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Review

A World without Hunger: Organic or GM Crops?

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Abstract: It has been estimated that the world population will increase to 9.2 billion by 2050; supplying the growing population with food will require a significant increase in agricultural production. A number of agricultural and ecological scientists believe that a large-scale shift to organic farming (OF) would not only increase the world's food supply, but might be the only way to eradicate hunger sustainably. Nevertheless, OF has recently come under new scrutiny, not just from critics who fear that a large-scale shift in this direction would cause billions to starve but also from farmers and development agencies who question whether such a shift could improve food security. Meanwhile, the use of genetically modified (GM) crops is growing around the world, leading to possible opportunities to combat food insecurity and hunger. However, the development of GM crops has been a matter of considerable interest and worldwide public controversy. So far, no one has comprehensively analyzed whether a widespread shift to OF or GM would be the sole solution for both food security and safety. Using a literature review from databases of peer-reviewed scientific publications, books, and official publications, this study aims to address this issue. Results indicate that OF and GM, to different extents, are able to ensure food security and safety. In developed countries, given that there are relatively few farmers and that their productivity, even without GMOs, is relatively high, OF could be more a viable option. However, OF is significantly less efficient in land-use terms and may lead to more land being used for agriculture due to its lower yield. In developing countries, where many small-scale farmers have low agricultural productivity and limited access to agricultural technologies and information, an approach with both GM and OF might be a more realistic approach to ensure food security and safety.

Keywords: agricultural sustainability; co-existence; small-scale farmers; food security; food safety

1. Introduction

The world's population and its consumption rates are growing, which, in turn, results in a growth in the demand for food and fuel. Moreover, in the developing world, diets are changing and people are looking for more dairy products and meat, which can put extra pressure on natural resources [1]. It has been estimated that the demand for agricultural products from 2005 to 2050 will grow by 1.1% annually while the world's population will reach an estimated 9.2 billion by 2050 [2]. In the 21st century, biotechnology has been utilized as one of the eco-techno-political technologies available to meet the needs of the growing population [3]. Many countries have developed technological strategies in order to improve their productivity in different fields [4]. It is a widely held belief that the application of these technologies could potentially contribute to the productivity of sustainable agriculture in ways that increase resource-poor farmers' income and ensure food security and safety [5]. However, it is time to question whether this technology truly is a promising way of harnessing scientific innovation to respond to challenges that food systems in many regions are facing, such as the lack of land, water, and capacity [6].

The recent data on the global status of GM crops show very significant net economic benefits at the farm level, amounting to about $17.7 billion in 2014 and $150.3 billion for the 19-year period 1996–2014. Around 65% of the gains have derived from yield and production gains, with the remaining 35% coming from cost savings [7]. A global meta-analysis conducted by Klümper and Qaim (2014) [8] on 147 published biotech crop studies from 1995 to 2014 confirms that there are multiple and significant benefits that have been generated by biotech crops over the past 20 years. According to this study, on average, the adoption of GM technology has reduced the use of chemical pesticides by 37%, increased crop yields by 22%, and increased farmer profits by 68%. Remarkably, in 1996, only 1.7 million hectares were planted with GM crops globally, but by 2015, GM crops were grown in 28 countries and on 179.7 million hectares of land; over 10% of the world's arable land [9]. Despite the growing area of GM crops planted worldwide, genetically modified organism (GMO) crops pose several important economic as well as environmental risks, which are increased by a lack of capacity in developing-countries to assess and manage such risks [10]. Wolson (2007) [11] found that a number of urban consumers and environmental interest communities in South Africa lately have become skeptical of GM crops. Additionally, recent activities in the area of policy development have shown a growing recognition in regards to the negative environmental impacts of GM with a potential loss of biodiversity and a hastening of the development of pest resistance [12–14]. Furthermore, some developing countries' authorities have not given farmers official permission to plant GM crops due to concerns about their biological safety [5].

The EU regulation that calls for strict labeling and traceability on all GM-derived foods and feeds (requiring a costly physical segregation of GM from non-GM foods, all the way up the marketing chain) may stop poor countries from planting GM crops [5]. Moreover, studies show that technology, in general, is bypassing those that suffer from poverty. The proclamation about how a new technology leads farmers to get out of poverty is fraught with problematic assumptions about the steady state of the economy. The technology might help farmers reduce their crop losses, which can improve their food security as subsistence farmers. The new technology can raise the overall level of income earned from crop production. It can also reduce the variability of that income. A study by Harris and Orr (2013) [15] shows that new technology can substantially increase net returns per hectare per cropping season. Therefore, crop production could be a pathway out of poverty, wherein smallholders are able to increase farm size or where markets stimulate crop diversification, commercialization, and increased farm profitability. For most smallholders, however, small farm size and limited access to markets means that returns from improved technology are too small for crop production alone to lift them above the poverty line. The direct benefit might improve household food security but is not necessarily an end to poverty.

In response to the concerns over agricultural biotechnology, many researchers have strongly advocated OF [16–18]. OF, as a holistic production system that aims to produce food with minimal harm to ecosystems, animals or humans, is the most prominent alternative farming system and is often proposed as a solution for more sustainable agriculture [19]. The environmental benefits of OF include protecting biodiversity, better soil, water and air quality, and energy efficiency [20]. Organic livestock farming is in line with the goals of environmentally friendly production, improving welfare standards and animals' health, and promoting high quality products [21]. According to a definition given by the International Federation of Organic Agriculture Movements (IFOAM), OF is based on four basic principles: health, ecology, fairness, and care for humans and ecosystems [22]. OF, by its nature, is a cost-effective system, and, through the use of local resources, it has a great potential to contribute to sustainable development in the poorest regions of the world [23]. There is also compelling evidence that supports the argument that OF can contribute to food security [5]. Organic farming has been questioned for its need for more land as a compensation for the low use of external inputs [24]. Where land use is concerned, we must not only think in terms of efficiency but also effectiveness, and OF puts land to effective and sustainable use. Organic production scores better in integrating and making effective use of landscapes and ecosystem services. In terms of overall sustainability and conservation of biodiversity and natural resources, organic farming can also provide increased food security in the long-term [25]. However, because of certain concerns regarding OF, mainly its need for more land and thin markets for OF products in developing countries, the uptake amongst poor farmers is limited [5].

It is important to note that, although OF and GM technology did not originally cause the technological treadmill, they have definitely exacerbated it. According to the theory of the treadmill, as overproduction causes crop prices to fall, farmers adopt new technology to increase yields at lower costs. The early adopters of the new technology get a profit by underpricing competition, thus driving farm prices down farther. Those who are late to adopt the technology go broke and sell their land to those who still operate, leading to ever-greater concentration in the industry. The survivors must adopt ever increasingly efficient technology and so the treadmill continues to cycle [26]. Accordingly, conventional farmers who are unwilling to grow GM crops might be financially disadvantaged if their lower yields make them uncompetitive with GM farmers. Hence, they might be forced to adopt GM crops to stay in business. However, GM crop adopters might benefit from reduced losses caused by pest and weed pressures, but after a certain threshold, when more and more farmers have adopted the technology, the prices will decline. The same is likely to happen to organic producers. There is high demand now, but eventually organic production is likely to exceed demand and the prices will level off and even decline.

In this situation, different agricultural systems are able to co-exist and play an integral role in global sustainable agri-food production systems [27]. All in all, when conventional agricultural methods are not able to supply the world with both food security and food safety, there is an ongoing debate and concerns over whether a widespread shift to OF or GM could be the unique solution for both food security and safety. Accordingly, the stakeholders could be divided into three parties: (i) those who believe that GM crops are the sole solution for both issues; (ii) those who believe that organic farming is the only answer to the issues; and (iii) others that believe that both approaches can simultaneously address the two issues. This review paper aims to outline the main challenges of GM and OF farming systems to face food security and food safety in developing and developed countries. To investigate these challenges, this paper compares the advantages and disadvantages of both GM crops and OF, then tries to clarify the existing tradeoffs between these two approaches. After that, the co-existence of GM crops with OF is discussed. Lastly, conclusions are drawn about the main debates and concerns discussed.

