POLICY CENTER FOR THE NEW SOUTH
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Policy Brief
February 2021, PB-21/06

Genetically Modified Organisms: Promising or Problematic for Food Security? A Review of Major Developments in Selected Developing Countries

Part II

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Executive Summary

Selected experiences with GMOs in industrialized and developing countries show that the promise of bioengineering for strengthening food security cannot materialize unless and until GMOs are accepted by the vast majority of consumers as being safe and environmentally friendly. To date, the main effort has been on the supply side: bioengineered plants have desirable traits helpful to farmers, e.g., increased yields, resistance to pests, resilience to weather extremes in a warming world. But there has little sustained official effort to inform and educate the public via trusted sources.

Thus, the success of bioengineering in inserting desirable traits at the farm level has not been sufficient to remove the substantial opposition to GM foods, especially in the European Union but also in the United States and in developing countries including China and South Africa, where the governments have been supportive.

Though undertaken in very different socio-economic contexts, surveys of public attitudes towards GM foods and drugs have some common findings. These are: (i) the public's knowledge of GMOs is slim; (ii) there is widespread distrust of government's ability to prevent food scandals; (iii) other sources of information such as from industry

are also suspect, (and even from scientists although there is more trust); (iv) the main sources of information about GMOs are mainly from social media, and media including television and newspapers, and NGOs and activist groups, which are largely anti-GMO; and (v) there is no clear positive correlation between high level of formal education and favorable perception of GMOs.

Is the opposition based mainly on ignorance, fear of the unknown, or breakdown in trust in government and industry? Or is the problem rather on the supply side in terms of the oligopolistic structure of the GM seed business, the market power imbalance between business and small farmers, the transparency of operations of bioengineers? Or is there a combination of both demand and supply factors? There is a lot to disentangle here.

What is clear is that the powerful technology of bioengineering cannot be viewed as a 'magic bullet' to solve widespread food insecurity, as hoped for by its early advocates. For African leadership interested in operationalizing the Africa Continent Free Trade Area (AfCFTA) in the near future to realize the full contribution of GMOs to the food security of its people, among other things, now is an opportune time to reevaluate both the supply of GM technologies and potential demand for such products in terms of food and feed safety, biological diversity, and environmental sustainability. This holistic evaluation is essential to shape the launching of a coordinated and effective Africa-wide approach.

Introduction

Norman Borlaug (1914-2009), the 'father of the Green Revolution' was in favor of genetic engineering. He viewed GMOs as the only way to increase food production as the world runs out of unused arable land as he argued that GMOs are not inherently dangerous. "Some people fear genetic modification, which is not very sound, because we've been genetically modifying plants and animals for a long time. Long before we called it science, people were selecting the best breeds". (Berger, 2008) In fact, reviewers[1] (2010) of Borlaug's 2000 publication entitled Ending World Hunger: The Promise of Biotechnology and the Threat of Antiscience Zealotry, (Plant Physiology, Oct. 2000) pointed out that "GM crops are as natural and as safe as today's bread wheat, opined Dr. Borlaug who also reminded agricultural scientists of their moral obligation to stand up against to the anti-science crowd and warn policy makers that global food insecurity will not disappear without this new technology, and ignoring this reality would make future solutions all the more difficult to achieve". [2] (Plant Physiology, Oct 2010).

In much of the developing world, hunger and food insecurity stalk millions. The Food and Agriculture Organization (FAO) warns that global hunger has been on the rise since 2014, with the prevalence of undernourishment (PoU) estimated at 8.6% of total population, or 690 million people, in 2019. The PoU in Africa was 19.1% in 2019, more than twice the world average and the highest among all regions. With the global onslaught of COVID-19 since early 2020, preliminary estimates of the increase in the number worldwide of undernourished people range from 83-120 million. As of 2020, the world is not on track to achieve the Zero Hunger target, Sustainable Development Goal (SDG) 2.1, by 2030 (FAO et al, 2020).

