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REVIEW

Agriculture Green Development in China and the UK: common objectives and converging policy pathways

Yuelai LU[1], David NORSE (✉)[2], David POWLSON[3]

1 School of International Development, University of East Anglia, Norwich, NR4 7TJ, UK
2 Institute of Sustainable Resources, University College London, London, WC1H 0NN, UK
3 Department of Sustainable Agriculture Sciences, Rothamsted Research, Harpenden, AL5 2JQ, UK

Abstract This paper has three aims. First, to examine how the negative environmental consequences of intensive agriculture have driven China and the UK to shift away from narrowly focused farm output policies and adopt more holistic green development pathways. Second, to explore the policy objectives they have in common. Third, to assess the numerous opportunities for joint research and knowledge sharing through the Sustainable Agriculture Innovation Network and other existing institutional mechanisms. The intensification of agricultural production in the UK started several decades earlier than in China as did the negative environmental consequences of the farm practices. However, their strategies and policies for sustainable intensification and green development have much in common. These are set out in two main documents: the Chinese State Council guidelines for green agriculture and the UK Department for Environment, Food and Rural Affairs 25 Year Environment Plan. There are substantial mutual advantages from greater collaboration on problem identification and monitoring; the development of appropriate technological and management responses and the formulation of sound policies. To achieve this potential, it is recommended that further thought be given to how best to bring together all of the key stakeholders along the whole food chain.

Keywords Agriculture Green Development, China, policy, UK

1 Introduction

China and the UK both have strong interests in developing agricultural systems that are productive and economically viable but have a minimum of adverse environmental impacts. In both countries, though in different ways, this has not been the case in the past but both are now developing policies aimed at achieving these goals. In China this approach is now termed “Agriculture Green Development” (AGD). Despite the very different conditions in the two countries, both now have common objectives in this area.

The common objectives stem from similar challenges that both countries must overcome if they are to achieve sustainable agricultural development in line with the United Nations Sustainable Development Goals. They both face serious pressures on their soil, water and ecosystems and consequently future agricultural development has to be shaped by resource conservation and environmental protection policies that achieve sustainable intensification. The latter is vitally important to both countries even though their farm structures are very different, and their food security objectives are far apart. For example, the average farm size in the UK is about 57 ha rising to 120 ha in the main cereal and field vegetable region. 62% of the cereal area is occupied by farms of > 100 ha. By contrast, the average farm size in China is less than 1 ha. Also the Chinese Government maintains a food self-sufficiency ratio of 95%, whereas the UK government leaves the market to set food import levels (currently about 60% of the self-sufficiency level).

The convergence in their green development policy pathways follows directly from the common natural resource use challenges they must overcome to achieve sustainable intensification. Political leaders in both countries have stressed the importance of breaking away from narrowly focused farm output policies and adopting more holistic approaches for resource use and environmental protection. In China, the State Council has complemented the relevant measures in the Thirteenth Five-Year Plan[1] by setting new guidelines for green agriculture[2], and the

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Correspondence: d.norse@ucl.ac.uk

Ministry of Agriculture and Rural Affairs of the People's Republic of China (MARA) has made proposals as to how these guidelines might be implemented[3]. Similarly, the UK Department of Environment, Food and Rural Affairs (Defra) has published a 25 Year Environment Plan[4] accompanied by a number of supporting documents for its implementation (e.g., Defra on the prevention of water pollution)[5]. The following brief description of these pathways indicates that they have many objectives in common, there are important areas of policy convergence and numerous opportunities for knowledge sharing and joint research.

2 State council and Defra proposed policy pathways for AGD

The policy framework proposed by the State Council is much more comprehensive than Defra's 25 Year Environment Plan and has two main foci. First, the promotion of innovation for AGD through the following measures:

· Optimizing the main function and spatial distribution of agriculture,

· Strengthening resource saving and protection,

· Strengthening environmental protection in agricultural production areas,

· Conserving and rehabilitating agricultural ecosystems, and

· Perfecting the mechanisms for innovation, incentive and restraint.

