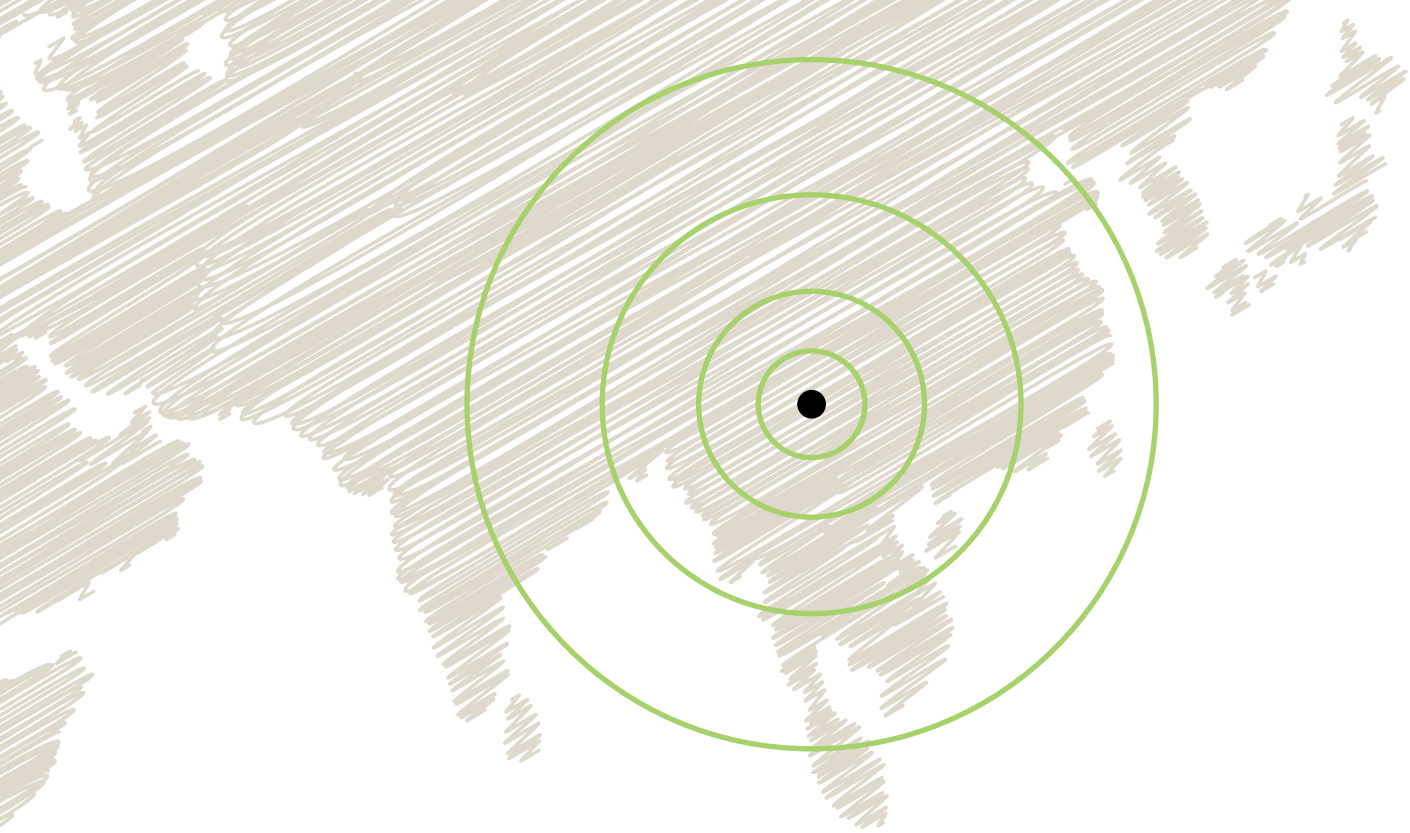

Stepping stones towards sustainable agriculture in China

An overview of challenges, policies and responses

Andreas Wilkes and Lanying Zhang

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About the authors

Andreas Wilkes, Director, Values for development Ltd
(a.wilkes@valuesfd.com)

Lanying Zhang, Executive Deputy Dean, Institute of Rural Reconstruction, Southwest University, Chongqing, China
(Lzhang2@hotmail.com)

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International Institute for Environment and Development
80-86 Gray's Inn Road, London WC1X 8NH, UK
Tel: +44 (0)20 3463 7399
Fax: +44 (0)20 3514 9055
email: info@iied.org
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In only a few decades, agriculture in China has evolved from a diverse "agriculture without waste" to one involving specialised, high-external input, resource-intensive, commercially-oriented models. This report charts this evolution, with a focus on sustainability – economic, environmental and social. It asks how China's modern development is affecting sustainability in farming and the rural environment, and looks in detail at the influence of policies and measures to transform agricultural production systems in more sustainable ways. The report concludes by considering some of the challenges and opportunities that could shape sustainable agriculture in China in the future.

Contents

Acronyms and abbreviations

CCP	Chinese Communist Party
CDFA	China Food and Drug Administration
CNY	Chinese Yuan
CSA	Community Supported Agriculture
DDT	dichlorodiphenyltrichloroethane
GDP	gross domestic product
GVAO	gross value of agricultural output
ha	hectare
HCH	hexachlorocyclohexane
kg	kilograms
kW	kilowatt
mWh	megawatt hours
N	nitrogen
NGO	non-governmental organisation
p.a.	per annum (per year)
R&D	research and development
STFR	Soil Testing and Fertiliser Programme
WUA	water user association

Summary

Farming in China has seen dramatic changes in the last few decades. The traditional, highly diverse, integrated and resource-recycling approach which historically has provided food for almost a fifth of mankind, and employment for more than 200 million farming households, is rapidly being replaced by specialised, high-external input, resource-intensive, and commercially-oriented models. This report explores what sustainable agriculture looks like in this context, and outlines the emerging policy and market-based opportunities for its expansion.

The report first sets the scene through an overview of the historical evolution of Chinese agriculture, focusing on the major changes since the economic reforms of the 1980s. It describes the key drivers of growth at national and regional level, and the diversity of cropping and livestock systems across the country. In describing recent reforms to rural land tenure systems, the emergence of large-scale agricultural enterprises, and the transformation of supply chains and marketing systems, it provides important context for understanding both the institutional environment for smallholder production today, and the focus of government policies in the sector.

All these changes, along with broader transformations such as large scale rural-urban migration, are driving the environmental, social and institutional challenges facing China's agriculture sector today. Urban expansion has been a major driver of the loss of arable land, with the quality of remaining arable land also a concern. Low fertility and other factors are limiting the potential for yield increases to meet growing food demand. Agriculture is the largest user of water, but water use efficiency is low, and climate change may increase the scarcity of water resources. Both land and water are affected by pollution. Excessive and inappropriate use of fertiliser and livestock waste are two leading causes of water pollution. Rural industry and mining have also led to heavy metal contamination of soils, affecting food safety. Large-scale rural-urban migration is having major impacts on agricultural labour supply, affecting farming families' ability to maintain sustainable practices such as manuring, crop residue recycling and the reuse of biogas residues. It is also driving efforts to aggregate fragmented land holdings into larger-scale agricultural operations.

