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Embracing innovation to meet food systems challenges

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Agrifood systems are powerful levers for improving livelihoods. They must also address an array of systemic challenges, including satisfying growing global food demand, improving diets, limiting greenhouse gas emissions, adapting to a warming climate, and sustaining the environment. Technology and innovation play a central role in meeting these challenges. This brief offers two policy recommendations to support the contribution of innovation. First, G20 countries should increase political and financial support to agrifood systems research in developing countries. Second, the G20 should promote and support science-based, responsible, and risk-assessed regulatory reforms that enable the safe deployment of promising bio-innovations.

Challenge

An agrifood system "fit for purpose" for the 21st century

Agrifood systems provide livelihoods for many of the world's poor and are powerful levers for reducing poverty, hunger, and malnutrition. However, agrifood systems also face an array of pressing and systemic issues, including:

- Satisfying global food demand, which is projected to rise by at least 30% over the next 30 years, primarily in developing countries.
- Fostering shifts in food consumption toward healthier and more nutritious diets.
- Limiting greenhouse gas emissions.
- Adapting to climate change.
- Preserving the environment and biodiversity.

In a desired future, food systems will improve livelihoods, reduce poverty and malnutrition, and confront the challenges listed above. To achieve these objectives, technology and innovation must play a central role, especially in developing countries. Innovations are required throughout the agrifood system and must reflect economic, social, environmental, technological, and policy dimensions of the food system.

Unfortunately, support for research for agrifood systems in developing countries has been uneven, with many of the poorest countries experiencing recent declines in research funding (ASTI 2020). This is particularly true for sub-Saharan Africa (SSA), where investment in public sector agricultural research declined from 2014 to 2016. In many developing countries, public research is the main source of innovation in agrifood systems, but underinvestment is occurring despite repeated findings of high social and economic returns for these investments (for example, see Fuglie et al. 2020).

At the same time, important innovations from existing agrifood systems research are not adequately applied. Among these are genetically engineered (GE) crops and a set of innovations commonly grouped under the label of new breeding technologies (NBTs). GE allows for the precise incorporation of desirable traits and can incorporate exogenous genes coding for these traits (transgenes). NBTs are a set of technologies developed in the past decade that include, most notably, CRISPR-Cas—a genome editing technique that controls the "specific introduction of targeted sequence variation, which provides a game-changing resource for rapid improvement of agricultural crops" (Chen et al. 2019, 670.)

GE crops have been cultivated since 1996 with a solid health and safety track record and demonstrated environmental and economic benefits. Yet, GE crops remain controversial despite this substantial evidence. Regulatory frameworks in many developing countries reflect the ongoing polarized debate, which has resulted in exclusive rather than inclusive approaches to regulation (Smyth 2017). Existing regulatory frameworks are also frequently asynchronous and non-science based, inhibiting the introduction of GE innovations and thus hindering the ability of developing countries to foment "fit for purpose" agrifood systems.

Looking forward, the opportunities presented by NBTs risk facing the same opposition as GE crops, even though NBTs seldom include the introduction of transgenic material—the source of much of the controversy around GE crops. The current body of research indicates that NBTs have the potential to address critical biotic and abiotic constraints in agriculture and livestock production efficiently (Ahmed et al. 2019, Chen et al. 2019, Haque et al. 2018, Lassoued et al. 2019, Petracca et al. 2016, Zhang et al. 2019).

Proposal

This brief offers two concrete policy proposals along with some specific actions to be taken by the G20. First, it calls for the significant expansion of public support to agrifood systems research in developing countries. Second, it proposes that the G20 should work closely with partners in developing countries to advance a more scientifically informed policy debate to facilitate more timely, efficient, and evidence-based approaches to the regulation of innovations produced through GE technologies and NBTs. A detailed description of the proposals and specific actions follows.

Increased support for public research related to agrifood systems in developing countries

The G20 should support the recommendations of the Global Commission on Adaptation (GCA) with respect to research into agrifood systems. The Commission, led by Ban Ki-Moon, Bill Gates, and Kristalina Georgieva, called for increased resource allocations to international agrifood systems research. This call emphasizes developing countries in recognition of the scale, context, and location of the challenges confronting the agrifood system. A focus on Africa and South Asia, where most incremental food demand is expected to materialize and where most production growth should logically occur, is particularly apt.