Second, formulation of a rural revitalization strategy aimed at building rural areas with thriving businesses, pleasant living environments, good social etiquette and civility, effective governance, and prosperity. This strategy has a comprehensive range of action points:

· Enhancing the quality of agricultural development,

· Advancing rural green development to build the harmony between humans and nature,

· Encouraging a prosperous and rich rural culture,

· Establishing a new governance framework to manage rural areas,

· Raising the level of livelihood security in rural areas,

· Winning the battle of poverty alleviation,

· Promoting institutional innovation and strengthening resource supplies in rural revitalization,

· Enhancing human capacity building to support rural revitalization, and

· Opening up the investment and financing channels for rural revitalization.

Defra's 25 Year Environment Plan does not have the wider socioeconomic objectives of the State Council's Rural Revitalization Strategy but its targets have much in common with those in China's policy framework for AGD. The Plan has nine main targets of particular relevance to green development:

· Achieving cleaner air through legally binding targets for the reduction of emissions for major pollutants,

· Ensuring clean and plentiful water supply,

· Enabling plants and wildlife to thrive,

· Reducing the risks of harm from flooding, drought and other environmental hazards,

· Using natural resources more sustainably and efficiently,

· Mitigating and adapting to climate change,

· Minimising waste through reuse, recycling and productivity improvements,

· Managing exposure to chemicals and reducing the entry of agrochemicals and veterinary medicines into the environment, and

· Enhancing biosecurity to protect wildlife and livestock from pests, diseases and invasive non-native species.

There is an important institutional difference between the MARA and Defra regarding climate change. The main responsibility for climate change in China is with the Ministry of Ecology and Environment although MARA does take the lead for green development actions such as reducing fertilizer use and increasing manure recycling. By contrast in the UK, Defra has full responsibility for the monitoring of greenhouse gas (GHG) emissions from agriculture and actions to reduce them, thereby making policy integration less problematic.

3 Critical and highly interdependent policy pathways for AGD

The following pathways illustrate the main differences, similarities and areas of convergence between China and the UK:

· Conserving land and water resources,

· Reversing soil and water degradation,

· Protecting and restoring ecosystems,

· Improving air quality, and

· Promoting low carbon agriculture.

The remainder of the paper examines some of the technical issues and policy approaches for each of these pathways.

3.1 Conserving land and water resources

China has set "red lines" to stabilize the area of arable land and improve water use efficiency (WUE) with targets for the minimum of arable land, the expansion of high efficiency irrigated land, and for improvements in WUE. In the main, the UK leaves such decisions to market forces. Both countries face major challenges in providing land for housing. Urbanization and construction of roads has removed large areas of land from arable food production as a result of China's rapid economic development. A related pressure is the conversion by farmers of land formerly used for grain crops (rice, wheat, maize) to growing fruit or vegetables because these crops are much more profitable. In the UK the main pressure on agricultural land is the need to construct additional housing.

However, with the on-going water supply and freshwater ecosystem problems arising from the over-extraction of water, which will be intensified by climate change, Defra's 25 Year Environment Plan sets new objectives. The aim is to reduce damaging abstraction of water from rivers by 8% and groundwater by 5% of current values by 2021. Thus, both countries have set challenging targets and have much to gain from the sharing of experience in raising WUE and the monitoring of water quality, supply and demand.

3.2 Reversing soil and water degradation

Poor agricultural land management is the primary cause of soil and water degradation in both countries. In China, much of the soil degradation has stemmed from erosion, and notably from cultivation of steep slopes and overgrazing. The very successful Sloping Land Conservation ("grain for green") Programme[6] has markedly reduced soil erosion such that soil losses from water erosion have been declining for over 10 years[7]. Soil erosion in the UK as in much of the European Union (EU) has also been declining[8] although there are still erosion hotspots from both water and wind erosion. However, visible soil erosion is often only a small contributor to land degradation, and the most serious impacts arise from biological, chemical and physical changes to the soil. In the UK the increase in the use of synthetic fertilizer, decreased use of manures and a decrease in crop rotations that include a pasture phase and increased use of heavy farm machinery (causing serious soil compaction) have contributed to the situation since the 1940s. In China the overuse of N fertilizers since the late 1990s has been a major factor behind this degradation. However, there is considerable debate about the implications of this degradation for the sustainability of agriculture and future food security. Specific questions concern the loss of soil organic matter and soil acidification but also the general issue of what is a healthy soil and how soil quality can be measured and monitored to assess progress of AGD. Consequently Defra's 25 Year Environment Plan commits the UK to develop a soil health index to help famers and institutions assess soil improvements and test their effectiveness at the farm and national level. Such an index is also needed in China, and Chinese scientists have made significant contributions to this task, e.g., in estimating changes in biological activity in soils, so there could be great benefits from joint action on this objective. For example, Stockdale et al.[9] describe a possible conceptual framework for assessing soil health and delivering action at a site-specific level. Stroud[10] describes the use of a simple test for assessing earthworm numbers that relies on farmers making the measurements themselves and results being presented in an easily understood color-coded format. Another approach, developed in the UK but tested internationally, comprises an approach for visually assessing soil physical structure[11] and has proved useful for detecting soil compaction.