2. Methodology

This study has used several 'inclusion' and 'exclusion' criteria to investigate the potential of GM, OF, and their co-existence to improve food security and safety. This was done in the context of a comprehensive review; the process of collecting, appraising, and then synthesizing data from a large number of sources. The review was done through different peer-review and non-peer-review articles, books, and official publications. The main keywords used to search the data were 'genetically modified crops', 'GM crops', 'bioengineered crops', 'bacillus thuringiensis (Bt) crops', 'herbicide tolerant (Ht) crops', 'OF crops', and 'Co-existence'. The terms were combined with 'governance', 'environmental impacts', 'social impacts', and 'economic impacts'. These keywords were used in order to find relevant studies in developed and developing countries. The inclusion criteria included the publications that were published after 1998. Publications in other languages than English and those from unreliable sources were excluded.

3. Advantages and Disadvantages

3.1. GM Crops

GM technology is not really a farming system, but a new standard for seeds that is used in the conventional farming system [28,29]. However, given that GM crops are not the same as conventionally crossbred crops, in this study, GM crops and conventional crops are considered as separated farming systems. Since GM crops were first introduced in the USA in 1994, farming with GM crops has greatly increased [9]. For the first time in 2012, developing countries planted more GM crops than developed nations, with 52% of global biotech crops. By 2015, out of the 28 countries that grew biotech crops, 20 were developing and only eight were developed countries (Figure 1). Latin American, African, and Asian farmers together grew 97.1 million hectares (54%) of the global 179.7 million biotech hectares, whereas industrial countries only planted 83 million hectares or 46% [9].

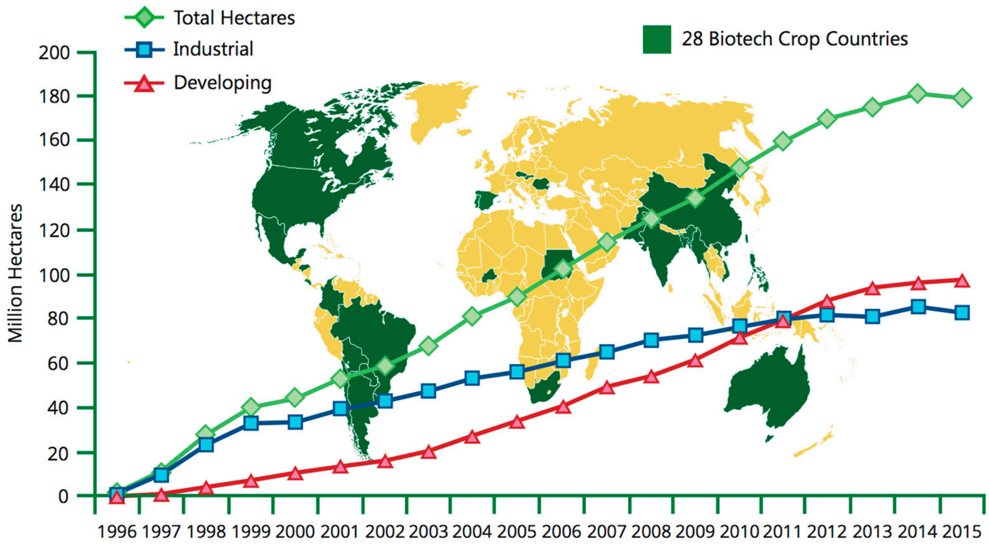

Figure 1. Global area of genetically modified (GM) crops in millions of hectares 1996–2015 (Source: James, 2015 [9]).

Genetic-engineering (GE) technologies have the potential to increase knowledge of plant genomes, the genetic basis of agronomic traits, and genotype germplasm. The genetic potential that exists in sexually compatible germplasm can be used to improve phenotypic traits in the crop. The recent evidence by National Academies of Sciences, Engineering, and Medicine (NASEM) (2016) [30] indicates that only two traits, insect resistance and herbicide resistance, had been genetically engineered into a few crop species and were in widespread use in 2015, though the overall quality of germplasm improved by GM technology is still questionable. Therefore, GM crop research has primarily been focused on labor and management enhancement, as opposed to basic research that would enhance the overall quality of the germplasm. According to this report, GM soybean, cotton, and maize have generally had favorable economic outcomes for producers who have adopted these crops, but outcomes have been heterogeneous depending on pest abundance, farming practices, and agricultural infrastructure. The crops with the insect-resistant trait generally decreased yield losses as well as the use of insecticides on small and large farms compared to non-GM varieties. Although biotechnology has brought revolutionary advances in agriculture, several hot debates on the advantages and disadvantages of this technology persist among academics and decision-makers in both developed and developing countries. Although reflections by the advocates of GM crops on the potential of these crops might attract more attention by providing solutions to the current problems of conventional agriculture [31], the critics portray a troublesome outlook on the negative environmental, economic, and social impacts of GM crops. Finger et al. (2011) [32] believes that the contradictions arising on both sides of the debate (pro and con-GM crops) point to individual studies. They found that it was necessary to review the impacts that have been observed in different countries in order to create a comprehensive global prospect. Their findings, as well as those from Brookes and Barfoot (2016) [7] on the impact of global GM crop production, show that the types and magnitude of GM crops' effects are quite diverse. Particularly according to the varieties of GM crops and geographic location of the adopted crops.

From an economic point of view, biotechnology creates new GM crops that can potentially produce more food with the use of fewer chemical pesticides. GM crops are often engineered to be more resistant to pests and to herbicides. Although insecticide-producing GM crops have led to a decrease in insecticides, herbicide-tolerant (HT) crops have led to an increase in herbicide usage. The introduction of crops resistant to dicamba and 2,4-D is likely to have some very serious environmental and human health impacts [33]. A GM crop could also transfer modified genes to wild relatives and potentially generate super weeds or could itself become a weed that could become a major threat to biodiversity [13,14]. The expansion of GM traits can also be harmful to valuable wild precursors of the crops and could invade organic and other non-GM crops of close proximity (or vice-versa). In addition, the use of pest-resistant GMOs may hasten the development of pest resistance [13,14].

Aside from higher yields, GM crops may have other advantages over conventional crops. For instance, pest and herbicide resistant crops are cheaper to grow, and smaller amounts of pesticides used for GM crops reduce the amount of carbon dioxide released into the environment [34]. There are also demonstrable health benefits for farm workers, which have been documented as a result of less chemical pesticide spraying [35]. Dramatic reductions in pesticide poisonings were later reported from a broader study of Chinese cotton farmers [36] and among cotton farmers in India [37]. According to Brookes and Barfoot (2016) [34], since 1996, the adoption of GM insect resistant and herbicide tolerant technology has reduced pesticide spraying by 581.4 million kg (8.2% reduction), and the environmental impact associated with herbicide and insecticide use on these crops, as measured by the EIQ (Environmental Impact Quotient) indicator, fell by 18.5%. According to Brookes and Barfoot (2016) [7], the income and profit from utilizing GM crops have been divided by roughly 50% both for farmers in developed and developing countries. It is worth noting that GM crops are grown only on 10% of the world's arable land [38] and represent a very narrow range of species and traits.

However, a study in India by Viswanathan and Lalitha (2010) [39] reflects on the socio-economic and environmental impacts of GM crops and aims to criticize the value of these crops for farming systems. They found that GM growing farmers had difficulties in marketing their products. Despite the fact that GM foods have been tested and regulated, there are still many problematic stories that dispute the safety and effectiveness of these crops. GM crops could possibly create environmental problems and also have a number of negative economic consequences. According to Azadi and Ho (2010) [5], a major environmental concern with respect to GM crops is the loss of biodiversity. Also, potentially, there are some environmental risks affecting ecosystems, agriculture, and health. Ironically, GM also has the potential to increase biodiversity [40].