Agrifood systems research has a long gestation period. It takes years (around a decade in Africa) from the funding of initial research on an idea to its manifestation as a benefit to people and the environment. Once in place, agricultural research yields very high returns, despite the long gestation period. For example, the estimated average rate of return to CGIAR research is approximately 40% (Rao et al. 2019). This means that one dollar invested in agrifood systems research yields around ten dollars in benefits, with the bulk of those benefits accruing to poor people. The best available estimates indicate that doubling the CGIAR budget, by itself, would go halfway to offsetting the impacts of climate change on global hunger by 2050, as well as generating a multiplicity of other human and environmental benefits (Rosegrant et al. 2017; also see Mason-D'Croz et al. 2019).

Less intuitively, the accumulated knowledge from research—knowledge stocks— depreciates once in place. New technologies and practices can make yesterday's achievements obsolete; pests and diseases adapt to exploit the weaknesses of efforts to control them; and shifting economic trends create new demands for knowledge.

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This return structure – a long gestation period, very high returns for a period, and then depreciation – to agrifood systems research has three important implications for decision-making with respect to food systems today. First, the investments pay off. International agrifood systems research is a ready and powerful lever for confronting the challenges facing these systems, including environmental challenges. Second, due to the long gestation periods, agrifood systems research budgets must increase now if the fruits of this research are to address the challenges of the 2030s and 2040s. Third, due to the eventual depreciation of knowledge stocks, continuous effort must be undertaken, or beneficial results will not be sustained.

Two examples of relevant research activities underscore the potential for innovations to help address global challenges linked to the food system and then a series of actions are recommended.

Innovations in fertilizers

Smart fertilizer technologies that provide alternatives to chemical fertilizers in terms of effectiveness, eco-friendliness, and a slow release of nutrition (notably controlled-release fertilizers) are becoming available but are not yet widely adopted. Controlled-release fertilizers comprise only 8–10% of the total fertilizers used in Europe (Lammel 2005; Shaviv 2005), 1% in the United States, and only 0.25% worldwide (Hall 2005).

Controlled-release fertilizers release nutrients gradually into the soil over time (up to 60 days; Zhang et al. 2019). They frequently reduce the quantity of fertilizer required by farmers (Trenkel 2010). They also help retain soil fertility, nourish soils for optimum crop growth, and improve soil function in many landscapes degraded by climate change (Mao et al. 2005). Consequently, researchers can transform desert sand into fertile soil with the help of controlled-release fertilizers and have successfully grown crops in the northern China desert (Zhijian and Zhao 2016). Moreover, controlled-release fertilizers are an innovative means to increase nitrogen use efficiency (NUE) and thus help lower the risk of leaching and N_2O emissions relative to standard nitrogen fertilizers (Zhao et al. 2013).

Biofertilizers are microbial or soil inoculants that can improve the fertility and productivity of plants and soil. These have the potential to be affordable and renewable, supplying a possible alternative to manufactured fertilizers. Biofertilizer approaches can offer a notable reduction in global greenhouse gas emissions, helping to limit the environmental footprint of agriculture.

Innovations in biological pest control

Biological pest controls offer another important set of innovations. There is the potential to introduce novel, environmentally beneficial biopesticides derived from, for example, spiders, marine cone snails, and sea anemones. These highly specialized organisms produce small peptides that attack insects' central nervous systems. Biopesticides may offer advantages over some synthetic pesticides, given their high levels of specificity, with formulations that can target particular pests. This contrasts with some synthetic, broad-spectrum pesticides, which may harm some beneficial species of insects, mammals, and birds. Biopesticides also tend to biodegrade more rapidly, thereby minimizing their ecological effects.

Given the novelty of many new technologies and the controversy that sometimes surrounds agricultural innovations, their release must be backed by policies and regulations that are science-based to give adequate assurance about their safety for both environmental and human health. Likewise, the ability to make these technologies accessible to large numbers of farmers is critical to maximizing their impacts on global food security.

Specifications

The following specific actions are recommended:

- Through the CGIAR and other available mechanisms, the implementation of the recommendations of the Global Commission on Adaptation with respect to funding public research for agrifood systems should be supported.
- National and regional research relevant to developing countries such as innovations in biofertilizers, biological pest control, and biotechnology, including GE and NBTs, should be expanded.
- While improved and new technologies are key components of solution sets for achieving goals such as the Sustainable Development Goals, technological innovations need to be complemented by an enabling environment created through appropriate policies, institutions, markets, and public and private investments.
- The G20 Agriculture Ministers should set up a partnership for research cooperation with all agricultural research institutions and

universities to facilitate and ensure sufficient funds are made available to support agricultural R&D.