3.3 Protecting and restoring resources and ecosystems

Both countries have set ambitious targets for this complex objective. Some of these targets are fairly straight forward given advanced planning and greater investment, for example, increased planting of woodland. Others are much more multidimensional such as improving water quality and restoring freshwater ecosystems where most of the water pollution is caused by agriculture. Both countries face this problem although it started earlier in the UK, which has been able to apply various policy approaches with mixed results. The sharing of this experience could help China develop its own policy pathway and speed up the achievement of this objective.

This potential is well illustrated by the example of nitrate pollution of surface and groundwater, the bulk of which is caused by the use of synthetic nitrogen fertilizers and the poor management of livestock manure. The early UK policy response was centered on the designation of nitrate vulnerable zones (NVZs) in the main arable areas with controls on the application of synthetic fertilizers and organic manures. Initially these zones (and the earlier nitrate sensitive areas) covered very small areas but this was found to be inadequate and the areas were expanded, now covering $>70\%$ of England and Wales. Some EU countries have declared the whole of their land area as NVZs with the accompanying restrictions on fertilizer and manure management. Importantly, these restrictions including the timing of inputs, not just quantity. However, in the UK, these measures failed to achieve the required decline in groundwater nitrate in the main arable areas (Fig. 1) and projections for key cereal producing areas suggest that it might be 10–30 years or more before concentrations fall to the WHO recommended level[12]. Surface water nitrate levels declined more quickly but the recovery of freshwater ecosystems could take another 10–20 years. Hence new policy approaches have been introduced such as catchment management plans that are encouraged by Defra but largely operated by the regional private sector water supply companies in partnership with farmers. These plans encourage improved N management practices including the use of offseason cover crops and checks on the settings of fertilizer application machinery. Factors influencing nitrate loss to water were extensively researched as part of the Defra "nitrates programme" during the 1980s–1990s and findings formed the basis for the later regulations relating to NVZs; some of the key findings regarding N management are summarized by Goulding[13]. The practices resulting from this research, including avoiding excessive N or manure applications and