Yet, most of the aforementioned advantages and disadvantages are not the same for every crop and every region [41]. For example, in corn, the productivity impact is mainly due to yield increase, and in soybeans, the GM technology allows saving on inputs such as chemicals and labor [5].

3.2. Organic Farming

According to Willer and Lernoud's (2016) research on certified organic agriculture worldwide, as of the end of 2014, data on organic agriculture was available from 172 countries [42]. There were 43.7 million hectares of organic agricultural land in 2014, including areas in conversion. The regions with the largest areas of organic agricultural land are Oceania (17.3 million hectares, 40% of the world's organic agricultural land) and Europe (11.6 million hectares, 27%). Latin America has 6.8 million hectares (15%), followed by Asia (3.6 million hectares, 8%), North America (3.1 million hectares, 7%), and Africa (1.3 million hectares, 3%) (Figure 2). Over a quarter of the world's organic agricultural land (11.7 million hectares) and more than 86% (1.9 million) of the producers were in developing countries and emerging markets in 2014 [42].

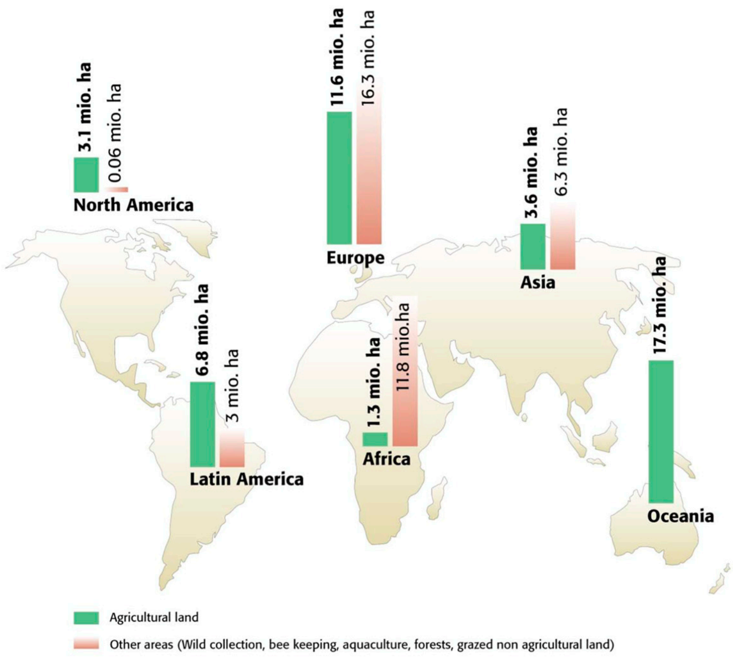

Figure 2. Organic agricultural land and other areas in 2014 (Source: Willer and Lernoud, 2016 [42]).

OF, as a holistic production system that aims to produce food with minimal harm to ecosystems, animals or humans, is the most prominent alternative farming system and is often proposed as a solution for more sustainable agriculture [19]. The environmental benefits of OF include biodiversity conservation, better soil quality, reduced evaporation and water harvesting, strengthened adaptation strategies, and reduced greenhouse gas emissions, as well as energy efficiency [19,20]. A meta-analysis by Rahmann (2011) [43] found that biodiversity in organic farms is higher than in conventional farms in that out of 396 relevant studies, 327 cases showed higher levels of biodiversity in organic farms. Another meta-analysis study by Bengtsson et al. (2005) [44] reveals that, on average, in OF farms, species richness increased by about 30% and the abundance of organisms was 50% higher in comparison with conventional systems. Species richness in birds, plants, soil organisms, and predatory insects increased while pest and non-predatory insects did not. The soil management methods in OF have the ability to restore degraded lands and to prevent further degradation in vulnerable regions [45]. The practices used to protect the soil in organic systems include minimum or no tillage of the land, contour cultivation, soil bunds, terraces, mulching, and planting cover crops [23]. A study shows that the amount of organic soil matter in OF systems is significantly more than in conventional systems [46]. Organic matter increases water penetration into the soil and thus reduces soil erosion by diversifying soil-food webs that improve the nitrogen cycle within the soil [47], thus protecting water supplies. In addition, due to the fact that chemical pesticides and fertilizers are banned in OF, the risk of water, soil, and air contaminations by chemical inputs is much lower than in conventional systems [48,49]. Compared to conventional systems with regard to energy use, the OF system has a remarkable advantage. For example, in organic corn production, fossil energy inputs were 31% lower than conventional farms and 17% lower in soybean production [50]. Another study on OF in Central Europe showed that the energy use and fertilizer inputs were reduced by 34% to 53% [51]. Finally, OF has the potential for both mitigation and adaptation strategies, both of which enhance the environment's resilience to climate change [46].

Studies show that farmers are able to obtain various economic benefits from OF, such as saving money through the reduction of input cost by substituting chemical inputs with locally available organic inputs [52]. They can also increase their income through the sale of their byproducts and by entering organic markets with certified products and selling their products at premium prices [23]. With regard to certified organic products and premium prices, some critics claim that export markets are feasible only for large-scale farmers or just very few well-organized small-scale farmers, and the benefits of organic products mostly go to middlemen and traders [53]. It is also important to note that premium prices applied to organic products are supply oriented. The premium may fall if the supply increases. A global meta-analysis by Crowder and Reganold (2015) [54] concerning the economic competitiveness of OF in five continents has shown that despite lower yields in OF, its economic profitability is significantly higher (22–35%) than other farming systems. According to their study, OF's profitability is due to the price premiums of organic products. Another comparative study on the economic profitability of organic and conventional farming in India reveals that, although the crop productivity decreased by 9.2%, OF still increased the net profit of farmers by 22% due to the 20–40% price premium and 11.7% reduction in production costs [55]. Another important issue that should be addressed is risk management. In general, due to a lack of access to risk reduction tools like crop insurance, farmers' capacity to handle risk is typically low [56]. However, according to a study conducted in the United States by Hanson et al. (2004), OF has remarkable potential to positively affect farmers' risk by diversifying products through intercropping and rotation and to help them reduce the risk of main crop failures. Hence, OF as a low-risk strategy is a feasible option for farmers in the United States [57], yet this advantage is not the same for all regions.

OF also increases social capital by supporting social organizations and NGOs at local or regional levels as well as defining new rules and responsibilities for managing resources [58]. Higher bargaining power, better access to credits and markets, exchanging knowledge and experiences, as well as reducing certification costs and facilitating contribution to policy institutions are the most important examples of how OF may empower poor farmers [23]. Given that OF is a labour-intensive system, it can increase employment opportunities in rural areas and improve the capability of poor farmers to afford better education and health services [45].

Despite such advantages and opportunities, farmers still experience some serious challenges when they try to switch to an organic system. First and foremost, the yields of organic farms are around 25% lower than conventional farms; although it is important to note that this difference is very dependent on the context and on local characteristics [19]. Some studies also argue that OF is not a feasible option for farmers who cannot produce sufficient amounts of compost and green manures in many regions like Africa. Since soil management practices are time consuming, soil fertility is depleted. A comparative study of organic and conventional systems on 362 published analyses reveals that OF yields are around 80% of conventional yields. In this study, which was conducted at the field level, researchers found higher yield gaps given the difficulties in management of nutrients in the soil [59]. On average, farmers need around five years to get the best return for their investment [60]. Farmers who convert to certified organic products also must face the problem of risk management during their three-year transitional period. During this period, and before their certification, farms should be managed organically, but farmers cannot sell their products at the higher prices of certified organic foods. It is a challenging period during which yields usually decrease and farmers need to invest money and time to get through it and achieve their organic certification [57]. Concerning the export market, due to relatively strict standards and high expectations of consumers and supermarkets in developed countries for high quality food, only a limited number of farmers can reach such markets [61]. It is estimated that only 43% of people in the rural areas of developing countries can reach markets within 2 h by motorized transport. This trend in some regions like sub-Saharan Africa is as low as 25% of the population [62].