In the face of this grim reality, should developing countries still burdened with extensive chronic hunger embrace the promise of bioengineering to raise their agricultural productivity, as Borlaug advocated, or reject it as the European Union is doing? Either way, what should be the major considerations? Following the first Policy Brief analyzing the situation in selected industrialized countries (Part I), this Policy Brief (Part II) addresses this question in two developing countries: the People's Republic of China which, alone among developing countries, has invested heavily in the research and development of biotechnology; and the

1. The reviewers were: Kevin Rozwadowski and Sateesh Kagale. (Plant Physiology, Oct. 2010)
2. Borlaug (Plant Physiology, Oct 2000) also wrote: "Nowhere is it more important for knowledge to confront fear born of ignorance than in the production of food, still the basic human activity. In particular, we need to close the biological science knowledge gap in the affluent societies now thoroughly urban and removed from any tangible relationship to the land... Privileged societies have the luxury of adopting a very low-risk position on the genetically modified crop issue, even if this action later turns out to be unnecessary. But the vast majority of humankind, including the hungry victims of wars, natural disasters, and economic crises who are served by the WFP, does not have such a luxury." (P 489-490)

Union of South Africa, considered the biotechnology leader in Africa, which has commercially planted GMOs widely, committing 2.7 m ha, only slightly lower than China's 2.9 m ha (2018)[3].

The People's Republic of China: Government support for GMOs[4]

How best to achieve food security, a top priority for decades? Feeding its population of 1.4 billion (2019) has been a central strategic priority of China's governments since 1949. To achieve this priority, the goal has been to increase agricultural productivity growth, and food supplies, and to reduce poverty and hunger. In the 1990s, China was 98% self-sufficient in grains (rice, wheat, and maize (referred to as corn in America)) (Huang et al, 2000). For the decade ahead, China wants to be food sovereign. By this, it means that it wants to maintain control over its food supply at all times. The goal is to achieve 95% self-sufficiency in grains (rice, wheat, and maize) by 2030 (China 2030). However, to seek self-sufficiency for China in grain feed (maize) in addition to food grains (rice and wheat) will seriously challenge its cereal self-sufficiency/food sovereign model, given (i) increasing land and water scarcity in the northern plains, and (ii) the prospect of increasing demand for livestock and feed. The main reason is that these grains are all major users of water (cubic m/ton of output): wheat: 1000 m/t; rice: 1200 m/t; maize (corn): 850 m/t[5]. It is in this resource-constrained context that China has invested heavily in biotech—its 26-billion-yuan special investment program (2009-2020)—to sustain its growth in agricultural productivity (World Bank, 2012).

Strong government support for biotechnology: Since the early 1980s, the Government of China (GOC) has invested substantially in genetic engineering to strengthen food security. With arable land and water resources for agriculture fast dwindling because of industrialization and urbanization—already, China has to feed 20% of the world population on just 7% of its arable land (World Bank, 2016)—biotechnology has been viewed as an important tool to increase agricultural productivity, and therefore food security. China ratified the Cartagena Protocol on Biosafety in 2005. By ratifying the Protocol, China implicitly accepted the Precautionary Principle. However, in a 2014 speech, President Xi Jinping declared that China must "boldly research and innovate, [and] occupy the high points of GMO techniques" (Chow, 2019). China's special research program, the National Major Science and Technology Projects of China for Breeding New Biotech Varieties (the National Major Projects (2009-2020), received total funding of approximately $3.5 billion, most of which came from central and local governments, with the rest being private-sector investment. The projects include research into both plant and animal species.

Key features of China's institutional and regulatory framework for GMOs

China has built a complex institutional structure for GMO development and commercialization. The main institutions cover agriculture and agri-food, environment, customs, food safety and overall coordination, and enforcement.

- The Ministry of Agriculture and Rural Affairs (MARA) is the main institution. It is primarily responsible for the approval of biotech products for domestic production and imports (for food, feed and processing), as well as the development of agricultural biotech policies and regulations. In 2017, Regulations on Safe Management of GMOs (which were originally issued in 2001) were revised. These regulations encompass the entire process of research, experimentation, production, processing, imports, and exports. A key revision was that the regulatory testing was to be entrusted to qualified technical institutes. These regulations require labeling of imports of GE soybeans, corn, rapeseed, seed cotton, and tomatoes. China also set up a safety committee for evaluating the safety of GMOs. In January 2002, China published regulations requiring labeling and safety certifications for all GM imports. In 2018, working with other educational institutions, MARA launched the Nationwide GMO Science Education Tour campaign to better inform the public and combat widespread misinformation spread by media (USDA, 2020).
- The China Food and Drug Administration (CFDA): It is in charge of food safety in the manufacturing, processing, distribution, and catering industries.