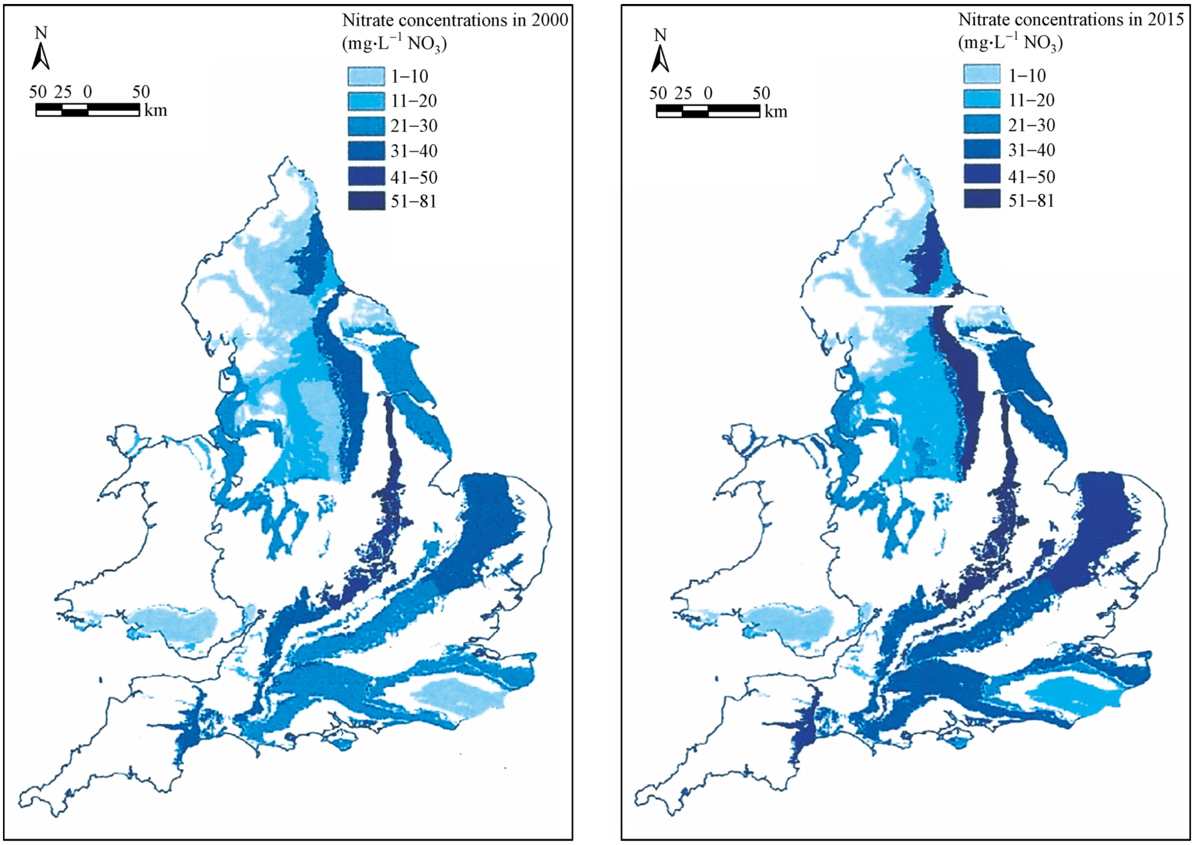

Fig. 1 Limited decline in groundwater nitrate levels in 2000 and 2015[12].

adjusting application timings to match crop uptake, can give up to 50% reduction in N leaching rates to surface water.

Since the 1990s N fertilizer application rates in China have increased to excessively high rates, often far in excess of crop requirements; this has been extensively investigated in numerous research activities together with on-farm studies aimed at providing improved strategies for N fertilizer management[14,15]. A significant issue for China is that the majority of farmers have very small land areas, as mentioned earlier, and are often part-time with much household income being earned from off-farm work, so there is resistance to adopting new management practices if these require additional labor input[16,17]. Given the great increase in animal production in China in recent years, improved management of manure is also of great importance for water quality and other environmental issues[18].

Since the problem of overuse and misuse of nitrogen fertilizers (and pesticides) was recognized, policy makers developed a zero-increase policy stating that the use of these inputs should not increase after 2020, though crop production must continue to increase. Once this policy is implemented it is expected that water quality with respect to nitrate should improve. However, in view of the legacy of many years of high nitrogen fertilizer use, there will almost certainly be a delay in improvements in groundwater quality and the restoration of freshwater and coastal ecosystems. Thus, this is another area where there may be policy convergence between the two countries, and a joint China-UK research collaboration has recently proposed a NVZ for China[19].

3.4 Improving air quality

Some of the measures required to meet this objective are an integral part of the preceding pathways, primarily aimed at improving water quality. However, the seriousness of agricultural impacts on human and ecosystem health through its contribution to poor air quality has led both countries to introduce specific plans to address the dominant agricultural emission, ammonia.

In the UK, some 88% of ammonia emissions come from agriculture and arise primarily from organic manures from the livestock sector (slurry, solid manure, sludge and compost) and secondarily from applied synthetic fertilizers in the form of urea. Past progress in limiting ammonia emissions has been slow (Fig. 2) despite regulatory and