Given the fact that OF is a knowledge-intensive system rather than input intensive, knowledge and research capacity building is of crucial importance in order to achieve the benefits of organic production, specifically regarding appropriate agro-ecological practices and certification, as well as essential information about marketing [63]. With respect to the research issue, it should also be noted that not only the overall share of OF research in comparison to conventional systems is globally lower [63], but also the majority of researchers have conducted their studies mainly in developed countries rather than within the developing world [19]. Adequate public research capacity on organic production has many spillover benefits for the appropriate development of biotechnology, including GM crops as well. Investments in OF research by improving environmental conditions, management practices, and socioeconomic and physical infrastructure is likely to have benefits for GM crop production as well. GM crop research tends to narrow its focus to single goals (such as increasing crop yields) rather than approaching a complex goal like the management of agro-ecosystems.

4. The Dilemma of Food Security and Safety

4.1. GM Technologies and Food Security

The main advantage of GM food crops is their potential promise of contributing to future food security and agricultural development requirements around the world [5]. GM crops can play a significant role in coping with associated problems of hunger, disease, malnutrition, immoderate increase in population, and poverty levels [64]. However, GM as a new technology cannot really solve poverty issues. There might be some economic boosts for early adopters, but those benefits are typically fleeting. It has been argued that we need GM foods because they will reduce production costs by reducing the need for additional chemicals (pesticides and fertilizers). Theoretically, these savings could be passed on to the consumer [65]. Moreover, it has been claimed that GM technology will promote food security while also being healthier and more stable [5].

The nutritional implications are also often cited as an obvious benefit for consumers, since bioengineering could create plants that are able to produce more nutritious food. An example of one such product that is currently being evaluated is 'Golden Rice'. Golden Rice, which is genetically enriched rice with provitamin A, could reduce deficiencies of vitamin A in Africa and South-East Asia, where vitamin A and malnutrition issues are common amongst children [66,67]. However, according to Stone and Glover (2016) [68], Golden Rice remains an unproven technology, even as the problems of micronutrient deficiencies have been reduced through the application of existing technologies, such as fortifying foods with vitamins and minerals. This raises the question of why so much time, effort, and publicity are being invested in an unproven technology.

There is also a growing body of literature showing the positive impacts of GM crops in relation to food security and poverty reduction [5,18]. A good example in this regard can be found in India, where Qaim and Kouser (2013) [69] analysed the food security impacts of GM crops at the micro-scale. They concluded that, due to higher family income, the adoption of GM cotton has substantially enhanced calorie consumption and dietary quality. This technology has indirectly decreased food insecurity by 15–20% among households who produced cotton. Similarly, through conducting a case study in Pakistan, Ali and Abdulai (2010) [70] found a positive and significant impact of Bt cotton adoption on yields, household income, and poverty reduction.

Nevertheless, biotechnology may heighten the gap between the poor and the rich by changing the structural arrangements and the possession of food production systems by aggregating more control to the hands of larger firms [20]. It may exacerbate food security problems, which some believe are caused not by food scarcity but by discriminating food policies in production, processing, and, most importantly, distribution. Nevertheless, studies of consumers' attitudes draw a vague picture. A survey on the consumers' attitudes toward GM foods in the United States by Ganiere et al. (2006) [71] shows four different categories; proponents, non opponents, moderate opponents, and extreme opponents.

4.2. GM Technologies and Food Safety

Some consider that GM foods are as safe as conventionally grown foods [5]. Changing a few genes does not inherently result in foods that are dangerous or less safe than those produced by more conventional techniques [72]. Humans have always eaten the DNA from plants and animals. Most plants or animal cells contain about 30,000 genes, and most GM crops contain an additional 1–10 genes in their cells. We all have DNA in our diets, mainly from fresh food, and the composition of DNA in GM food is the same as that in non-GM food. Eating GM food will not affect a person's genes. Most of the food we eat contains genes of the product, although in cooked or processed foods, most of the DNA has been destroyed or degraded and the genes are fragmented. Our digestive system breaks them down without affecting our genetic make-up [73]. A study by Butelli et al. (2008) [74] on animal feeding trials of GM tomatoes modified to produce high levels of antioxidants showed the GM tomatoes reduced the levels of cancer. This is not because the tomatoes are GM but rather because they produce antioxidants, which are known to reduce cancer. According to NASEM (2016) [30], the large number of experimental studies provided reasonable evidence that animals were not harmed by eating food derived from GM crops. Additionally, long-term data on livestock health before and after the introduction of GM crops showed no adverse effects associated with having GM crops in their feed. The study also examined epidemiological data on the incidence of cancers and other human-health problems over time and found no substantiated evidence that foods from GM crops were less safe than foods from non-GM crops.

A few studies claim damage can occur to the health of humans or animals from specific foods that have been developed using GM. The claims were not about the GM method itself but about the specific gene introduced into the crop or about agricultural practices associated with the crop such as herbicide treatments. There has been no documented allergic reaction associated with GM food [75].

4.3. OF and Food Security

Although organic crops are promoted as environmentally friendly products, they have provoked a great amount of controversy concerning food security and a low agricultural productivity. There is compelling evidence that supports the argument that OF can contribute to food security [5]. Since OF is based on the efficient use of local resources and knowledge, it has great potential to improve food security and its sustainable access to poor and resource-restricted farmers [64]. OF can produce a variety of foods at low costs [55]. Specifically, in challenging environments like dry regions, small-scale farmers can increase their food production by adopting OF practices [76]. A study conducted by United Nations Environment Programme (UNEP) (2008) [77] on 114 organic or near organic projects in 24 African countries showed that the average yield increased by 128%. In some regions, like Africa, the majority of farmers are smallholders who produce crops with no or very low amounts of chemical inputs, hence converting to OF is a feasible option for them to increase their yields and access to food. Food shortage in rural areas is usually the result of crop failure in monoculture systems, while OF advocates multi-culture and consequently decreases the risk of crop failures and food insecurity [78]. Moreover, food access is another important issue that should be considered. Studies suggest that OF can improve the food access of farmers through different ways, including gradual increases in yield as well as improved farmer income, which leads to higher purchasing power [45].

Although many food policy makers and scientists believe that the total food production in OF could be enough to feed the global population [79], low yield in OF is one of the most important issues regarding the ability of OF to improve food security. As evidenced by different studies, lower yield in OF is a controversial issue. A study by Badgley et al. (2007) [80] argues that the yield of OF systems is higher than conventional systems, but others suggest lower yields [21,59]. It is also worth mentioning that the yield gap between OF and conventional farming is highly dependent on the region as well as the crops [19,71]. Nevertheless, Murphy et al. (2007) [81] noted that comparisons between conventional and organic yields in some studies are not accurate and tend to be biased towards higher yields in conventional systems because the crop species and varieties were adapted only for conventional high input systems. It is also important to note that, currently, around 95% of organic production is based on conventional crop varieties and animal breeds and that there is a need to introduce new and suitable varieties for low input organic farming products. Furthermore, a study shows that the transition from conventional to organic farming can lead to higher yields [80].

4.4. OF and Food Safety

Regarding food safety and quality, according to a review study on the nutritional quality of organic food conducted by the French Agency for Food Safety (AFSSA), the amounts of dry matter, minerals like Fe and Mg, and anti-oxidant micronutrients are higher in organic plant products [82]. In addition, the amount of polyunsaturated fatty acids in organic animal products was higher than in conventional products [83,84]. In addition, the amount of polyunsaturated fatty acids found in organic animal products was higher than in conventional products. With regard to pesticide residues, organic foods compared to the non-organic had the least amounts of chemical residues. Moreover, the concentration of nitrate is lower in organic products [82]. A recent meta-analysis based on 343 studies found that there are considerable nutritional differences between organic and conventional foods. According to this study, the use of chemical fungicides is prohibited in OF; the level of toxic heavy metals like cadmium and pesticides residues is also lower in organic foods [85]. Last but not least, through the elimination of synthetic inputs in farms, OF can reduce the risk of farmers' exposure to chemical pesticides.