These challenges to sustainability are well-recognised in China, and many government policies and programmes are being implemented to address them. For example, the recently issued *National Plan for Sustainable Development of Agriculture (2015–2030)* will provide the overarching framework for government policies in the years to come. Specific challenges are being tackled through a variety of policies, For example, institutional mechanisms have been set up to avoid further net loss of arable land. Soil nutrient testing and fertiliser formulation, water-saving irrigation technologies and livestock waste treatment measures are all being promoted to tackle pollution. The government is also expanding specific forms of sustainable agriculture, including ecological and circular agriculture models, and organic agriculture.

The report concludes by highlighting some key issues that will affect the future course of efforts to pursue agricultural sustainability in the coming years. While the policy environment for sustainable agriculture has become increasingly supportive, the development and implementation of government policies and measures can be strengthened by information feedbacks on the effects of policy implementation and by giving greater voice to farmers in decision-making processes and research and extension. Ongoing land tenure reforms, development of the rural social security system and reforms to urban citizenship rights will have major impacts on farmers' livelihood options, the values they attach to land, and their investment decisions. Thus, the outcomes for farmers of future changes in the agri-food sector will not only depend on specific agricultural policies. Within the agriculture sector, the diverse impacts of policies to promote large-scale production and supply-chain integration deserve greater attention. China's food system will continue to undergo rapid change. The opportunities for farmers and companies to engage in, innovate and promote sustainable agricultural practices will depend on the collaborative relationships that they are able to build with each other and with government agencies.

Background and introduction

Endowed with a diversity of ecosystems, geography has profoundly influenced the historical development of agriculture in China. This chapter identifies what 'sustainable agriculture' means in China's diverse context, before reviewing the diversity of its farming systems in both time and space. It also examines the factors behind recent major productivity increases.

1

China is a huge country encompassing a diversity of agro-ecosystems and a range of agricultural production systems managed by more than 200 million households. Together they provide agricultural products to meet the needs of almost one-fifth of mankind. Agriculture fulfils numerous key functions – the provision of food and fibre, as well as environmental services and employment for hundreds of millions of people. Traditional farming practices emphasised maintenance of soil fertility through recycling of on-farm resources and efficient resource use in a context of land scarcity. In recent decades, conventional forms of agriculture that rely largely on high external inputs have become dominant. The result has been the inefficient use of scarce resources (e.g. water, energy, nutrients) and the emission of pollutants into the environment. These challenges are now the focus of national agricultural policy.

This report charts the historical evolution of agriculture in China from an 'agriculture without waste', with minimal reliance on inputs imported from outside the farm,[1] to how it is practised today. Its focus is on sustainability – economic, environmental and social. It asks how China's modern development is affecting sustainability in farming and the rural environment, and looks in detail at the influence of policies and measures to transform agricultural production systems in more sustainable ways. The report concludes by considering some of the challenges and opportunities that could shape sustainable agriculture in China in the future.

The report is primarily based on the authors' experience combined with a review of the academic literature and policy documents, and supplemented by interviews with officials, farmers and non-governmental organisations (NGOs). It also draws on a workshop held in Beijing in March 2015 at which Chinese researchers and other stakeholders in sustainable agriculture shared and debated their experiences.[2]

1.1 What do we mean by 'sustainable agriculture'?

Treated holistically, sustainable agriculture should be economically viable, environmentally sustainable and socially just.[3] Yet even this concept of sustainability is contested.[4] Different actors emphasise different aspects of 'sustainable agriculture', with some focusing more on environmental aspects, some stressing the need to ensure food security, and others emphasising aspects of social justice or the need to provide economic opportunities for rural people. Identifying 'sustainable agriculture' is especially difficult in China's diverse context (see also Section 5.1). This report takes a practical approach, looking at practices and policies to address the various shortcomings and adverse impacts of the types of conventional agriculture that have become common throughout China. Thus, it considers sustainable agriculture as involving a continuum of practices, from measures to address particular challenges within otherwise conventional systems to more holistic approaches or models that seek to balance long-term economic, environmental and social objectives.

1.2 An agriculture of forty centuries

China's 135 million hectares (ha) of arable land account for just 14% of the country's total land area, and less than 10% of global arable land.[5] Endowed with a diverse variety of ecosystems, 66% of China's land mass is mountainous or hilly, while the remaining 34% comprises relatively low-lying plains. About half of the total land area is arid or semi-arid.

China's traditional farming practices have evolved over a history which stretches back at least 4,000 years to when agriculture originated in the Yellow River and Yangtze River basins. Prior to the 14th century, many technologies were developed, such as ploughing and irrigation. However, the emergence of traditional farming as it is now understood was largely a response to rapid population growth between the 14th and 20th centuries. By the 1950s there were 8-10 times more people (ca. 540 million people) than in the late 14th century.[6] To feed this growing population from the limited area of arable land, small-scale, labour-intensive farming has been essential, as has the use of labour and technological advances to maximise land productivity for both subsistence and trade purposes. Between the 14th and early-20th centuries, the yield per unit area of the major grain crops almost doubled, due to the introduction of new crops and varieties, farm implements, irrigation, and changes in cropping systems.[7] One of the key features of intensive farming

[1] King, F. 1911. *Farmers of Forty Centuries, or Permanent Agriculture in China, Korea and Japan*. Rodale Press, Emmaus, Pennsylvania.
[2] Cook, S. and Buckley, L. (eds) 2015. *Multiple Pathways: Case Studies of Sustainable Agriculture in China*. IIED, London.
[3] FAO. 2013. *Sustainable Food and Agriculture: Vision, Principles and Approaches*. FAO, Rome.
[4] Pretty, J. 1998. Supportive Policies and Practice for Scaling Up Sustainable Agriculture. In: Roling, N., and Wagemakers, M. (eds). *Facilitating Sustainable Agriculture: Participatory Learning and Adaptive Management in Times of Environmental Uncertainty*. Cambridge University Press, Cambridge.
[5] People.cn, 24 January 2014. Ministry of Agriculture: China's actual arable land area has not increased, but there is potential for increased grain yield. See http://politics.people.com.cn/n/2014/0124/c70731-24221990.html (in Chinese); FAOSTAT Statistics Database http://faostat3.fao.org/.
[6] Perkins, D. 1969. *Agricultural Development in China, 1368–1968*. Aldine Publishing Company, Chicago.
[7] Perkins, D. 1969. *Agricultural Development in China, 1368–1968*. Aldine Publishing Company, Chicago.

in this period was the rapid expansion of multiple cropping (Table 1). Cropping systems based on three harvests in two years or four harvests in three years became common in the Yellow River basin. In the Yangtze River basin, two harvests per year became the dominant practice. Double cropping (i.e. two harvests per year) of rice spread from southern to central China, and triple cropping of rice was practised in the Pearl River and Min River areas (see Section 2.2). Complex and diversified farming practices prompted tighter temporal and spatial arrangements in field cultivation, and promoted the development of cultivation, irrigation, fertilisation and pest control techniques. Many farming techniques were developed or improved between the 14th and 20th centuries – such as wheat transplantation, deep ploughing, use of crop residues as soil amendments, and manure application based on the growth stage of seedlings – and continue to be used even today.