3. The other African countries are: Burkina Faso (2008), Sudan (2012) and Egypt (2008).
4. GNI/CAP: $ 10,410 (value of 2019, following Atlas method)
5. Water requirement for soybean is 3200 cubic m/ton of output. China is a leading importer of soybeans from Brazil, the United States, and Argentina.

- The Ministry of Environmental Protection (MEP) is the lead agency which negotiated, signed (2000), and ratified the Cartagena Protocol on Biosafety (2005).
- General Administration of Customs (GACC): It is responsible for enforcing regulations issued by MARA. These regulations have been criticized by exporters to China for effectively acting as trade barriers because they are opaque, cumbersome, and unpredictable, causing unnecessary delays. China does not allow any foreign biotech developer to operate domestically, or the importation of any foreign GM seed (USDA, Feb 2020).
- The Joint Ministerial Conference for Biosafety Management for Agricultural Genetically Modified Organisms: This group is made up of 12 government bodies including the Ministry of Science and Technology (MOST) and the National Health Commission. It coordinates biotech policies.
- The State Administration for Market Regulation (SAMR): It is the authority for comprehensive market oversight, which includes law enforcement with respect to market supervision, and administration of food safety nationwide. It enforces the Implementing Regulations for the Food Safety Law of October 2019, e.g. compliance with the labeling requirements for GMO products.

Selected research and field developments

The first GMO plant was a virus-resistant tobacco plant in 1988, but its cultivation was stopped in the early 1990s for trade reasons (Gale et al, 2003). In 2003, the China Academy of Sciences had a program to bioengineer rice varieties with high yield and high quality. In addition, the China National Rice Research Institute also spearheaded research into rice varieties for not only higher yields and quality, but also for greater pest and drought resistance. The other important research crops were corn, soybeans, and cotton. Foreign-developed GM products are not allowed for domestic cultivation. Since the late 1990s, Bt cotton has been cultivated and is the only one widely cultivated, occupying most of the total area devoted to cotton (Zhang and Zhou, 2005). Insect-resistant cotton was popular as it reduced farmers' production costs by 14-33% (Gale et al, 2003). In 2018, 95% of total area under cotton was Bt cotton. (USDA, Feb 2020). By the early 2000s, research was ongoing into a variety of horticultural crops, some of which were also commercialized; e.g., virus-resistant tomato, sweet pepper, chili, and papaya (Huang and Rozelle, 2004). Despite sustained public investment in bioengineering since the 1980s, China approved Bt cotton only in 1997, and GM papaya only by the late 1990s for domestic cultivation/commercialization. Also, it was not until January 2020 that the GOC announced that certain varieties of GM corn and soybean had passed biosafety evaluations and that the 15 day' period for public feedback passed without objections (Cremer, 2020). The slow pace of such approval seems consistent with China's acceptance of the precautionary principle when it ratified the Cartagena Protocol in 2005 (Xiang, 2020).

Despite strong government support, consumer distrust of GMOs has increased in China: In the early 2000s, consumer acceptance was not an issue. However, after major food adulteration scandals, the most infamous being the Sanlu melamine milk powder scandal in 2008 [6], consumer confidence in the government's ability to ensure food safety plummeted. In fact, food adulteration scandals totaled over 9000 between 2003 and 2013. A nationwide survey in 2014 found that nearly 48% of respondents had a negative view of GMOs, with 14% believing them to be a form of bioterrorism (Chow, 2019). The main food categories that consumers worry about are cooking oil, dairy and meat products, fresh vegetables, and seafood (Liu and Ma, 2016). It is therefore not surprising that consumers extend this worry to GMOs. Furthermore, misinformation about GMOs on social media is alleged to be pervasive. For example, the anti-GMO line was popularized by a TV personality Cui Yongyuan with over 20 million followers online (Zhang, 2013). The debate between the pro- (usually scientific community) and anti- (usually social media) GMO groups rages on in China (Zhang, 2017). Despite these controversies, it is still unclear how to interpret them for policy purposes since surveys repeatedly found that positive or negative perceptions of GMOs are dependent on one's understanding of genetic engineering and most people knew little about it (Cui and Shoemaker, 2018). With so much controversy and confusion, the effectiveness of MARA's recent (2018) education initiative is still to be seen.