With regard to food quality and the nutritional benefits of OF, a few studies reject the claim that organic foods are healthier or taste better than conventional foods [86]. In addition, since the use of chemical fungicides is prohibited in OF, mycotoxin contamination in organic foods is more prevalent [87].

5. Co-Existence of GM Crops with OF

Co-existence may be applied to grow crops with different quality characteristics or to supply them for different demands at internal or external markets. The practice has been proposed in the same vicinity without becoming mingled but to cooperatively bring more economic value to the agricultural community [88] and to the society (ecosystem services). Co-existence is an economic issue that is related to the consequences of the adventitious presence of materials from one crop to another and the principle that farmers should be able to freely cultivate the agricultural crops they choose, whether it is GM or OF. The European Commission also refers to co-existence as an issue of the farmers ability and preference to provide consumers with a choice between organic and GM products. Therefore, the co-existence approach is directly linked to consumer choice; to provide consumers with trustworthy information that allows them to make a choice between GM, conventional, and organic foods.

The issue is neither about product/crop safety nor about environmental or health risks but rather about the economic impact of production and marketing, despite the fact that the economic impacts, in the long term, can be influenced by health and environmental risks [89]. This is because it refers to the growth of crops that have previously been authorized as safe for the environment and human health and which are therefore available commercially to farmers. Thus, the main concern is the potential economic loss through the admixture of GM and organic crops, which could lessen their value in the eyes of both farmers and consumers. The concern is also related to the cost and time spent on determining practical management measures in order to minimize such admixture. The concern is also related to the cost and time spent on determining practical management measures in order to minimize such admixture [27].

According to the European Commission (EC) (2009) [90], to develop the knowledge base concerning co-existence, further research activities will be required in the medium-term to address the segregation of GM and non-GM production chains beyond the farm gate. An assessment of the best way forward to address co-existence must take into account commercial experience in the member states. It must include a solid assessment of the effectiveness and efficiency of the measures put in place and an analysis of the impact of national measures on the competitiveness of farmers and the freedom of choice of both farmers and consumers. At the present time, there is no indication of the need to deviate from the subsidiarity-based approach on co-existence and to develop further harmonization on this matter. EU regulations have introduced a 0.9% labelling threshold for the adventitious presence of GM material in non-GM products. Since agriculture does not take place in a closed environment, suitable technical and organizational measures during cultivation, harvest, transport, and storage may be necessary to ensure co-existence. Co-existence measures should make it possible for farmers growing non-GM crops to keep the adventitious presence of GM material in their harvest below the labelling thresholds established by community law.

All in all, there are some significant advantages to the co-existence approach, particularly considering the opportunities offered by different crops to cope with different production systems and varying environmental conditions, including climate change [27]. Recently, some papers highlight the term 'sustainable intensification' as another strategy of the co-existence concept, with eco-efficiency as the driving force [91]. Allocating more farmlands planted using conventional methods might lead us to more environmental loss, thus the answer is to dedicate more land to co-existence farming, which is more likely to ensure food security and safety [92].

6. Discussion and Conclusions

Policy makers interested in improving food security would be well advised to invest in both GM and OF approaches, and each of these approaches has its own pros and cons. This study showed that both GM and OF crops bring benefits and challenges to improve the economic, social, and environmental performance of farmers. Conventional farming systems with GM crops can achieve some efficiencies and mass production that organic systems cannot yet achieve. Overall, the crops are bound to be the most advantageous for farmers economically. Higher economic performance as a result of adopting GM crops was documented in previous reviews or in meta-analyses around the world [32].

The study also showed that the most significant advantages of OF are environmental protection and reduced pesticides. However, the main challenges of this food production system include the limits to increase yields in comparison to conventional systems. Organic farming systems introduce some beneficial system-oriented knowledge, which is important for improving long-term sustainability and enhancing biodiversity and is useful for small farmers who lack the resources to invest in large-scale conventional farming. However, because of the lack of research investments, organic systems are not yet achieving the productive efficiencies that conventional cropping systems have achieved. Investments in the research and diffusion of OF systems, like other farming systems, are vital for solving agricultural production and food security problems since they could increase organic yields dramatically. Therefore, policy makers and agricultural advocacy organizations should be promoting investment in both types of research and in the development of both GM and OF systems to production, while promoting regulatory frameworks that enable coexistence.

All in all, most of the aforementioned advantages and disadvantages vary for every crop and every region. This is due to varying geography, conditions, and practices. Most advantages and challenges of GM crops and OF are contingent on market conditions at international agendas and domestic policies (e.g., labelling, traceability and segregation). The regulatory systems of some governments are more encouraging to GM crop commercialization than others. The advantages and challenges are also affected by consumers and markets, sub-national administrations, local authorities and eventually by farmers. Considering all the opportunities and challenges and despite the fact that GM crops and OF might create some important challenges for farmers, they should still be considered as a part of the solution to improve their livelihood within an integrated approach that uses the best practices of different production systems. The co-existence of GM crops with OF (as a feasible agricultural framing system) is more promising in the hope that it can open more market opportunities, maintain cultural values, conserve biodiversity and cope with dissimilar ecological conditions to ensure 'food security' and 'food safety' in developing countries.

The advent of different agricultural systems has resulted in different policy responses in various countries. The underutilization of GM crops in developing countries is not because the farmers in these regions benefit more from non-GM crops. There are a lot of issues affecting the adoption of GM technology in these countries. Among others, one of the major challenges that can delay access to GM crops is the economic situation of farmers. Small-scale farmers do not have capabilities and necessities to meet their basic requirements or are living in lasting fear of losing their recourses. Most farmers do not have access to many crops, and they lack the resources to purchase the improved seeds. Many resource-poor farmers do not even have access to hybrid maize because of the cost of seeds, let alone GM. According to Azadi et al. (2016) [18], the challenges faced by small-scale farmers in the adoption of GM crops are comprised of the availability and accessibility of GM crop seeds, seed dissemination, and price, as well as the lack of adequate information. It seems clear that GM technology has not been designed with an initial goal of assisting poor farmers but is mainly to boost industrial agriculture, which is not the case in many developing countries yet. Nevertheless, if public-private sectors are engaged from the creation up to marketing stages of these crops, they may have the potential to be considered as an alternative for some farmers after careful selection of the targeted crop and farmers and the establishment of local legislations [18]. Given that there are relatively few farmers in Europe and that their productivity, even without GM, is relatively high compared to that of developing countries (European farmers are able to afford mechanization, fertilizers, herbicides, and pesticides to raise productivity), the economic cost to Europe of banning GM is mostly in the form of modestly higher prices for some foods. However, given that more laborers in developing countries work on farms and that they have very low levels of agricultural productivity, reduced access to improved seeds imposes significant costs to them.

In the context of developing countries, the most urgent requirement is food security. This need has already become the main concern of policy makers so that their first expectation from the agricultural sector is to make the country independent in producing cereals (mainly wheat, rice, and maize) and livestock (mainly red meat), which are highest demanded foods in the world. Otherwise, the policy makers will not be able to meet the main need of the growing population in the developing world. Furthermore, policy makers should be very careful when dealing with cereals because most of the farmers in developing countries mainly produce and therefore earn their livelihoods from cereals. Putting the benefits of these two target groups together, it seems that GM technology is potentially a more secure strategy to bring higher yields and therefore income for the farmers on one hand and sufficient food for the growing population on the other. Furthermore, the rapid and continued growth of organic markets in the developed world, particularly in Europe, provides an impetus for farmers in developing countries to change practices to meet this demand. The rejection of conventional agriculture and GM crops in the EU might be a simple explanation as to the trend of increased organic production, as poorer countries are taking advantage of this opportunity to export high-value agricultural products to the EU markets. Accordingly, a co-existence approach may work better in a way that developing countries can take the advantage of in various agricultural systems (including GM, organic, and conventional agriculture) to feed their people while increase their economic achievements. Although this strategy could be a realistic approach in developing countries, it might not be a very good approach in the developed world, where there are few farmers and productivity levels are high. Accordingly, in developed countries, OF, as a more environmentally-friendly approach, could be more a viable option.