Intensive farming coupled with soil fertility management became the essence of China's traditional agriculture. Intensive use of organic fertilisers was key to soil fertility management, including the use of human and animal excreta as manure, the use of legumes as green manures, recycling of crop residues, composting, and application of river mud. In his 1910 book *Farmers of Forty Centuries: Permanent Agriculture in China, Korea and Japan*, the American agronomist F.H. King introduced many ingenious examples of traditional Chinese agriculture to the world, and highlighted that the key to long-term maintenance of soil fertility was China's adoption of 'an agriculture without waste', with minimal reliance on inputs imported from outside the farm.[8] At that time, China's traditional agriculture was already among the most advanced and productive agricultural systems in the world.

1.3 Recent transformations

Prior to the Communist revolution in the late 1940s, about one-third of farming families owned no land and were instead tenants. Rent was paid in grain, and with low profitability in the farming sector, indebtedness was common. Living conditions in this war-ravaged country varied considerably across regions and socio-economic strata.[9] Transformation of the social relations and means of production in agriculture was a key component of the Chinese Communist Party's strategy for capital accumulation and industrialisation. The transformation of the countryside began in the late 1940s and early 1950s with land reform and the expropriation of land from landlords and richer farmers. During this period about 43% of the total arable land area was redistributed.[10] Farmers were encouraged to form 'mutual aid teams', which were later followed by the formation of cooperatives of about 160 households each.[11] Alongside these changes in production institutions, markets were replaced with a planned economy, and compulsory procurement quotas at administratively-set prices were introduced for grain and more than 200 other products. Private production and marketing of vegetables and other 'minor' items were severely restricted.[12] While early Communist Party and government plans had proposed a gradual transition to more 'advanced cooperative' institutions, Mao Zedong supported a more rapid transition, which in the late

Table 1. Historical evolution of cropping intensity in China

PERIOD	HAN DYNASTY (206 BCE–220 BCE)	TANG DYNASTY (618–906 CE)	SONG DYNASTY (960–1279 CE)	19th CENTURY	1920S-30S	LATE 20th CENTURY
Cropping index	0.6	0.8	1.0	1.4	1.3	1.6

Note: The cropping index is the ratio of the total sown area to the total area of arable land, a measure of the number of times crops are planted in the same field in a year. BCE: before the common era; CE: common era.
Source: Zhang, S and Xu Z (2009) Cropping system reform and its impact on the development of agricultural technology, *Crops* (1):1–3 [张世煌,徐志刚. 2009 年. 耕作制度改革及其对农业技术发展的影响. 作物杂志 (1): 1–3]

[8] King, F. 1911. *Farmers of Forty Centuries, or Permanent Agriculture in China, Korea and Japan*. Rodale Press, Emmaus, Pennsylvania.
[9] Martin, M. 1991. Rural living conditions in pre-liberation China: A survey of three recent studies. *Journal of Peasant Studies* 19(1) 122–137.
[10] Perkins, D. 1969. *Agricultural Development in China, 1368–1968*. Aldine Publishing Company, Chicago.
[11] For descriptions of the change in agricultural institutions in this period, see e.g. Selden, M. and Lippit, V. (eds). 1982. *The Transition to Socialism in China*. Croom Helm, London.
[12] Nolan, P. 1988. *The Political Economy of Collective Farms*. Polity Press, Cambridge.

1950s led to the amalgamation of cooperatives into larger 'rural people's communes', each with about 5,000 households.[13] As is now well recognised, the communes were unable to provide sufficient incentives to farmers to increase production, and the top-down planning system led to the inefficient allocation of resources. These factors played a key role in the famine of 1959–1961 in which some 30 million people died.[14] In some parts of the country, per capita consumption of many foods in the 1970s was lower than in the 1950s.[15]

The transformation of the means of production was another focus of Party and government efforts. In the 1950s, the irrigated area doubled, and more than 5 million new wells were sunk in semi-arid areas of northern China.[16] The famine of 1959–1961 in particular saw a shift in government policy towards the promotion of 'modern' agricultural technology. In the first half of the 1960s there was a rapid expansion in rural electrification, and the use of farm implements, motors, power pumps and other machinery. Crop varietal improvements and chemical fertiliser were key technologies promoted in this period. Between 1957 and 1966, China's imports of chemical fertiliser more than doubled, and domestic production of chemical fertiliser increased by 7–8 times.[17] Dwarf varieties of rice and wheat introduced in the early 1960s had replaced most other varieties by the late 1970s.[18] Despite the massive human, social and economic costs and inefficiencies of the collective system, some have argued that it enabled significant investment in rural industrialisation, which laid the basis for rapid agricultural and industrial growth after the economic reforms of the 1980s.[19]

In the late 1970s, peasants and local officials experimented with new institutional arrangements to encourage greater agricultural production. In the early 1980s, these innovations were adopted nationwide and became known as the Household Responsibility System, which is the basis for contemporary arable land tenure in China (Box 1).[20] Agricultural product markets were also gradually liberalised.

Since the early 1980s, per capita food supply in rural and urban areas has increased dramatically.[21] Most of this increase has been met by growth in domestic production of the main crop and livestock products (Figures 1a and b). In part, this has been enabled by major changes in the structure of crop production (Figure 1c). In addition, growing productivity has been a key source of increased domestic supply. Total sown area has increased by about 0.7% a year since 1990, while output of the major agricultural crops has increased by more than 4% a year over the same period.[22] Average yields for grain (Table 2) grew by 2–3% every year between 1980 and 2010, and the cropping index rose from about 1.3 in 1952 to about 1.6 in 1997.[23] Livestock product supply has also increased markedly, particularly for poultry, dairy products and pork, with output growing faster than animal populations. Overall, since the 1980s, China has maintained self-sufficiency in the supply of most major food crops and livestock products at more than 90%.[24] However, there has been a significant increase in recent years in imports of maize and soybeans for use as animal feed.