- Partnerships should be supported to address the visible disruption of food supply chains due to the COVID-19 outbreak, which has highlighted the need for innovative technologies to produce new varieties of crops that are favored by local temperature and climatic conditions.

Timely and efficient regulatory frameworks for the safe use of GE and NBT technologies

Regulatory delays are preventing scientifically proven, safe bio-innovations from reaching farmers in a timely manner. In Africa and Asia, a host of viable technologies continue to sit on the shelf, frequently due to regulatory paralysis. Mounting evidence indicates that these delays impose sizable opportunity costs on developing countries, with negative implications for agricultural growth, poverty reduction, hunger eradication, and environmental sustainability.

Bangladesh provides a recent and thoroughly researched case. In 2013, four GE varieties of eggplant (one of the most heavily pesticide-treated crops in the country) were approved for cultivation after rigorous scientific assessments for food, feed, and environmental safety. These varieties contain genes from the naturally occurring soil bacterium Bacillus thuringiensis (Bt) that produce bioactive proteins effective against the fruit and shoot borer, eggplant's primary and most destructive insect pest. These Bt proteins form the basis of many biological pesticides preferred by organic farmers.

In 2017–2018, an evaluation of one open-pollinated GE eggplant variety, planted predominantly by smallholders, was undertaken using randomized controlled trials, which are recognized as the "gold-standard" of impact evaluation. This evaluation demonstrated large benefits in every dimension considered. These included an increase in yield by 42 percent, an improvement in farmers' incomes by USD 400 per hectare, reduction in fruit and shoot borer infestation by 95 percent, reduction in the frequency of pesticide application by 51 percent, decreases in the level of environmental toxicity of pesticides by 56 percent, and declines in the symptoms associated with pesticide exposure among farmers by 10% (Ahmed et al. 2019). Despite these benefits and an extensive regulatory evaluation of this variety in Bangladesh, GE eggplant has not been approved for cultivation in many other countries.

This experience in Bangladesh adds to the extensive evidence on the significant economic and environmental benefits from countries where GE crops have been adopted and commercialized, alongside a strong safety record. Three meta-studies have been performed over the years to assess GE crops. Klümper and Qaim (2014) analyzed economic performance observations from 147 individual studies comparing GE crops to conventional counterparts. GE crops exhibited improved yields (+22 percent), reduced pesticide quantities (-37 percent), lower costs (-39 percent), and greater profits to farmers (68 percent). Qualitatively similar positive results were estimated by Areal, Riesgo, and Rodriguez-Cerezo (2013), based on 72 publications and 97 performance indicators for yield, gross income, and production costs. Finger et al. (2011) also estimated similar results for five adopting countries (China, India, South Africa, Australia, and the United States).

Despite this evidence highlighting the benefits of GE crops, non-science-based regulations in many countries prevent the release of these crops in farmers' fields. As a result, it is not possible to conduct ex post impact evaluations of these technologies along the lines of the evaluation of the GE eggplant in Bangladesh. Nevertheless, there is a solid body of literature documenting the benefits of GE crops ex ante, particularly in countries where the technology has not yet been approved for commercialization. The International Food Policy Research Institute (IFPRI) maintains a database of the economics literature on the impacts of GE crops in developing economies (bEcon n.d.) with more than 60 references related to ex ante assessments. For sub-Saharan Africa, Zambrano et al. (2019) documented and analyzed indicators from 36 ex ante studies, with nearly all demonstrating positive projected benefits. Most recently, ex ante assessments for specific GE crops in Ethiopia (Yirga et al. 2020), Ghana (Dzanku et al. 2019), Nigeria (Phillip et al. 2019), Tanzania (Ruhinduka et al. 2020), and Uganda (Kikulwe et al. 2020) estimated substantial benefits for nationally identified priority GE crops. These assessments, like the ex post study in Bangladesh, indicate that smallholders stand to benefit from the adoption of these technologies through gains in productivity, reductions in labor use, and reductions in overall production costs. Consumers also stand to gain through lower prices. But, clearly, gains cannot be realized if regulatory frameworks effectively bar the deployment and adoption of GE crops by farmers.