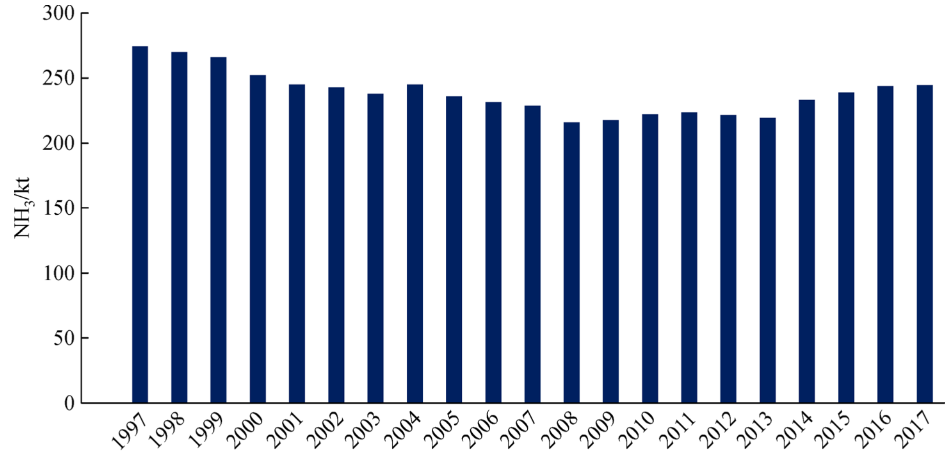

Fig. 2 Ammonia emission trends in the UK. Data from Defra[20].

other actions. Consequently, Defra has set challenging targets for ammonia reduction (8% in 2020 and 16% in 2030) to be met by a mixture of voluntary and regulatory measures backed by financial incentives.

Ammonia emissions are a more recent concern in China, in part because the production and disposal of manure did not become an increasingly serious problem until the 1990s with the rapid expansion of the concentrated animal feeding operations which generally have little or no associated land for manure disposal and utilization. Also, the concerns in the UK were largely related to impacts on ecosystems through soil and water acidification and nutrient enrichment by nitrate and phosphate, whereas in China an important policy driver has been the impact on human health. This is because ammonia interacts with other compounds in the atmosphere to form small $PM_{2.5}$ particles and particularly in urban areas leading to serious pollution that contributes to respiratory diseases[21,22]. Despite these differences the solutions are similar in both countries: better storage and application of manure and synthetic fertilizers; improvements in the formulation of livestock diets; better design of livestock housing and the management of urine and faeces. The UK started to tackle these problems in the 1970s before the main expansion of livestock production in China. Consequently, it has experience to share with China and has been doing so through the UK-China Sustainable Agriculture Innovation Network (SAIN) and Newton Fund programs, although there are a number of other opportunities for collaboration on the policy frameworks and implementation (see Section 4).

3.5 Promoting low carbon agriculture

The importance of this pathway and the common interest of both countries in achieving it was recognized over 10 years ago with the establishment of the MARA and UKFCO project "Improved Nutrient Management in Agriculture: a Key Contribution to the Low Carbon Economy"[23]. This collaboration led to improved estimates of the different sources of greenhouse gas emissions from agriculture, the overall carbon footprint of cropping and livestock sectors, and of the potential contributions and costs of a wide range of mitigation strategies. These include the works of Nayak et al.[24], Wang et al.[25], and Zhang et al.[26]. A key finding from these studies, and other research, is that increasing the N use efficiency from fertilizers and manures, and decreasing N losses, is generally the factor that can make the greatest contribution to decreasing the overall carbon footprint of agricultural systems. This work also gave greater prominence to the role of the livestock sector in controlling methane emissions. These conclusions reflect the reality that the non-CO_2 greenhouse gases, N_2O and methane, have very large greenhouse warming potentials: about 300 and 30 times that of CO_2, which previously had been the main focus of Chinese Government policy. In the case of N_2O, emissions are classified as direct and indirect. Direct emission refers to the N_2O emitted from the soil in the field where N fertilizer or manure is applied. Indirect refers to N_2O arising from transformations of other N forms leaving the field. These are mainly nitrate leached from soil to surface or subsurface water and ammonia volatilized to the atmosphere and later redeposited on land or water. Appreciating the significance of these non-CO_2 greenhouse gas emissions from agriculture is extremely important for policy makers in the wider context of low-carbon development. This is often not realized by policy makers with a narrow focus on CO_2 emissions or increasing soil C stocks to achieve C sequestration. A recent study demonstrated that, despite sequestration of C in soil arising from increased crop yields depositing additional organic C in roots and crop residues into soil, GHG emissions associated with the management practices were 12 times greater than additional soil C sequestration when expressed on a CO_2-equivalent basis[27].

4 Future opportunities for joint R&D and knowledge sharing

The future opportunities for joint R&D and knowledge sharing between the UK and China are considerable because of the technological and environmental problems they have in common. This is indicated by the strong political will at the government level, the growing demand from academic and business communities, and the strong policy and organisational foundation for implementing the joint R&D and knowledge sharing.