6. It is considered one of the worst since it claimed an estimated 300,000 victims, including 54,000 babies requiring hospitalization.

The Republic of South Africa: Government support for GMOs[7]

Food self-sufficient but with widespread poverty, food insecurity, high inequity, and a public health system under severe strain: After 1994, the African National Congress (ANC) government inherited a food self-sufficient agricultural system but with low productivity growth amidst widespread poverty and food insecurity. Already, by the late 1980s, South African white agriculture produced more basic food commodities than all other countries of the Southern African Development Community (SADC)[8] combined; e.g., maize, wheat, sunflower, and sugar (World Bank, 1994). Under Apartheid, agriculture total factor productivity (TFP, % per year) grew by 1.26 between 1947 and 1991. This is low by international standards, and masks much variation among subsectors, with the labor-intensive horticultural sector growing by 2.42, and livestock and field crops by only 0.77. Since the end of Apartheid, even with increased market- and export-orientation, growth in agricultural production and exports has been sluggish. TFP growth of the entire economy under Apartheid was also low by international standards[9]. After Apartheid, there was substantial poverty reduction between 1996 and 2008; however poverty reduction has stagnated since, while income and wealth inequality remains among the highest in the world. Extensive poverty still exists, irrespective of the poverty level used—it ranges from about 16% at $1.90/day to 57% at $5.50/day (2014)[10]. Using South Africa's national poverty lines, about 25% of South Africans in 2015 could not meet their food requirements (the food poverty line); about 56% could not meet their other necessities. In the former "homelands", poverty was at 81% compared to urban areas at 41% (2015). Multi-dimensional poverty remains concentrated in these previously disadvantaged regions; e.g. in the provinces of Eastern Cape, KwaZulu-Natal, and Limpopo with their high concentrations of former "homelands". (Republic of South Africa et al, March 2018).[11]. The COVID-19 pandemic has exacerbated an already difficult situation, with South Africa's bi-modal public health infrastructure severely tested. An estimated 48% of total health expenditure has to serve some 84% of the population, while the private system serves the remaining 16% of the population on 52% of total health expenditure (World Bank Group, April 2018). Indeed, South Africa seems to be in the grip of the symbiotic relationship between poverty and tuberculosis (WHO, 2005). Furthermore, South Africa suffers from the "quadruple burden of disease": (i) infectious (communicable) diseases, in particular, HIV/AIDS and TB[12]; (ii) non communicable diseases (e.g., diabetes, hypertension, and cardiovascular); (iii) high maternal and child mortality; and (iv) trauma.

Within this challenging environment, genetic engineering is viewed as powerful tool to increase agricultural productivity, exports, and food security: In 1997, the government approved the commercial release of the GM insect-resistant maize (corn) and cotton. The first GM crops in South Africa were planted in the late 1990s, soon after GMOs started to spread commercially in the United States. By 2018, an estimated 2.7m ha had been planted with maize, cotton and soybeans (ISAAA, 2018). The GM plantings are for insect-resistant and herbicide-tolerant corn (94%), soybeans (95%) and Bt cotton. South Africa is a net exporter of corn for most years (except in years of drought): white corn to neighboring countries including Botswana, Mozambique, and Lesotho; and yellow corn to countries including Japan, Vietnam, and South Korea. The average corn yield has more than doubled—from 2.2 t/ha to 4.5 t/ha—over the past 20 years (USDA, 2019). Other than commercial planting, South Africa invests in the research and development of GMO vegetables, ornamental plants, indigenous crops, grapes, and sugar cane.