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References

1. Godfray, H.C.J.; Beddington, J.R.; Crute, I.R.; Haddad, L.; Lawrence, D.; Muir, J.F.; Toulmin, C. Food security: The challenge of feeding 9 billion people. *Science* **2010**, *327*, 812–818. [CrossRef] [PubMed]
2. McKenzie, F.C.; Williams, J. Sustainable food production: Constraints, challenges and choices by 2050. *Food Secur.* **2015**, *7*, 221–233. [CrossRef]
3. Lamichhane, S.A. Genetically Modified Foods-Solution for Food Security. *Int. J. Genet. Eng. Biotechnol.* **2014**, *5*, 43–48.
4. Rusly, N.S.; Amin, L.; Zainol, Z. The need for Biosafety education in Malaysia. *Procedia Soc. Behav. Sci.* **2011**, *15*, 3379–3383. [CrossRef]
5. Azadi, H.; Ho, P. Genetically modified and organic crops in developing countries: A review of options for food security. *Biotechnol. Adv.* **2010**, *28*, 160–168. [CrossRef] [PubMed]
6. Floros, J.D.; Newsome, R.; Fisher, W.; Barbosa-Cánovas, G.V.; Chen, H.; Dunne, C.P.; Bruce German, J.; Hall, R.L.; Heldman, D.R.; Karwe, M.V.; et al. Feeding the World Today and Tomorrow: The Importance of Food Science and Technology. *Compr. Rev. Food Sci. Food Saf.* **2010**, *9*, 572–599. [CrossRef]
7. Brookes, G.; Barfoot, P. Global income and production impacts of using GM crop technology 1996–2014. *GM Crop. Food* **2016**, *7*, 38–77. [CrossRef] [PubMed]
8. Klümper, W.; Qaim, M. A Meta-Analysis of the impacts of genetically modified crops. *PLoS ONE* **2014**, *9*, e111629. [CrossRef] [PubMed]
9. James, C. *20th Anniversary (1996 to 2015) of the Global Commercialization of Biotech Crops and Biotech Crop Highlights in 2015*; ISAAA Brief No. 51; ISAAA: Ithaca, NY, USA, 2015.
10. Meijer, E.; Stewart, R. The GM Cold War: How Developing Countries Can Go from Being Dominos to Being Players. *RECIEL* **2004**, *13*, 247–262. [CrossRef]
11. Wolson, R.A. Assessing the prospects for the adoption of biofortified crops in South Africa. *AgBioForum* **2007**, *10*, 184–191.
12. Hawes, C.; Haughton, A.J.; Osborne, J.L.; Roy, D.B.; Clark, S.J.; Perry, J.N.; Rothery, P.; Bohan, D.A.; Brooks, D.R.; Champion, G.T.; et al. Responses of plants and invertebrate trophic groups to contrasting herbicide regimes in the Farm Scale Evaluations of genetically modified herbicide-tolerant crops. *Philos. Trans. R. Soc. Biol. Sci.* **2003**, *358*, 1899–1913.
13. Gressel, J. Dealing with Transgene Flow of Crop Protection Traits from Crops to Their Relatives. *Pest Manag. Sci.* **2015**, *71*, 658–667. [CrossRef] [PubMed]
14. Ryffel, G.U. Transgene flow: Facts, speculations and possible countermeasures. *GM Crops Food* **2014**, *5*, 249–258. [CrossRef] [PubMed]
15. Harris, D.; Orr, A. Is rainfed agriculture really a pathway from poverty? *Agric. Syst.* **2014**, *123*, 84–96. [CrossRef]
16. Chappell, M.J.; LaValle, L.A. Food security and biodiversity: Can we have both? An agroecological analysis. *Agric. Hum. Values* **2011**, *28*, 3–26. [CrossRef]
17. Schoonbeek, S.; Azadi, H.; Mahmoudi, H.; Derudder, B.; De Maeyer, P.; Witlox, F. Organic agriculture and undernourishment in developing countries: Main potentials and challenges. *Crit. Rev. Food Sci. Nutr.* **2013**, *53*, 917–928. [CrossRef] [PubMed]
18. Azadi, H.; Samiee, A.; Mahmoudi, H.; Jouzi, Z.; Rafiaani Khachak, P.; De Maeyer, P.; Witlox, F. Genetically modified crops and small-scale farmers: Main opportunities and challenges. *Crit. Rev. Biotechnol.* **2016**, *36*, 434–446. [CrossRef] [PubMed]
19. Seufert, V.; Ramankutty, N.; Foley, J.A. Comparing the yields of organic and conventional agriculture. *Nature* **2012**, *485*, 229–232. [CrossRef] [PubMed]
20. Reganold, J.P.; Wachter, J.M. Organic agriculture in the twenty-first century. *Nat. Plants* **2016**, *2*, 15221. Available online: http://www.db.zs-intern.de/uploads/1454660735-ReganoldWachternplants2016.pdf (accessed on 9 April 2017). [CrossRef] [PubMed]
21. Sundrum, A. Organic livestock farming: A critical review. *Livest. Prod. Sci.* **2001**, *67*, 207–215. [CrossRef]