[13] On the politics of rural transformation, see Selden, M. 1982. Cooperation and conflict: Cooperative and collective formation in China's countryside. In: Selden, M. and Lippit, V. (eds). *The Transition to Socialism in China*. Croom Helm, London.
[14] Lin, J. 1990. Collectivization and China's agricultural crisis in 1959–1961. *Journal of Political Economy* 98(6) 1228–1252.
[15] Nolan, P. 1988. *The Political Economy of Collective Farms*. Polity Press, Cambridge.
[16] Perkins, D. 1969. *Agricultural Development in China, 1368–1968*. Aldine Publishing Company, Chicago.
[17] Perkins, D. 1969. *Agricultural Development in China, 1368–1968*. Aldine Publishing Company, Chicago; Chao, K. 1975. The production and application of chemical fertilisers in China. *China Quarterly* 64 712–729; Kueh, Y. 1984. Fertiliser supplies and foodgrain production in China, 1952–1982. *Food Policy* 9(3) 219–231.
[18] Jin, S. *et al.* 2002. The creation and spread of technology and total factor productivity in China's agriculture. *American Journal of Agricultural Economics* 84(4) 916–930.
[19] Bramall, C. 1993. *In Praise of Maoist Economic Planning: Living standards and economic development in Sichuan since 1931*. Clarendon Press, Oxford.
[20] Kelliher, D. 1992. *Peasant Power in China: The Era of Rural Reform, 1979–1989*. Yale University Press, New Haven; Nolan, P. 1988. *The Political Economy of Collective Farms*. Polity Press, Cambridge.
[21] For an overview of trends in urban and rural food consumption, see Cao, L. *et al.* 2013. Recent food consumption trends in China and trade implications to 2020. *Australasian Agribusiness Review* 21 15–44. For overviews of food production, see Huang, J. and Rozelle, S. 2009. *Agricultural Development and Nutrition: the Policies behind China's Success*. World Food Programme, Rome; Fan, M. *et al.* (2011) Improving crop productivity and resource use efficiency to ensure food security and environmental quality in China. *Journal of Experimental Botany* 63(1) 13.
[22] National Bureau of Statistics National Data Database (http://data.stats.gov.cn); Ministry of Agriculture Cropping Management Section, China Cropping Sector Information Website http://202.127.42.157/nongqing.aspx (in Chinese)
[23] Duan, H. 2000 Key issues of cropping system in Southern China and its situational study. *Tillage and Cultivation* 6 1–4. [段红平, 2000年.中国南方耕作制度面临的主要问题与研究现状.耕作与栽培. 2000(6) 1–4].
[24] Norse, D., Lu, Y. and Huang, J. 2014. China's food security: Is it a national, regional or global issue? In: Brown, K. (ed.). *China and the EU in Context*. Palgrave, London.

BOX 1. DEVELOPMENTS IN LAND TENURE SYSTEMS SINCE THE EARLY 1980s

When the communes were disbanded in the late 1970s and early 1980s, their collective ownership and management of agricultural land was replaced by the Household Responsibility System. Under this system the village collective still owns the farmland, but individual households receive contracts to cultivate specific plots of land and pay agricultural taxes.[25] This system enabled farmers to manage production on their own initiative, but in the early years, farmers were still subject to production contracts, and markets were still heavily regulated. The introduction of the Household Responsibility System, and subsequent changes to procurement and marketing policies, were crucial in encouraging farmers to increase their output.[26] Initially, contracts were for 15 years, but were extended to 30 years in the 1990s.[27]

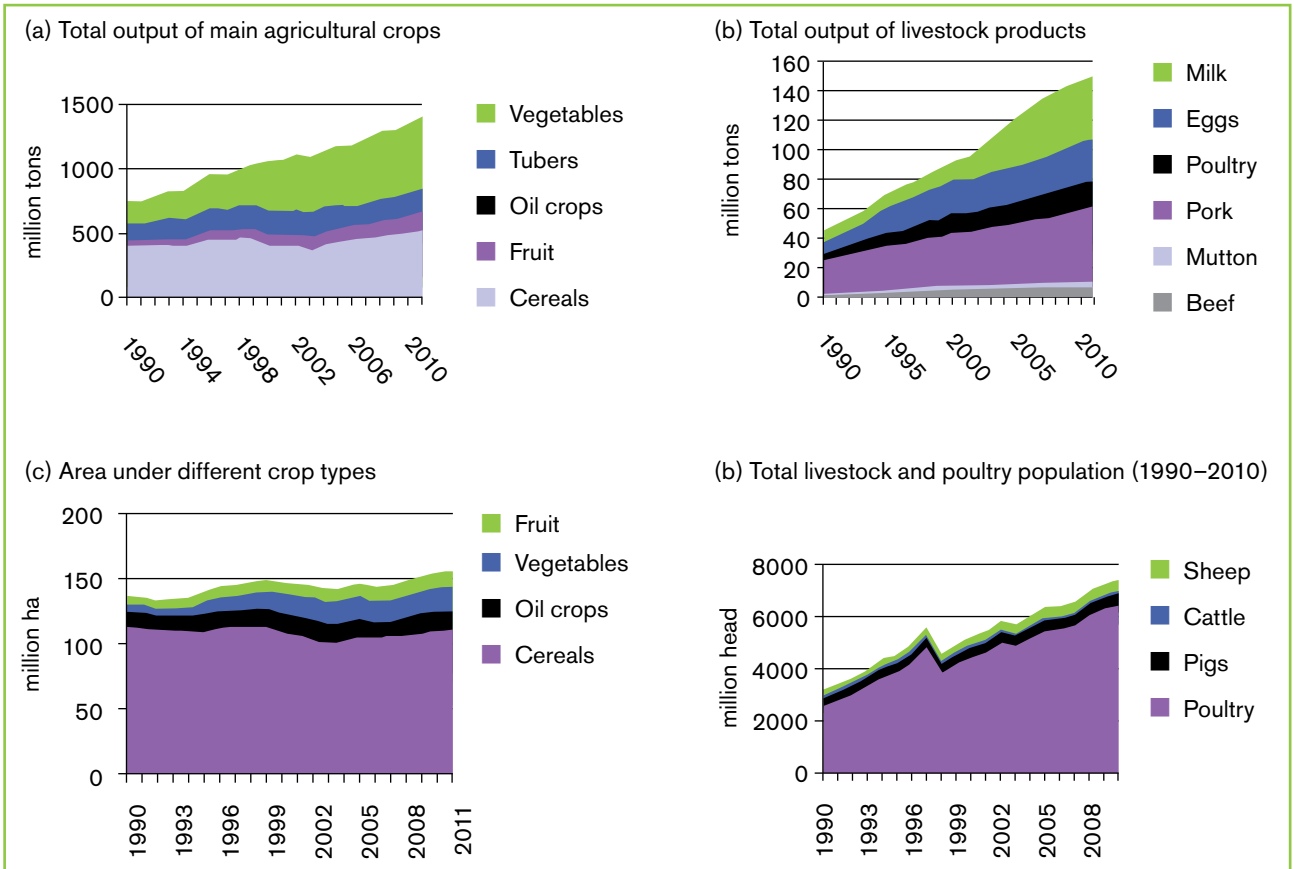
In the 1980s, when contract rights were issued to individual households, the location and size of the land to which they were given use rights depended on the quality of land plots and the number of household members and/or able bodied labourers in each household. This, and subsequent division of assets between generations, led in many areas to the excessive fragmentation of land plots, with households having contract rights over very small areas (on average 0.6 ha)[28] comprised of numerous individual small plots scattered around the village. The small size of farming operations and land fragmentation have often been seen as major constraints to economically efficient and competitive agricultural production. They are also perceived to be significant obstacles to the adoption of improved agricultural practices, such as resource cycling and reducing environmental externalities.[29]

Underlying these reforms is a land tenure system which distinguishes between ownership, contract and use rights. Land is owned by the village collective,[30] while farmers retain contract and use rights. Contract rights initially included obligations to pay agricultural taxes, but these were abolished in 2006. In the 1990s – a period coinciding with large-scale rural-urban migration – a market for agricultural land rental began to develop. This involves a household transferring use rights over the land (e.g. to a cooperative or agribusiness), while the household retains the contract rights, which cannot be freely transferred. A legal framework for land use rights transfers began to be put in place from 2001 onwards.[31] Recent years have seen explicit and strong government support for rural land-use rights markets.