7. GNI/CAP: $ 6,040. (Value for 2019 following Atlas method)

8. SADC has 16 member countries: Angola, Botswana, Comoros, Democratic Republic of Congo, Eswatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, United Republic of Tanzania, Zambia, and Zimbabwe. It was formed on Aug. 17, 1992.

9. Thus TPF growth (% per year) in South Korea, Taiwan, and Japan from 1950 to 1973 was 2.8, 3.5, and 5.5 respectively; for the 1973-1984 period, the figures were 1.4, 1.3, and 2.0 respectively.

10. World Bank. Development Research Group.

11. The South African Multidimensional Poverty Index (SAMPI) captures severe deprivations in terms of health, education, economic activity, and living standards. The MPI score (2016) was highest in Eastern Cape at 12.7%, followed by Limpopo at 11.5%; and KwaZulu-Natal at 10%. The lowest score was at 1% in Western Cape. (RSA, March 2018)

12. TB (tuberculosis) is the leading cause of death in South Africa. It is mostly associated with the HIV/AIDS epidemic affecting more than 7.2 millions South Africans. There is also a symbiotic relationship between poverty and TB. Poverty fuels TB and vice versa.

Key features of the institutional and regulatory framework for GMOs in South Africa:

The Department of Agriculture, Forestry and Fisheries (DAFF) is responsible for administering South Africa's GMO Act of 1997, which was modified in 2005 to accommodate South Africa's ratification of the Cartagena Biodiversity Protocol (CBP), and again in 2006 to accommodate environmental and consumer concerns. The amended GMO Act went into effect in February 2010. Three bodies within the DAFF administer the GMO Act. These are:

- The Executive Council which advises the Minister of DAFF and either approves or rejects GM applications. It consists of representatives from seven departments within the government: DAFF, Water and Environmental Affairs, Health, Trade and Industry, Science and Technology, Labor, and Arts and Culture. All decisions require the full consensus of all departments. If not, the application is denied.

- The Advisory Council which consists of 10 scientists appointed by the Minister of DAFF. Its role is to provide advice to the Executive Council on all applications. The Advisory Council in turn is supported by a subcommittee of scientific experts from various disciplines. These experts perform the risk assessments of all applications as they relate to food, feed, and environmental impact. They submit their evaluations to the Executive Council.

- The Registrar, also appointed by the Minister of DAFF, is responsible for the day-to-day administration of the GMO Act. It acts on the instructions and conditions laid down by the Executive Council. Its responsibility is ensuring conformity of applications with the GMO Act. It also monitors all facilities that are used, including trial release sites. .

Two other acts address the environment and biodiversity, and consumer health. These are: the National Environment and Biodiversity Act (2004), and the Consumer Protection Act (2004). The Biodiversity Act gives the Minister of Environmental Affairs the power to deny a permit for release of a GM product if it decides it poses a threat to any indigenous species or the environment. The Consumer Act enforces health regulations, which largely follow the scientific guidelines of the Codex Alimentarius[13]. These health regulations mandate labeling of GM foods only when allergens, and human/animal proteins are present, and when the GM food differs significantly from a non-GM equivalent. There is however no mandatory GM labeling for all consumer products that contain GMOs, although the necessity of such labeling has been discussed for years. The Consumer Protection Act (2011), which would have required such mandatory labeling, is still on hold (USDA, 2019).

Public perceptions of GMOs in South Africa—priority concern for food safety and the environment