In 2015, MARA and Defra renewed their agreement on sustainable agriculture cooperation and identified priority areas for cooperation which include further enhancing cooperation on quality and safety of food and agricultural products, improvement of agricultural productivity, agricultural environmental protection, and the expansion of trade in agricultural products and food, to promote the agricultural development of both sides[28]. This action was reinforced at the UK-China Economic and Financial Dialogue 2019, chaired by the Chinese Vice Premier and the UK's Chancellor of the Exchequer in London, which declared that "Both sides are ready to further strengthen cooperation in rural development, AGD, and farmers' cooperative organisations. Particularly promoting policy, technology, and personnel exchange in such areas as rural development planning, infrastructure development, agritourism and eco-friendly agriculture. Both sides are ready to further strengthen science and technology cooperation in agriculture, with the support of SAIN and encourage more agricultural research and educational institutions to conduct collaborative research in advanced agricultural technologies, so as to deliver stronger science and technology support to agricultural development."[29]

There is strong demand for cooperation in AGD from both academic and farmer communities in the two countries.

At the UK-China Agriculture Green Development Forum held in May 2019 in Beijing, the attendees proposed a "Pledge to Promote UK-China Cooperation in Agriculture Green Development". The pledge calls for the following actions to boost UK-China cooperation:

· Deepening research cooperation on AGD,

· Strengthening innovation and integration of technologies for AGD,

· Promoting the demonstration and dissemination of AGD in both countries,

· Promoting cooperation on standards for AGD, and

· Building mutually beneficial cooperation mechanisms for AGD.

Such actions by the research community are being complemented by proposals at the farmer level. For example, during a recent visit (June 2019) by the Chinese Fruit Farm Association to UK fruit farms in Kent, opportunities for mutually beneficial cooperation were identified. These included demonstration trials on technologies and facilities, rootstock and scion varieties, fertilizer management, pruning, storage, as well as increased knowledge exchange on farmers training in nursery practices.

There is a strong existing foundation for the joint R&D and knowledge sharing. Although the cooperative R&D between the UK and China in agriculture has become more diversified in recent years, SAIN remains the most systematic program to address sustainability issues. The SAIN network has been developing many aspects of AGD for more than a decade, with wide engagement with governmental as well academic organization in both countries[30]. In China, new institutional mechanisms are also emerging. For example, the establishment of the National Academy of Agriculture Green Development in China Agricultural University is a new innovative action to connect academic research with farmer communities as well as international organizations to explore integrated solutions. The UK-China Knowledge Sharing and Mutual Learning Platform has been established as a central comprehensive resource center to facilitate, promote and disseminate UK cooperation on agri-food-environment issues.

5 Conclusions

China and the UK share similar objectives for the achievement of AGD and sustainable intensification. They also set these objectives in the wider context of shifting the national economy toward a development model that improves the welfare and natural ecosystems for future generations

This paper has shown that although there are substantial differences in the structure of agriculture and the level of agricultural intensification, they face similar challenges and can share and collaborate on the implementation of similar policy pathways. Some of the challenges are quite fundamental but important for determining the success or failure of AGD policies. A clear example is innovative ways of monitoring soil health which neither country currently has but which could be a valuable area for collaboration. For other challenges the countries are out of phase, for example, the environmental impacts of intensive livestock production, for which the UK started to introduce policy responses some 10–30 years earlier than China.

In view of the convergence in policy objectives and common interests in technological requirements, the case for greater joint R&D and knowledge sharing is strong. What is less clear is whether national and bilateral efforts to advance green agricultural development can achieve their wider environmental objectives by the government's proposed target dates. Production subsidies and technologies can be changed within 10–20 years or less but ecosystems can take much longer to recover.

The challenge now is how to seize the opportunities and strengthen the impacts. Should China and the UK develop an integrated cooperation program to incorporate the multiple dimensions of AGD, or implement separated programs, funded through various agencies, to work on separate aspects of AGD? A further challenge is how to integrate the technical and non-technical aspects regarding AGD. Policies, regulations, subsidies, standards, certifications, and the farm operation models have equal importance as technical interventions. AGD is related to cross government agencies as well as business influence on the whole food supply chain; the third challenge is institutionally how to integrate and address the interests and responsibilities of different stakeholders.

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Compliance with ethics guidelines Yuelai Lu, David Norse, and David Powlson declare that they have no conflicts of interest or financial conflicts to disclose.

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