microorganisms, fungi, insects, algae), and build international solidarity to effectively redistribute surplus food through stable channels will significantly contribute to global food security. Sustainable food supply chains are needed to improve food availability in all regions of the world, with special emphasis on regions and countries that are unable to feed their populations for reasons that escape human control. The absence of such measures will contribute to migration, thus exacerbating the global refugee crisis.

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