What drove these important productivity increases? Major drivers included reforms in land tenure and market liberalisation in the early to mid-1980s. Since then, technological change – particularly the development of high-yielding grain varieties and associated high-input production practices – has been the major driver of agricultural productivity growth.[32] These drivers have been underpinned by agricultural research and extension, improvements in agricultural infrastructure and the increased application of external inputs. Investment in agricultural R&D tripled between 1990 and 2010, and today China has one of the largest public agricultural R&D budgets of all developing countries.[33] Innovation in crop varieties has been identified as a significant driver of productivity increase.[34] Along with modern crop varieties, the use of inorganic fertiliser has also increased significantly. The average per unit area application of fertiliser in China is now several times higher than in the USA.[35] Application rates on vegetables and fruits are particularly high,[36] and the area on which they are grown has been expanding. Although increased fertiliser application was instrumental in

[25] Ye, J. 2015. Land transfer and the pursuit of agricultural modernization in China. *Journal of Agrarian Change 15*(3) 314–337.
[26] Agricultural taxes and levies were finally abolished in 2006, which also improved production incentives.
[27] Ye, J. 2015. Land transfer and the pursuit of agricultural modernization in China. *Journal of Agrarian Change 15*(3) 314–337.
[28] Huang, J., Wang, X. and Qiu, H. 2012. Small-Scale Farmers in China in *the Face of Modernisation and Globalisation*. IIED/HIVOS, London/The Hague.
[29] Zuo, Y. et al. 2015. China's on-going debates over large-scale farming: What are the pros and cons? *China Agricultural Economic Review* 7(3) 338–343.
[30] While in law land is owned by the village collective, the state has the right to make compulsory purchase of land under certain circumstances, as described in Qian, Z. 2015. Land acquisition compensation in post-reform China: Evolution, structure and challenges in Hangzhou. *Land Use Policy* (46) 250–257.
[31] Ye, J. 2015. Land transfer and the pursuit of agricultural modernization in China. *Journal of Agrarian Change* 15(3) 314–337.
[32] Huang, J. and Rozelle, S. 1996. Technological change: rediscovering the engine of productivity growth in China's agricultural economy. *Journal of Development Economics* (49) 337–369; Fan, S. 1991. Effects of technological change and institutional reform in production growth of Chinese Agriculture. *American Journal of Agricultural Economy* 73(2) 266–275; Fan, S. and Pardey, P. 1997. Research productivity and output growth in Chinese agriculture. *Journal of Development Economics* (53) 115–137.
[33] Beintema, N. and Stads, G. 2010. Public agricultural R&D investments and capacities in developing countries. ASTI Background Note. IFPRI, Washington, DC; Pardey, P. and Pingali, P. 2010. Reassessing international agricultural research for food and agriculture. Report prepared for the Global Conference on Agricultural Research for Development (GCARD), Montpellier, France, 28–31 March 2010; Hu, R. *et al.* 2011. Privatization, public R&D policy, and private R&D investment in China's agriculture. *Journal of Agricultural and Resource Economics* 36(2) 416.
[34] Jin, S. *et al.* 2002. The creation and spread of technology and total factor productivity in China's agriculture. *American Journal of Agricultural Economics* 84(4) 916–930.
[35] FAOSTAT Statistics Database (http://faostat3.fao.org/)
[36] Zhang, W. *et al.* 2013. New technologies reduce greenhouse gas emissions from nitrogenous fertiliser in China. *Proceedings of the National Academy of Sciences* 110(21) 8375–8380.

Figure 1. Recent trends in China's crop and livestock statistics



Source: Figures produced by the authors using data from FAOSTAT (http://faostat.fao.org)

Table 2. Annual growth rates (%) of China's agricultural economy, 1970–2010

	PRE-REFORM	REFORM PERIOD				
	1970–78	1979–84	1985–95	1996–00	2001–05	2006–10
Agricultural GDP	2.7	7.1	4.0	3.4	4.3	4.5
Output:						
Grains[a]	2.8	4.7	1.7	-0.7	1.1	2.5
Cotton	-0.4	19.3	-0.3	-1.9	5.3	-0.9
Oil crops	2.1	14.9	4.4	5.6	0.8	2.7
Fruits	6.6	7.2	12.7	10.2	21.0	5.9
Meats (pork/beef/poultry)	4.4	9.1	8.8	6.5	4.9	2.3
Fishery	5.0	7.9	13.7	10.2	3.6	3.9
Planted area:						
Vegetables	2.4	5.4	6.8	9.8	3.1	2.0
Orchards (fruits)	8.1	4.5	10.4	2.0	2.4	8.1

Note [a]: Chinese statistical reports of grains include cereals, tubers, soy and other beans.
Source: Huang, J, Yang, J and Rozelle, S (2010) China's agriculture: drivers of change and implications for China and the rest of world. *Agricultural Economics* 41(s1) 47–55.

increasing yields until the 1990s, its efficiency of use has greatly decreased, as fertiliser application rates often exceed plant nutrient requirements. It is estimated that 30–50% of nitrogen fertiliser is now surplus to plant growth requirements,[37] and fertiliser pollution of soil and water is a widely recognised problem. The use of other agricultural inputs has also increased dramatically (Table 3). The expansion of irrigation infrastructure has made significant contributions to agricultural growth. The proportion of arable land under irrigation increased from 46% in 1980 to about 56% in 2011.[38] Today irrigated land accounts for about 70% of the area sown to grain and 80% of grain production.[39]

In short, across large parts of the country, and in all areas with significant agricultural output, high external-input agriculture has become the prevalent, conventional form of agriculture. The significant environmental impacts of this are now widely recognised and are discussed in Chapter 3.

Table 3. The growth in agricultural inputs in China, 1952–2010

TYPES OF AGRICULTURAL INPUTS	1952	1962	1970	1980	1990	2000	2010
Irrigated area (million ha)	199.59	305.45	No data	448.88	474.03	538.2	603.48
Agricultural machinery in use (million kW power)	0.184	7.57	21.65	147.46	287.08	525.74	927.80
Fertiliser produced (million tons)	0.078	0.63	No data	8.84	25.90	53.82	55.62
Rural electricity use (million mWh)	0.05	1.61	9.57	32.08	84.45	242.13	663.23
Pesticides produced (million tons)	No data	No data	No data	No data	0.77[a]	1.28	1.76
Plastic sheeting produced (million tons)	No data	No data	No data	No data	0.64[a]	1.34	2.17
Diesel used for agricultural production (million tons)	No data	No data	No data	No data	No data	14.05	20.23

Notes: [a] figure for 1991.
Sources: http://data.stats.gov.cn and National Statistical Bureau Rural Social and Economic Section (ed.). 2006. China Agricultural Statistical Data Compilation, 1949–2004. China Statistics Press, Beijing. [国家统计局农村社会经济调查司编. 2006年.中国农业统计资料汇编, 1949–2004.中国统计出版社, 北京.]