While producers value insect-resistance, herbicide-tolerance, and yield growth, consumers value food safety, biodiversity, and environmental sustainability. Although reasons given against GMOs so far are scientifically plausible, there is no evidence to date (after over 20 years of cultivation and sale) that GM foods are unsafe, and their environmental impact is harmful. Nevertheless, the debate about GMO food safety and environmental risk rages on (Muzhinji and Ntuli, 2020). As is the case in many surveys elsewhere, public perceptions of GMOs in South Africa are mixed. Public perceptions are heavily influenced by several factors including: (i) public understanding of bioengineering is mainly minimal; (ii) public experiences of recent food scandals; (iii) public trust (or lack thereof) in different sources of information, including government, industry, professionals including the scientific research community, social media and the press, NGOs and other civil society/activist groups; (iv) what people value most about their food; e.g. what priority they place on safety, nutritional quality, and health, versus taste and freshness (or shelf life), versus cost; (v) people's socio-economic values; e.g., the plight of poor farmers and the extent to which they are viewed as victims of non-competitive, predatory marketing of major input-supply corporations; and (vi) religious values; e.g. whether bioengineering is viewed as 'playing God'. A 2019 survey of Cape Town residents, representative of a multi-racial, young society in which the majority has

13. The Codex Alimentarius is a set of international food standards, guidelines, and codes established in 1963 by the joint FAO/WHO Food Standards Program to protect consumer health and promote fair practices in international food trade.

at most secondary school education, echoed many of these findings. It showed that: (a) only a minority (35%) had a good understanding of GMOs; (b) most would be either pro-GMO or neutral if they believed GMOs brought tangible benefits, while only 14% would remain anti-GMO; (c) good nutrition and health benefits (food safety) as opposed to taste, shelf-life, or environmental concerns, were the main priorities for people in food purchases; (d) strong preference for the status quo in traditional food supply as opposed to switching to an alternative like GMOs; and (e) despite this bias in favor of the status quo, there is great willingness to switch to an environmentally-friendly agricultural technology. So, this survey suggests that public perceptions are likely to improve significantly if GM technology can be shown to be also environmentally friendly (Dovey and Ntuli, 2020).

Conclusion

Our review of experiences with GMOs in selected industrialized (in Part I) and developing countries (Part II) shows that the effort to realize the promise of bioengineering for strengthening food security is still in its early stages. Biotechnology has a long way to go to convince most consumers that GM food is safe, nutritious, and environmentally friendly. Evidence so far that GM products have not inflicted any harm on consumers or the environment has not convinced skeptics and critics. The reasons for the controversies vary by country and context but there is a common thread. In most cases, GM controversies are inextricably bound up with a host of concerns relating to food and agriculture, but which are not about the science of bioengineering itself. These concerns include deep misgivings about food scandals, mistrust of authority, e.g., government and industry, sharp disparities in socio-economic the power of small farmers and powerful corporations with monopolistic power, and fear of the unknown in relation to the power of bioengineering. These controversies show that bioengineering must be accepted by most consumers before it can become a valued tool for farming as the Green Revolution technology has been. It is not enough that genetic modification impacts beneficially on traits that the producers value. Consumers cannot be coerced into acceptance. China is an interesting case in which even a powerful state apparatus seems unable to control the narrative, given increasing public distrust of its ability to prevent food scandals. South Africa is also an interesting case in which the extent of the spread of GMOs does not depend only on public support but also on consumer acceptance. On what does consumer acceptance depend? It is essential to better understand this if governments want to successfully address the challenge of balancing the promise of agricultural biotechnology as a tool for strengthening food security, with the perceived risks to consumer health and the environment.