22. Rundgren, G.; Parrott, N. Organic Agriculture and Food Security: IFOAM. Available online: https://www.ifoam.bio/sites/default/files/organic_agriculture_and_food_security_printcopy.pdf (accessed on 9 April 2017).
23. Kilcher, L. How organic agriculture contributes to sustainable development. *JARTS* **2007**, *89*, 31–49.
24. Trewavas, A. Urban myths of organic farming. *Nature* **2001**, *410*, 409–410. [CrossRef] [PubMed]
25. Kukreja, R.; Meredith, S. *Resource Efficiency and Organic Farming: Facing up to the Challenge*; IFOAM EU Group: Brussels, Belgium, 2011. Available online: http://www.ifoam-eu.org/sites/default/files/page/files/ifoameu_policy_resource_efficiency_handbook_201112.pdf (accessed on 26 November 2013).
26. Sagoff, M. Biotechnology and Agriculture: 8e Common Wisdom and Its Critics. *Indiana J. Glob. Leg. Stud.* **2001**, *9*, 2. Available online: http://www.repository.law.indiana.edu/ijgls/vol9/iss1/2 (accessed on 9 April 2017).
27. Jank, B.; Rath, J.; Gaugitsch, H. Co-existence of agricultural production systems. *Trends Biotechnol.* **2006**, *24*, 198–200. [CrossRef] [PubMed]
28. Giddings, L.V.; Atkinson, R.D.; Wu, J.J. *Suppressing Growth: How GMO Opposition Hurts Developing Nations*; Information Technology & Innovation Foundation: Washington, DC, USA, 2016.
29. Stein, H. Intellectual Property and Genetically Modified Seeds: The United States, Trade, and the Developing World. *Northwest. J. Technol. Intell. Prop.* **2005**, *3*, 160–178.
30. NASEM (National Academies of Sciences, Engineering, and Medicine). *Genetically Engineered Crops: Experiences and Prospects*; The National Academies Press: Washington, DC, USA, 2016.
31. Ghasemi, S.; Karami, E.; Azadi, H. Knowledge, attitudes and behavioral intentions of agricultural professionals toward genetically modified (GM) foods: A case study in Southwest Iran. *Sci. Eng. Ethics* **2013**, *19*, 1201–1227. [CrossRef] [PubMed]
32. Finger, R.N.; Benni, E.; Kaphengst, T.; Evans, C.; Herbert, S.; Lehmann, B.; Stupak, N. A Meta Analysis on Farm-Level Costs and Benefits of GM Crops. *Sustainability* **2011**, *3*, 743–762. [CrossRef]
33. Benbrook, C.M. Impacts of genetically engineered crops on pesticide use in the U.S.—The first sixteen years. *Environ. Sci. Eur.* **2012**, *24*, 1–13. [CrossRef]
34. Brookes, G.; Barfoot, P. Environmental impacts of genetically modified (GM) crop use 1996–2014: Impacts on pesticide use and carbon emissions. *GM Crops Food* **2016**, *7*, 84–116. [CrossRef] [PubMed]
35. Sanvido, O.; Romeis, J.; Bigler, F. Ecological impacts of genetically modified crops: Ten years of field research and commercial cultivation. *Adv. Biochem. Eng. Biotechnol.* **2007**, *107*, 235–278. [PubMed]
36. Huang, J.; Hu, R.; Pray, C.; Qiao, F.; Rozelle, S. Biotechnology as an alternative to chemical pesticides: A case study of Bt cotton in China. *Agric. Econ.* **2003**, *29*, 55–67. [CrossRef]
37. Kouser, S.; Qaim, M. Impact of Bt cotton on pesticide poisoning in smallholder agriculture: A panel data analysis. *Ecol. Econ.* **2011**, *70*, 2105–2113. [CrossRef]
38. World Bank. Total Arable Land 1407.134 MHa. 2013. Available online: http://data.worldbank.org/indicator/AG.LND.ARBL.ZS (accessed on 16 May 2016).
39. Viswanathan, P.K.; Lalitha, N. GM technology and sustainable agriculture future: Empirical evidences from Bt cotton farmers in Maharashtra and Gujarat in India. *J. Dev. Agric. Econ.* **2010**, *2*, 7–17.
40. Carpenter, J.E. Impact of GM crops on biodiversity. *GM Crops* **2011**, *1*, 7–23. [CrossRef] [PubMed]
41. Glover, D. Is Bt Cotton a Pro-Poor Technology? A Review and Critique of the Empirical Record. *J. Chang.* **2010**, *10*, 489–509. [CrossRef]
42. Willer, H.; Lernoud, J. (Eds.) *The World of Organic Agriculture: Statistics and Emerging Trends*; Research Institute of Organic Agriculture (FiBL), Frick, and IFOAM-Organics International: Bonn, Germany, 2016.
43. Rahmann, G. Biodiversity and Organic farming: What do we know? *vTI Agric. Forstery Res.* **2011**, *61*, 189–208.
44. Bengtsson, J.; Ahnström, J.; Weibull, A.-C. The effects of organic agriculture on biodiversity and abundance: A meta-analysis. *J. Appl. Ecol.* **2005**, *42*, 261–269. [CrossRef]
45. Jouzi, Z.; Azadi, H.; Taheri, F.; Zarafshani, K.; Gebrehiwot, K.; Van Passel, S.; Lebailly, P. Organic farming and small-scale farmers: Main opportunities and challenges. *Ecol. Econ.* **2017**, *132*, 144–154. [CrossRef]
46. Gattinger, A.; Muller, A.; Haeni, M.; Skinner, C.; Fliessbach, A.; Buchmann, N.; Mäder, P.; Stolze, M.; Smith, P.; Scialabba, N.E.H.; et al. Enhanced top soil carbon stocks under organic farming. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 18226–18231. [CrossRef] [PubMed]
47. Pimentel, D.; Hepperly, P.; Hanson, J.; Seidel, R.; Douds, D. Environmental, energetic, and economic comparisons of organic and conventional farming systems. *Bioscience* **2005**, *55*, 573–582. [CrossRef]

48. Baker, B.P.; Benbrook, C.M.; Groth, E.; Benbrook, K.L. Pesticide residues in conventional, integrated pest management (IPM)-grown and organic foods: Insights from three US data sets. *Food Addit. Contam.* **2002**, *19*, 427–446. [CrossRef] [PubMed]
49. Lotter, D.; Seidel, R.; Liebhardt, W. The performance of organic and conventional cropping systems in an extreme climate year. *Am. J. Altern. Agric.* **2003**, *18*, 146–154. [CrossRef]
50. Pimentel, D. Impacts of Organic Farming on the Efficiency of Energy Use in Agriculture—An Organic Center State of Science Review. 2006. Available online: https://www.organic-center.org/reportfiles/ENERGY_SSR.pdf (accessed on 9 April 2017).
51. Mäder, P.; Fliessbach, A.; Dubois, D.; Gunst, L.; Fried, P.; Niggli, U. Soil fertility and biodiversity in organic farming. *Science* **2002**, *296*, 1694–1697. [CrossRef] [PubMed]
52. Qiao, Y.; Halberg, N.; Vaheesan, S.; Scott, S. Assessing the social and economic benefits of organic and fair trade tea production for small-scale farmers in Asia: A comparative case study of China and Sri Lanka. *Renew. Agric. Food Syst.* **2015**, *31*, 246–257. [CrossRef]
53. Abele, S.; Dubois, T.; Twine, E.; Sonder, K.; Coulibaly, O. Organic agriculture in Africa: A critical review from a multidisciplinary perspective. *J. Agric. Rural Dev. Trop. Subtrop.* **2007**, *89*, 143–166.
54. Crowder, D.W.; Reganold, J.P. Financial competitiveness of organic agriculture on a global scale. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, 7611–7616. [CrossRef] [PubMed]
55. Ramesh, P.; Panwar, N.R.; Singh, A.B.; Ramana, S.; Yadav, S.K.; Shrivastava, R.; Rao, A.S. Status of organic farming in India. *Curr. Sci.* **2010**, *98*, 1190–1194.
56. Eyhorn, F.; Ramakrishnan, R.; Mäder, P. The Viability of Cotton-Based Organic Farming Systems in India. *Int. J. Agric. Sustain.* **2007**, *5*, 25–38.
57. Hanson, J.; Dismukes, R.; Chambers, W.; Greene, C.; Kremen, A. Risk and risk management in organic agriculture: Views of organic farmers. *Renew. Agric. Food Syst.* **2004**, *19*, 218–227. [CrossRef]
58. Rice, R.A. Noble goals and challenging terrain: Organic and fair trade coffee movements in the global marketplace. *J. Agric. Environ. Ethics* **2001**, *14*, 39–66. [CrossRef]
59. Ponti, T.D.; Rijk, B.; Van Ittersum, M.K. The crop yield gap between organic and conventional agriculture. *Agric. Syst.* **2012**, *108*, 1–9. [CrossRef]
60. Lotter, D. Facing food insecurity in Africa: Why, after 30 years of work in organic agriculture, I am promoting the use of synthetic fertilizers and herbicides in small-scale staple crop production. *Agric. Hum. Values* **2015**, *32*, 111–118. [CrossRef]
61. Kirsten, J.; Sartorius, K. Linking agribusiness and small-scale farmers in developing countries: Is there a new role for contract farming? *Dev. S. Afr.* **2002**, *19*, 503–529. [CrossRef]
62. Smale, M.; Byerlee, D.; Jayne, T. *Maize Revolutions in Sub-Saharan Africa*; An African Green Revolution; Springer: Dordrecht, The Netherlands, 2011.
63. Ponisio, L.C.; M'Gonigle, L.K.; Mace, K.C.; Palomino, J.; Valpine, P.D.; Kremen, C. Diversification practices reduce organic to conventional yield gap. *Proc. R. Soc. Lond. B Biol. Sci.* **2015**, *282*, 20141396. [CrossRef]
64. Bazuin, S.; Azadi, H.; Witlox, F. Application of GM crops in Sub-Saharan Africa: Lessons learned from Green Revolution. *Biotechnol. Adv.* **2011**, *29*, 908–912. [CrossRef] [PubMed]
65. Schneider, K.R.; Schneider, R.J.; Richardson, S. *Genetically Modified Food*; IFAS Extension, University of Florida: Gainesville, FL, USA, 2014.
66. Ye, X.; Al-Babili, S.; Klöti, A.; Zhang, J.; Lucca, P.; Beyer, P.; Potrykus, I. Engineering the provitamin A (beta-carotene) biosynthetic pathway into (carotenoid-free) rice endosperm. *Science* **2000**, *287*, 303–305. [CrossRef] [PubMed]
67. Paine, J.A.; Shipton, C.A.; Chaggar, S.; Howells, R.M.; Kennedy, M.J.; Vernon, G.; Wright, S.Y.; Hinchliffe, E.; Adams, J.L.; Silverstone, A.L.; et al. Improving the nutritional value of Golden Rice through increased pro-vitamin A content. *Nat. Biotechnol.* **2005**, *23*, 482–487. [CrossRef] [PubMed]
68. Stone, G.D.; Glover, D. Disembedding grain: Golden Rice, the Green Revolution, and heirloom seeds in the Philippines. *Agric. Hum. Values* **2016**, *33*, 1–16. [CrossRef]
69. Qaim, M.; Kouser, S. Genetically Modified Crops and Food Security. *PLoS ONE* **2013**, *8*, e64879. [CrossRef] [PubMed]
70. Ali, A.; Abdulai, A. The Adoption of Genetically Modified Cotton and Poverty Reduction in Pakistan. *J. Agric. Econ.* **2010**, *61*, 175–192. [CrossRef]