[37] Ju, X. *et al.* 2009. Reducing environmental risk by improving N management in intensive Chinese agricultural systems. *Proceedings of the National Academy of Sciences* 106(9) 3041–3046.
[38] World Bank Open Data (http://data.worldbank.org).
[39] Wang, J. *et al.* 2012. China's water-energy nexus: greenhouse gas emissions from groundwater use for agriculture. *Environmental Research Letters* 7(1) 014035.

Diversity and change in China's agriculture today

The reforms in land tenure and market liberalisation in the 1980s have seen China's agricultural output grow steadily, although with significant variation between regions. This chapter reviews the trends in Chinese agriculture today. The size of the country and its diverse agro-climatic conditions make for a rich diversity of cropping systems. Modern supply chains are emerging, and land tenure, the nature of farming enterprises and marketing systems are all transforming in response to the changing context.

2

China's agriculture continues to change. Increasing specialisation in different regions is reflected in varying growth rates of output of different types of agricultural crops and in changes in cropping systems. New forms of agricultural operations are emerging, including agribusinesses and cooperatives, and marketing channels are changing. This chapter provides an overview of the diversity across the country and recent trends in how agricultural production and marketing are done.

2.1 Agricultural patterns in China's regions

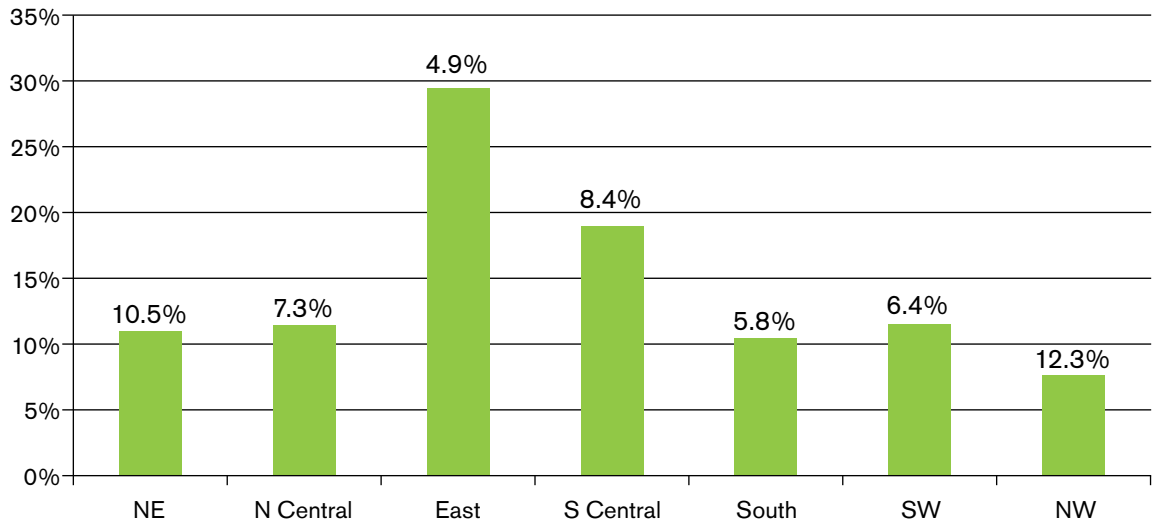
China's official agricultural zoning method[40] identifies a number of agricultural zones based on their natural conditions, crop suitability and levels of agricultural productivity. However, data on agricultural inputs, crop production and the agricultural economy are reported according to administrative regions, which differ from the agricultural zones. This section uses data from the main administrative regions to illustrate the diversity of agricultural production across China. The regions are (Figure 2): the northeast (i.e. Heilongjiang, Jilin and Liaoning provinces), the north central region (i.e. Hebei, Shanxi, Inner Mongolia and the cities of Beijing and Tianjin), the eastern region (i.e. Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi and Shandong), the central south (i.e. Henan, Hubei and Hunan), the south (i.e. Guangdong, Guangxi and Hainan), the southwest (i.e. Chongqing, Sichuan, Guizhou, Yunnan and Tibet), and the northwest (i.e. Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang).

Figure 3 shows the contribution of each region to the total gross value of agricultural output (GVAO) in 2010. Nearly two-thirds of GVAO is produced in China's eastern, south central and southern regions, with the largest contribution from the eastern region. The eastern region includes Shandong province (i.e. Huang-Huai-Hai agricultural zone), which is by far the biggest producer of agricultural output value of all the provinces. It also includes the lower reaches of the Yangtze River (i.e. Jiangsu, Zhejiang, Anhui provinces), which is a major zone for double cropping (e.g. rice-wheat rotations) due to its beneficial climatic conditions. Together, the eastern, south central and southern regions produce about half of China's cereal crops,[41] as well as 60% of its vegetables. Inorganic fertiliser use is particularly high in these regions, with severe impacts on the environment.[42]

Figure 2. China's main agricultural regions defined according to administrative boundaries

[40] National Agricultural Zoning Committee (1981) *Comprehensive Agricultural Zonation in China*. China Agricultural Press, Beijing [全国农业区划委员会, 1981年.《中国综合农业区划》.中国农业出版社，北京].
[41] These are defined in Chinese statistical reports as grains, tubers and legumes.
[42] Ju, X. *et al.* 2009. Reducing environmental risk by improving N management in intensive Chinese agricultural systems. *Proceedings of the National Academy of Sciences* 106(9) 3041–3046.

Figure 3. Regional contribution to gross value of agricultural output, 2000–2010



Annual average (bars) and real growth rates of GVAO between 2000 and 2010 (figure above bars)*
*Nominal GVAO deflated by the agricultural product price index.
Source: Compiled by the authors from data obtained from data.stats.gov.cn

Annual average growth rates in GVAO between 2000 and 2010 were highest in the northwest and northeast regions. The northeast is characterised by intensive rainfed agriculture, much of which is mechanised. Large parts of the region have rich peatland soils that are high in organic matter. The region has some of the highest unit area yields in the country, and produces about one-third of the national maize output. Agribusiness investment in grain and vegetable production and processing has been growing rapidly in recent years. However, expansion of arable land into peatlands and inappropriate cultivation methods have led to considerable soil erosion in the region.[43]

By contrast, the northwest is mostly arid or semi-arid, with large areas of desert. In some parts of the northwest (e.g. the Yinchuan Plains in Ningxia Autonomous Region,[44] oases in Xinjiang Autonomous Region) agriculture is dependent on irrigation. Elsewhere (e.g. the Loess Plateau zone), rainfed agriculture is still the main form of production. In these regions, single cropping is prevalent due to the seasonal scarcity of water. In the Loess Plateau with its sandy soils, soil erosion has been a widespread issue for decades.[45] Although the northwest contributes only a small proportion of national GVAO, all provinces in that region experienced high growth rates between 2000 and 2010, mainly driven by growth in vegetables, fruit and other cash crops. For example, Shaanxi produces about 10% of the world's apple output. Grapes in Ningxia and wolfberry in Ningxia and Qinghai are also rapidly growing cash-crop industries. In Xinjiang, cotton production accounted for a considerable share of growth.