Bibliography

- Berger, Eric. July 13, 2008. “Norman Borlaug: Genetic modification can feed the world”. Chron.com https://blog.chron.com/sciguy/2008/07/norman-borlaug-genetic-modification-can-feed-the-world/
- Borlaug, Norman E. Nobel Prize Laureate for Peace (1970) “Ending World Hunger. The Promise of Biotechnology and the Threat of Antiscience Zealotry” in Plant Physiology, Oct 2000. Vol 124: pp 487-490. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1539278/pdf/hw0487.pdf
- Chow, K Eugene. May 21, 2019. “China’s GMO Paradox: For all its power, the government can’t get people to trust genetically modified crops”. The Diplomat. (Accessed Nov 09, 2020) https://thediplomat.com/2019/05/chinas-gmo-paradox/
- Cremer, Justin. Jan 23, 2020. “China moves towards commercialization of GM corn and soy.” Cornell Alliance for Science. https://allianceforscience.cornell.edu/blog/2020/01/china-moves-toward-commercialization-of-gmo-corn-and-soy/
- Cui, Kai and Sharon P. Shoemaker. June 05, 2018. “Public perception of genetically-modified (GM) food: A Nationwide Chinese Consumer Survey”. Science of Food. 2, Article number 10 (2018).https://www.nature.com/articles/s41538-018-0018-4
- Dovey, Benjamin and Herbert Ntuli. July 2020. Consumer Preferences for Genetically Modified Organisms in Cape Town: A Choice Experiment Approach. Economic Research Southern Africa (ERSA), Working Paper # 827. http://www.econrsa.org/system/files/publications/working_papers/working_paper_827.pdf
- FAO, IFAD, Unicef, WFP, WHO. 2020. The State of Food Security and Nutrition in the World. Executive Summary: The State of Food Security and Nutrition Around the World in 2020. http://www.fao.org/3/ca9692en/online/ca9692en.html#chapter-executive_summary
- FAO and WHO. Codex Alimentarius: International Food Standards. http://www.fao.org/fao-who-codexalimentarius/about-codex/en/#c453333
- Huang, Jikun, Chunlai Chen, Scott Rozelle, and Francis Tuan. 2000. “Trade Liberalization and China’s Food Economy in the 21st Century: Implications for China’s Food Security” Chinese Academy of Social Sciences; University of California at Davis; and ERS, USDA. https://aic.ucdavis.edu/research1/rozelle.htm
- Huang, Jikun and Scott Rozelle. March 2004. “China aggressively pursuing horticultural and plant biotechnology.” California Agriculture, 58 (2): 112-113. https://www.researchgate.net/publication/261948541_China_aggressively_pursuing_horticultural_and_plant_biotechnology
- International Service for the Acquisition of Agri-Biotech Applications. (ISAAA) Table 1: Global Area of Biotech Crops in 2018: By Country (Million Hectares) https://www.isaaa.org/resources/publications/briefs/54/executivesummary/default.asp
- Gale, Fred, William Linn, Bryan Lomar, and Francis Tuan. 2003. “Is Biotechnology in China’s Future?” in China’s Food and Agriculture: Issues for the 21st Century /AIB 775. Economic Research Service of the USDA https://www.ers.usda.gov/webdocs/publications/42432/15178_aib775m_1_.pdf?v=0#:~:text=GM%20tobacco%20was%20China's%20first,in%20GM%20crops%20in%202001

- Liu, Peng and Liang Ma. July 2016. "Food scandals, media exposure, and citizens' safety concerns: A multilevel analysis across Chinese cities". Food Policy 63: 102-111. https://www.researchgate.net/publication/305810680_Food_scandals_media_exposure_and_citizens'_safety_concerns_A_multilevel_analysis_across_Chinese_cities

- Muzhinji, Norman and Victor Ntuli. 2020. Genetically Modified Organisms and Food in Southern Africa: Conundrum and Discourse. GM Crops and Food 12:1, 25-35. https://www.tandfonline.com/doi/pdf/10.1080/21645698.2020.1794489

- Rozwadowski, Kevin and Sateesh Kagale. "Global Food Security: The Role of Agricultural Biotechnology—Commentary." In Plant Physiology, Oct 2010. Vol 154: pp 1. Saskatoon, Saskatchewan: Saskatoon Research Center, Agriculture and Agrifood, Canada. https://web.archive.org/web/20150924115318/http://www.plantphysiol.org/site/misc/pp160549.pdf. Also: http://www.plantphysiol.org/sites/default/files/additional_assets/pp160549.pdf

- South Africa, Dept. of Planning, Monitoring and Evaluation; Statistics South Africa; NDP 2030; The World Bank Group. March 2018. Overcoming Poverty and Inequality in South Africa: An Assessment of Drivers, Constraints and Opportunities. https://openknowledge.worldbank.org/bitstream/handle/10986/29614/124521-REV-OUO-South-Africa-Poverty-and-Inequality-Assessment-Report-2018-FINAL-WEB.pdf?sequence=1&isAllowed=y

- USDA Foreign Agricultural Service. Feb 05, 2019. The Republic of South Africa: Agricultural Biotechnology Annual. https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Agricultural%20Biotechnology%20Annual_Pretoria_South%20Africa%20-%20Republic%20of_2-5-2019.pdf