Regulatory delays are a significant barrier to realizing benefits. Table 1 reports 24 GE products that are in the pipeline pending regulatory approval. The data focus on Ethiopia, Ghana, Nigeria, Tanzania, and Uganda, and cover maize, rice, cotton, cowpea, sweet potato, cassava, sorghum, and banana.

GE crop trait	Count of GE products, all countries
Insect resistance, drought tolerance	3
Insect resistance	5
Other pest resistance (e.g., virus resistance)	8
Nitrogen use efficiency, water use efficiency, salt tolerance	3
Nutritional improvement	5

Table 1: **Number of GE crops in the product pipeline in selected African countries by trait**
Source: **Zambrano et al. (2019), updated to 2020.**

With the emergence of NBTs, particularly gene-editing technologies, the opportunity costs of unnecessary regulatory delays may rise dramatically. Contrary to GE innovations that were concentrated on a few crops (mainly maize, cotton, and soybeans) and a handful of technologies (mainly insect resistance and herbicide tolerance), gene editing has expanded to numerous crops/species and traits (Chen et al. 2019). This wider range of applications, combined with lower costs of development for NBTs (as compared with GE technologies), implies large potential for positive impacts, notably for developing countries.

Driven by success stories from adopting countries (such as GE eggplant in Bangladesh), a strong safety record, and the promise of NBTs, there has been some encouraging recent progress in Africa. For example, in 2015, Ethiopia passed a revised Biosafety Proclamation that promoted a shift toward regulations informed by scientific evidence and global best practices, thus facilitating testing and cultivation of GE crops. Ethiopia currently permits planting of GE cotton and is working through the required assessments for the approval of GE maize. Another important recent example is Nigeria, which, in December 2019, approved the commercialization of insect-resistant cowpea, the first GE staple crop approved in SSA outside of South Africa. This gathering momentum should be encouraged by the G20 in a wider number of countries and extended to include NBTs.

Specific actions to advance this proposal include:

- Grounded in their relatively more advanced track record in the development of regulatory frameworks and their established links to developing countries, the G20 (countries) should use available mechanisms to support developing countries to advance their regulatory capabilities, including the strengthening of institutions and stakeholder capacity at different levels.
- Cooperation among regulatory agencies in developing countries should be supported and involve both more experienced agencies where regulations have been passed and others still going through the process. Resources should be mobilized to establish mechanisms for South-North-South cooperation to assist these regulatory agencies.
- Enhanced regulatory capabilities should be promoted and informed by empirical evidence and science-based research that better balances economic, environmental, and social risk and benefits with respect to bio-innovation technologies.
- Objective information on those benefits, the cost of regulatory delays to society, and the management of potential risks should be generated and broadly disseminated using all the available communication means to reach the relevant stakeholders.
- Regulations regarding different biotechnology innovations should acknowledge and clarify the differences between GEs and NBTs to avoid unnecessary delays in the release of innovations developed using NBTs.

References

Ahmed, Akhter U., John F. Hoddinott, Kazi Md Shaiful Islam, A. S. M. M. R. Khan, Naveen Abedin, Nusrat Z. Hossain, Julie Ghostlaw, et al. “Impacts of Bt Brinjal (eggplant) Technology in Bangladesh.” Washington, DC: U.S. Agency for International Development (USAID). https://pdf.usaid.gov/pdf_docs/PA00TZ7Z.pdf.

Areal, F. J., L. Riesgo, and E. Rodriguez-Cerezo. 2013. “Economic and Agronomic Impact of Commercialized GE Crops: A Meta-Analysis.” Journal of Agricultural Science 151, no. 1: 7–33. https://doi.org/10.1017/S0021859612000111.

ASTI. 2020. “Agricultural Science and Technology Indicators.” Accessed August 22, 2020. https://www.asti.cgiar.org/data.

bEcon n.d. “Economics Literature About the Impacts of Genetically Engineered Crops in Developing Economies.” Accessed July 10, 2020. https://ebrary.ifpri.org/digital/collection/p15738coll6/search.

Chen, Kunling, Yanpeng Wang, Rui Zhang, Huawei Zhang, and Caixia Gao. 2019. “CRISPR/Cas Genome Editing and Precision Plant Breeding in Agriculture.” Annual Review of Plant Biology 70: 667–697. https://doi.org/10.1146/annurev-arplant-050718-100049.