Agriculture in north central China and parts of central south China (e.g. Henan) is largely practised on the North China Plain. Multiple cropping involving crop rotations is common, with crops and rotations varying according to factors such as the availability of irrigation and labour. A large variety of crops may be involved in rotational cropping, such as wheat, maize, millet, sorghum, barley, and cash crops such as cotton, soy bean, peanut, sesame or tobacco. Winter wheat is usually followed by beans or millet, maize or yam; while spring crops are mainly millet, maize or sorghum. In recent years, the area under one crop a year or two crops a year has increased. This is partly because of the increase in the area of cash crops (e.g. cotton). The economic return from cotton is much higher than for many grain crops, but cotton has a long growth period, so it cannot be followed by winter wheat. On the other hand, increased access to irrigation has enabled many areas to grow two crops a year. Over-extraction

[43] *China Meteorological Bulletin* 廉毅，高枞亭,任红玲．2001年．20世纪90年代中国东北地区荒漠化的发展与区域气候变化.气象学报 59(6) 730-736].
[44] Autonomous Regions are province-level administrative units with significant ethnic minority populations.
[45] Zhao, G. *et al.* 2013. Soil erosion, conservation and eco-environment changes in the Loess Plateau of China. *Land Degradation & Development* 24(5) 499–510.

of underground water resources has become a major issue in northern China.[46] High levels of nitrogen fertiliser application are also common in this region.[47]

A high proportion of the land area in southwest China is mountainous. In mountain areas, rainfed agriculture involving mixed crop-livestock systems is common, but crop production in mountain areas is affected by environmental conditions (e.g. low temperatures at higher elevations) and the frequent occurrence of natural disasters (e.g. drought, flooding).[48] However, these mountain areas are also rich in biodiversity, and some households and enterprises have been developing production of medicinal plants and other 'green' products in recent years.

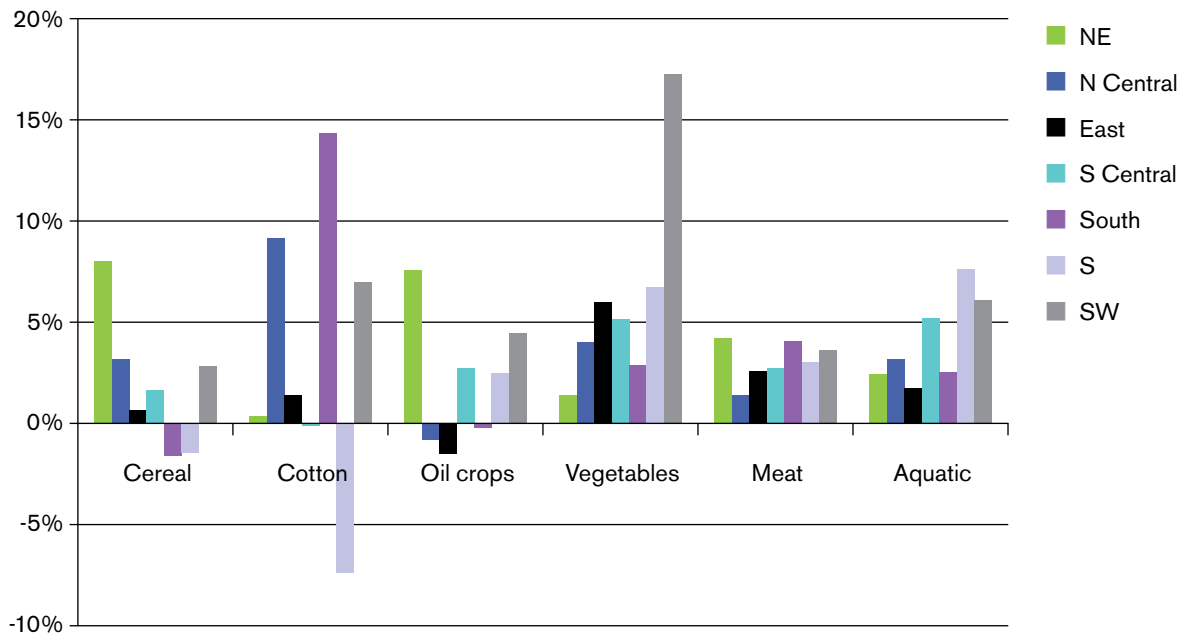
The rate of growth in the output of different agricultural products has varied considerably between regions and provinces in recent years. In some provinces (e.g. Zhejiang, Fujian), the total output of cereals and grain crops has decreased, while in others output has grown rapidly. In part this reflects a process of increasing regional specialisation. For example, in 2007, 13 of the country's 31 province-level units produced about 75% of the total national grain output, and 9 of these 13 provinces supplied 96% of the grain surplus (excess to local consumption demand).[49] In part, this also reflects the effects of rural-urban migration and urbanisation on agriculture in China's more developed regions, challenges that are discussed in more depth in Chapter 3. Figure 4 shows the regional variations in annual average growth rates of some of the main agricultural products between 2000 and 2010.

While cereal crop output has decreased in south and southwest China, it has grown by between 1 and 3% a year in the other regions, except for northeast China where it has grown by more than 7% a year. Cotton and oil crop output have also seen decreases in some regions and increases in others, mainly reflecting trends in specialisation. In 2010, about 45% of all cotton was produced in the northwest (mainly Xinjiang), while 60% of oil crops were produced in east and south central China. By contrast, vegetable, meat and aquatic product output has increased across all regions. This mainly reflects strong domestic demand for these products from rural and urban consumers alike. Figure 5 illustrates regional differences in growth rates for the three major grain crops. Rice production has declined in the southern, southwest and northwest regions, and wheat production has declined in south and southwest China. Much of this decrease is due to substitution by maize or vegetables, which have seen rapid growth. The growth of maize production is mainly driven by the increase in demand for livestock feed, with livestock product output growing in all regions (Figure 6).[50]

There have also been significant changes in livestock production. While milk production has continued in its traditional heartland (north central China), it has grown rapidly in other regions (Figure 6). Pork and poultry production have gradually moved towards the south and southeast. Livestock production has become increasingly specialised, and large numbers of farmers have exited from the livestock industry over the years, due to a combination of economic and policy pressures.[51] Pig rearing is a risky economic enterprise, with large swings in pork prices often making it unprofitable.[52] Farmers who have ceased raising pigs have tended to be those more heavily engaged in off-farm employment.[53] The number of dairy farmers exiting the industry after the 2008 melamine scandal also rose as policies enforcing biosafety inspections made market participation increasingly difficult.[54] Government policies have also promoted pig rearing in concentrated areas and provided financial support to the development of larger pig farms.[55] Although smallholders still account for the vast majority of farmers raising pigs and chickens, larger specialised operations account for the majority of pork and poultry product output.[56] Livestock production has become increasingly concentrated in peri-urban areas, and livestock waste management has become increasingly de-linked from crop cultivation.