- USDA Foreign Agricultural Service. Feb. 24, 2020. People's Republic of China: Agricultural Biotechnology Annual. Report # CH2019-0202. https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Agricultural%20Biotechnology%20Annual_Beijing_China%20-%20Peoples%20Republic%20of_10-20-2019

- World Health Organization (WHO). 2005. Addressing Poverty in TB Control: Options for National TB Programmes. https://www.who.int/tb/publications/tb_2005_352_tb_poverty.pdf

- Wikipedia. "Genetically Modified Food in Africa" (Last edited April 16, 2020) https://en.wikipedia.org/wiki/Genetically_modified_food_in_Africa#:~:text=Genetically%20modified%20(GM)%20crops%20have,grew%20GM%20cotton%20in%202012.

- Wikipedia. "Norman Borlaug". (Last edited Jan 28, 2021). https://en.wikipedia.org/wiki/Norman_Borlaug

- World Bank. 1994. South African Agriculture: Structure, Performance and Options for the Future. World Bank. Southern Africa Department. Working Paper # 12950. Retrieved from http://documents.worldbank.org/curated/en/309521468777031091/pdf/multi-page.pdf

- World Bank. 2012. The Role of Agriculture in a Modernizing Society: Food, Farms and Fields in China 2030. By Luc Christiaensen; Discussion Paper # 77367. A background paper to China 2030 https://openknowledge.worldbank.org/bitstream/handle/10986/26882/773670WP0EASER00Box377296B00PUBLIC0.pdf?sequence=1&isAllowed=y

- World Bank and the Development Research Center of the State Council, People's Republic of China. 2013. China 2030: Building a Modern, Harmonious, and Creative Society. http://documents1.worldbank.org/curated/en/781101468239669951/pdf/China-2030-building-a-modern-harmonious-and-creative-society.pdf

- World Bank. 2016. China's arable land as % of its total land area is: 12.6% https://tradingeconomics.com/china/arable-land-percent-of-land-area-wb-data.html#:~:text=Arable%20land%20(%25%20of%20land%20area)%20in%20China%20was%20reported,compiled%20from%20officially%20recognized%20sources

- World Bank Group. April 30, 2018. Republic of South Africa Systematic Country Diagnostic: An Incomplete Transition—Overcoming the legacy of exclusion in South Africa. Report # 125838-ZA. https://openknowledge.worldbank.org/bitstream/handle/10986/29793/WBG-South-Africa-Systematic-Country-Diagnostic-FINAL-for-board-SECPO-Edit-05032018.pdf?sequence=1&isAllowed=y

- World Bank. GNI/CAP. 2019. Current USD. Atlas method. https://data.worldbank.org/indicator/NY.GNP.PCAP.CD

- World Bank and Development Research Center of the State Council (DRC), People's Republic of China. 2013. China 2030:Building a Modern, Harmonious and Creative Society. https://openknowledge.worldbank.org/bitstream/handle/10986/12925/9780821395455.pdf?sequence=5&isAllowed=y

- Xiang, Wen. May 4, 2020. "New Analysis: Precautionary Principle and Regulation of GMOs in China." Univ of Copenhagen. ThinkChina. A Thinktank on China.https://www.thinkchina.ku.dk/news/new-analysis-precautionary-principle-and-regulation-of-gmos-in-china/. https://www.thinkchina.ku.dk/publications/thinkchina-analysis/TC_Analysis_Gmos_in_China.pdf

- Zhang,Tao and Shudong Zhou. 2005. "The Economic and Social Impact of GMOs in China." China Perspectives. https://journals.openedition.org/chinaperspectives/359

- Zhang Zhihao. Sept 14, 2017."Experts call for better education and awareness". China Daily.https://www.chinadaily.com.cn/china/2017-09/14/content_31977994.htm

- Zhang Ziwei. Dec 26, 2013. "Celebrity feud ramps up on GM debate". Global Times.https://www.globaltimes.cn/content/834197.shtml#.UsrVWHmaQd

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