Dzanku, Fred M., Patricia Zambrano, Ulrike Wood-Sichra, Jose Falck-Zepeda, Judith A. Chambers, Hillary Hanson, and Paul Boadu. 2018. “Adoption of GM Crops in Ghana: Ex Ante Estimations for Insect-Resistant Cowpea and Nitrogen-Use Efficient Rice.” IFPRI Discussion Paper 1775, International Food Policy Research Institute, Washington, DC.

Finger, Robert, Nadja El Benni, Timo Kaphengst, Clive Evans, Sophie Herbert, Bernard Lehmann, Stephen Morse, and Nataliya Stupak. 2011. “A Meta-Analysis on Farm-Level Costs and Benefits of GE Crops.” Sustainability 3, no. 5: 743–762. https://doi.org/10.3390/su3050743.

Fuglie, Keith, Madhur Gautam, Aparajita Goyal, and William F. Maloney. 2020. Harvesting Prosperity: Technology and Productivity Growth in Agriculture. Washington, DC: World Bank. https://doi.org/10.1596/978-1-4648-1393-1.

Hall, A. 2005. “Benefits of Enhanced-Efficiency Fertilizer for the Environment.” Paper prepared for the IFA – International Workshop on Enhanced-Efficiency Fertilizers, Frankfurt, June 28–30.

Haque, Effi, Hiroaki Taniguchi, Md Hassan, Pankaj Bhowmik, M. Rezaul Karim, Magdalena Śmiech, Kaijun Zhao, Mahfuzur Rahman, and Tofazzal Islam. 2018. “Application of CRISPR/Cas9 Genome Editing Technology for the Improvement of Crops Cultivated in Tropical Climates: Recent Progress, Prospects, and Challenges.” Frontiers in Plant Science 9: 617. https://doi.org/10.3389/fpls.2018.00617.

Kikulwe, Enoch Mutebi, José Benjamin Falck-Zepeda, Herbert Kefa Oloka, Judith A. Chambers, John Komen, Patricia Zambrano, Ulrike Wood-Sichra, and Hillary Hanson. 2020. “Benefits from the Adoption of Genetically Engineered Innovations in the Ugandan Banana and Cassava Sectors: An Ex Ante Analysis.” IFPRI Discussion Paper 1927, International Food Policy Research Institute, Washington, DC. https://doi.org/10.2499/p15738coll2.133716.

Klümper, Wilhelm, and Matin Qaim. 2014. “A Meta-Analysis of the Impacts of Genetically Modified Crops.” PloS One 9, no. 11: e111629. https://doi.org/10.1371/journal.pone.0111629

Modified Crops." PLoS One 9, no. 11: e111629. https://doi.org/10.1371/journal.pone.0111629.

Lammel, J. 2005. "Cost of the Different Options Available to the Farmers: Current Situation and Prospects." Paper prepared for the IFA – International Workshop on Enhanced-Efficiency Fertilizers, Frankfurt, June 28–30.

Lassoued, Rim, Diego Maximiliano Macall, Hayley Hesseln, Peter WB Phillips, and Stuart J. Smyth. 2019. "Benefits of Genome-Edited Crops: Expert Opinion." Transgenic Research 28, no. 2: 247–256. https://doi.org/10.1007/s11248-019-00118-5.

Mason-D'Croz, Daniel, Timothy B. Sulser, Keith Wiebe, Mark W. Rosegrant, Sarah K. Lowder, Alejandro Nin-Pratt, Dirk Willenbockel, et al. 2019. "Agricultural Investments and Hunger in Africa Modeling Potential Contributions to SDG2–Zero Hunger." World Development 116: 38–53. https://doi.org/10.1016/j.worlddev.2018.12.006.

Petracca, G., A. Van Eenennaam, and M. A. Lema. 2016. "Gene Editing: Do Not Forget About Animal Agriculture." Journal of Advanced Research in Biotechnology 1, no. 1: 2. https://doi.org/10.15226/2475-4714/1/3/00109.

Phillip, Dayo, Alejandro Nin-Pratt, Patricia Zambrano, Ulrike Wood-Sichra, Edward Kato, John Komen, Hillary Hanson, José Benjamin Falck-Zepeda, and Judy A. Chambers. 2019. "Insect-Resistant Cowpea in Nigeria: An Ex Ante Economic Assessment of a Crop Improvement Initiative." IFPRI Discussion Paper 1896, International Food Policy Research Institute, Washington, DC. https://doi.org/10.2499/p15738coll2.133541.