71. Ganiere, P.; Chern, W.S.; Hahn, D. A Continuum of Consumer Attitudes toward Genetically Modified Foods in the United States. *J. Agric. Res. Econ.* **2006**, *31*, 129–149.
72. Miller, H.I. The regulation of agricultural biotechnology: Science shows a better way. *New Biotechnol.* **2010**, *27*, 628–634. [CrossRef] [PubMed]
73. Rizzi, A.; Raddadi, N.; Sorlini, C.; Nordgrd, L.; Nielsen, K.M.; Daffonchio, D. The stability and degradation of dietary DNA in the gastrointestinal tract of mammals—Implications for horizontal gene transfer and the biosafety of GMOs. *Crit. Rev. Food Sci. Nutr.* **2012**, *52*, 142–161. [CrossRef] [PubMed]
74. Butelli, E.; Titta, L.; Giorgio, M.; Mock, H.; Matros, A.; Peterek, S.; Schijlen, E.; Hall, R.; Bovy, A.; Luo, J.; et al. Enrichment of tomato fruit with health-promoting anthocyanins by expression of select transcription factors. *Nat. Biotechnol.* **2008**, *26*, 1301–1308. [CrossRef] [PubMed]
75. Lehrer, S.B.; Bannon, G.A. Risks of Allergic Reactions to Biotech Proteins in Foods: Perception and Reality. *Allergy* **2005**, *60*, 559–564. [CrossRef] [PubMed]
76. Te Pas, C.M.; Rees, R.M. Analysis of differences in productivity, profitability and soil fertility between organic and conventional cropping systems in the tropics and sub-tropics. *J. Integr. Agric.* **2014**, *13*, 2299–2310. [CrossRef]
77. United Nations Environment Programme (UNEP). *Organic Agriculture and Food Security in Africa*; United Nations Publication: New York, NY, USA, 2008.
78. Setboonsarng, Sununtar. *Organic Agriculture, Poverty Reduction and the Millennium Development Goals*; International Workshop on Sufficiency Economy, Poverty Reduction, and the MDGs Organized under the Umbrella of the Exposition of Sufficiency Economy for Sustainable Development, 2006. Available online: http://www.adbi.org/files/2006.09.dp54.organic.agriculture.mdgs.pdf (accessed on 9 April 2017).
79. Tscharntke, T.; Clough, Y.; Wanger, T.C.; Jackson, L.; Motzke, I.; Perfecto, I.; Whitbread, A. Global food security, biodiversity conservation and the future of agricultural intensification. *Biol. Conserve* **2012**, *151*, 53–59. [CrossRef]
80. Badgley, C.; Moghtader, J.; Quintero, E.; Zakem, E.; Chappell, M.J.; Aviles-Vazquez, K.; Perfecto, I. Organic agriculture and the global food supply. *Renew. Agric. Food Syst.* **2007**, *22*, 86–108. [CrossRef]
81. Murphy, K.M.; Campbell, K.G.; Lyon, S.R.; Jones, S.S. Evidence of varietal adaptation to organic farming systems. *Field Crops Res.* **2007**, *102*, 172–177. [CrossRef]
82. Lairon, D. Nutritional quality and safety of organic food. A review. *Agron. Sustain. Dev.* **2010**, *30*, 33–41. [CrossRef]
83. Srednicka-Tober, D.; Barański, M.; Seal, C.; Sanderson, R.; Benbrook, C.; Steinshamn, H.; Gromadzka-Ostrowska, J.; Rembialkowska, E.; Skwarlo-Sonta, K.; Eyre, M.; et al. Composition differences between organic and conventional meat: A systematic literature review and meta-analysis. *Br. J. Nutr.* **2016**, *115*, 994–1011. [CrossRef] [PubMed]
84. Średnicka-Tober, D.; Barański, M.; Seal, C.J.; Sanderson, R.; Benbrook, C.; Steinshamn, H.; Gromadzka-Ostrowska, J.; Rembialkowska, E.; Skwarlo-Sonta, K.; Eyre, M.; et al. Higher PUFA and n-3 PUFA, conjugated linoleic acid, alpha-tocopherol and iron, but lower iodine and selenium concentrations in organic milk: A systematic literature review and meta- and redundancy analyses. *Br. J. Nutr.* **2016**, *115*, 1043–1060. [CrossRef] [PubMed]
85. Barański, M.; Średnicka-Tober, D.; Volakakis, N.; Seal, C.; Sanderson, R.; Stewart, G.B.; Giotis, C. Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: A systematic literature review and meta-analyses. *Br. J. Nutr.* **2014**, *112*, 794–811. [CrossRef] [PubMed]
86. Mulet, J.M. Should we recommend organic crop foods on the basis of health benefits? Letter to the editor regarding the article by Baranski et al. *Br. J. Nutr.* **2014**, *112*, 1745–1747. [CrossRef] [PubMed]
87. Wu, F. Mycotoxin reduction in Bt corn: Potential economic, health, and regulatory impacts. *Transgenic Res.* **2006**, *15*, 277–289. [CrossRef] [PubMed]
88. European Commission. *GMOs: Commission Publishes Recommendations to Ensure Co-Existence of GM and Non-GM Crops*; European Commission: Brussels, Belgium, 2003. Available online: http://europa.eu/rapid/pressReleasesAction.do?reference=IP/03/1096&format=HTML&aged=0&language=EN&guiLanguage=en (accessed on 9 April 2017).
89. Brookes, G.; Barfoot, P. *Co-Existence in North American Agriculture: Can GM Crops Be Grown with Conventional and Organic Crops?* PG Economics Ltd.: Dorchester, UK, 2004.

90. European Commission (EC). *Report from the Commission to the Council and the European Parliament on the Coexistence of Genetically Modified Crops with Conventional and Organic Farming*; European Commission: Brussels, Belgium, 2009. Available online: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0153:FIN:en:PDF (accessed on 9 April 2017).
91. Charles, H.; Godfray, J.; Beddington, R.; Crute, I.; Haddad, L.; Lawrence, D.; Muir, J.; Pretty, J.; Robinson, S.; Thomas, S.; et al. Food Security: The Challenge of feeding 9 Billion People. *Science* **2010**, *327*, 812–818.
92. Garnett, T.; Appleby, M.C.; Balmford, A.; Bateman, I.J.; Benton, T.G.; Bloomer, P.; Burlingame, B.; Dawkins, M.; Dolan, L.; Fraser, D.; et al. Sustainable intensification in agriculture: Premises and policies. *Science* **2013**, *341*, 33–34. [CrossRef] [PubMed]

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