Mao, Xiao-yun, Ke-jun Sun, De-han Wang, and Zong-wen Liao. 2005. "Controlled-Release Fertilizer (CRF): A Green Fertilizer for Controlling Non-Point Contamination in Agriculture." Journal of Environmental Sciences 17, no. 2: 181–184.

Rao, Xudong, Terrance M. Hurley, and Philip G. Pardey. 2019 "Are Agricultural R&D Returns Declining and Development Dependent?" World Development 122: 27–37. https://doi.org/10.2499/p15738coll2.133541.

Rosegrant, Mark W., Timothy B. Sulser, Daniel Mason-D'Croz, Nicola Cenacchi, Alejandro Nin-Pratt, Shahnila Dunston, Tingju Zhu et al. 2017. "Quantitative Foresight Modeling to Inform the CGIAR Research Portfolio." Project Report for USAID. Washington, DC: International Food Policy Research Institute.

Ruhinduka, Remidius D., Jose B. Falck-Zepeda, Ulrike Wood-Sichra, Patricia Zambrano, Haji Semboja, Judith A. Chambers, Hilary Hanson, and Gerald Lesseri. 2020. "Ex Ante Economic Assessment of Impacts of GM Maize and Cassava on Producers and Consumers in Tanzania." IFPRI Discussion Paper 1911, International Food Policy Research Institute, Washington, DC. https://doi.org/10.2499/p15738coll2.133636.

Shaviv, A. 2005. "Controlled Release Fertilizers." Paper prepared for the IFA – International Workshop on Enhanced-Efficiency Fertilizers, Frankfurt, June 28–30.

Smyth, S. 2017. "Genetically Modified Crops, Regulatory Delays, and International Trade." Food and Energy Security 6, no. 2: 78–86. https://doi.org/10.1002/fes3.100.

Trenkel, M. E. 2010. "Slow- and Controlled-Release and Stabilized Fertilizers: An Option for Enhancing Nutrient Use Efficiency in Agriculture." Paris: International Fertilizer Industry Association.

Yirga, Chilot, Alejandro Nin-Pratt, Patricia Zambrano, Ulrike Wood-Sichra, Endeshaw Habte, Edward Kato, John Komen, José Falck-Zepeda, and Judith A. Chambers. 2020. "GM Maize in Ethiopia: An Ex Ante Economic Assessment Of TELA, a Drought Tolerant and Insect Resistant Maize." IFPRI Discussion Paper 1926, International Food Policy Research Institute, Washington, DC. https://doi.org/10.2499/p15738coll2.133714.

Zambrano, Patricia, Namita Paul, Judith A. Chambers, José Falck-Zepeda, and Hillary Hanson. 2019. "bEcon 4 Africa: An Overview of the Literature on the Economic Assessment of GE Crops in the Continent, 1996–2016." IFPRI Discussion Paper 1841, International Food Policy Research Institute, Washington, DC.

Zhang, Yi, Karen Massel, Ian D. Godwin, and Caixia Gao. 2018. "Applications and Potential of Genome Editing in Crop Improvement." Genome Biology 19, no. 1: 210. https://doi.org/10.1186/s13059-018-1586-y.

Zhang, L., K. C. Loh, S. Sarvanantharajah, Y. Shen, Y. W. Tong, C. H. Wang, and Y. Dai. 2019. "Recovery of Nitrogen and Phosphorus Nutrition from Anaerobic Digestate by Natural Superabsorbent Fiber-Based Adsorbent and Reusing as an Environmentally Friendly Slow-Release Fertilizer for Horticultural Plants." Waste and Biomass Valorization, online. https://doi.org/10.1007/s12649-019-00915-3.

Zhao, Bin, Shuting Dong, Jiwang Zhang, and Peng Liu. 2013. "Effects of Controlled-Release Fertiliser on Nitrogen Use Efficiency in Summer Maize." PLoS One 8, no. 8: e70569. https://doi.org/10.1371/journal.pone.0070569.

Zhijian, Y., and Chaohua Zhao. 2016. "Desert 'Soilization': An Eco-Mechanical Solution to Desertification." Engineering 2: 270–273. https://doi.org/10.1016/J.ENG.2016.03.002.

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