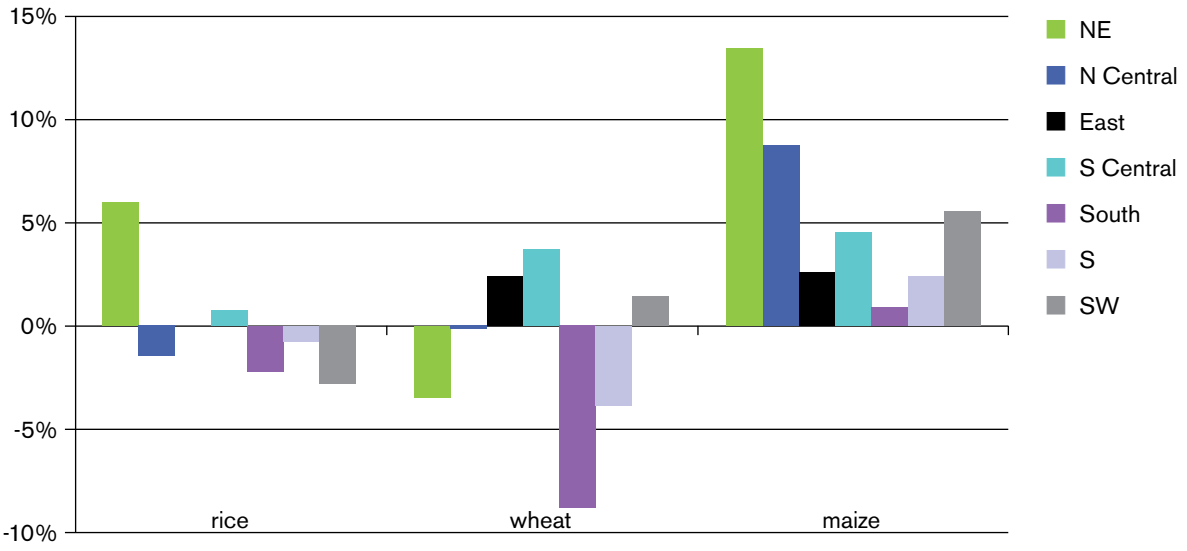
[46] Wang, J., Huang, J. and Rozelle, S. 2005. Evolution of tubewell ownership and production in the North China Plain. *Australian Journal of Agricultural and Resource Economics* 49(2) 177–195.
[47] Ju, X. *et al.* 2009. Reducing environmental risk by improving N management in intensive Chinese agricultural systems. *Proceedings of the National Academy of Sciences* 106(9) 3041–3046.
[48] Su, Y. *et al.* 2012. Coping with climate-induced water stresses through time and space in the mountains of Southwest China. *Regional Environmental Change* 12(4) 855–866.
[49] National Development and Reform Commission. 2009. *National Plan to Add 50 Billion Kilogrammes of Grain Production Capacity*. National Development and Reform Commission, Beijing [国家发展与改革委员会. 2009年. 全国新增1000亿斤粮食生产能力规划].
[50] Gale, F., Hansen, J. and Jewison, M. 2015. *China's Growing Demand for Agricultural Imports*. USDA Economic Information Bulletin 136. USDA Economic Research Service, Washington DC.
[51] Rae, A. and Zhang, X. 2009. China's booming livestock industry: Household income, specialization, and exit. *Agricultural Economics* 40(6) 603–616; Jia, X. *et al.* 2012. China's milk scandal, government policy and production decisions of dairy farmers: The case of Greater Beijing. *Food Policy* 37(4) 390–400.
[52] Gale, F., Marti, D. and Hu, D. 2012. *China's Volatile Pork Industry*. Report LDP-M-211-01. USDA Economic Research Service. US Department of Agriculture, Washington DC.
[53] Jia, X. et al. 2014. Pig Production, Smallholders, and the Transformation of Value Chains in China. IIED Issue Paper. IIED, London.
[54] Mo, D. *et al.* 2012. Checking into China's cow hotels: Have policies following the milk scandal changed the structure of the dairy sector? *Journal of Dairy Science* 95(5) 2282–2298.
[55] Garnett, T. and Wilkes, A. 2014. *Appetite for Change: Social, economic and environmental transformations in China's food system*. Food Climate Research Network, Oxford.
[56] Jia, X. et al. 2014. op. cit.

Figure 4. Regional annual average growth rates of main agricultural products, 2000–2010



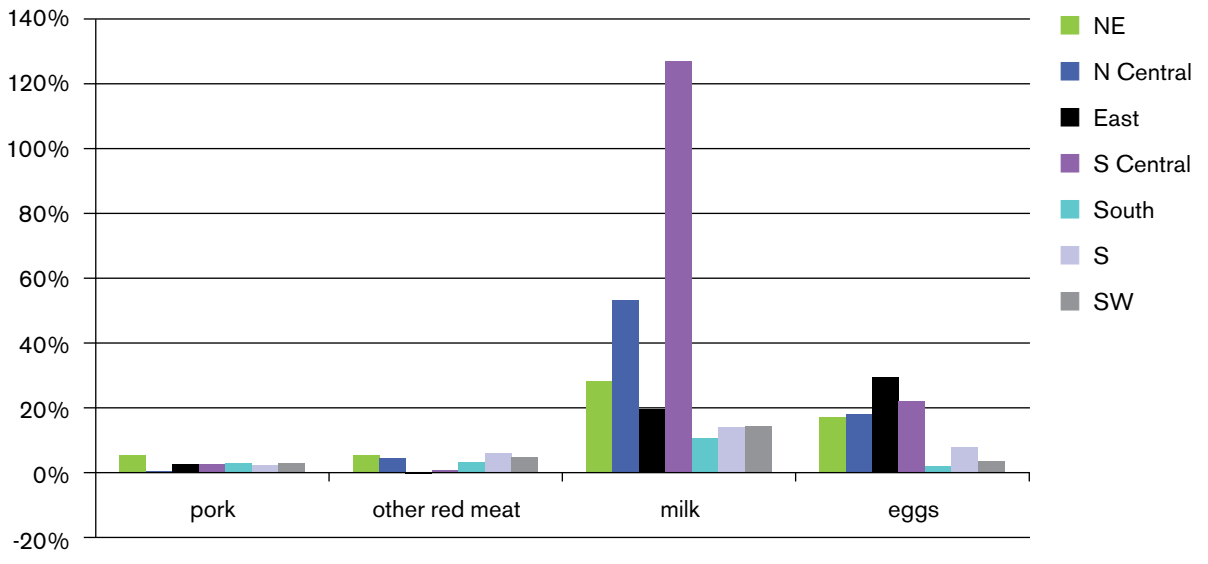
Growth rate of output by weight (%)
Source: Compiled by the authors from data obtained from data.stats.gov.cn

Figure 5. Regional annual average growth rates of main crop products, 2000–2010



Growth rate of output by weight (%)
Source: Compiled by the authors from data obtained from data.stats.gov.cn

Figure 6. Regional annual average growth rates of main animal products, 2000–2010



Source: Compiled by the authors from data obtained from data.stats.gov.cn

2.2 Diversified farming systems

Farming systems in China are characterised by particular planting patterns and crop rotations. Planting patterns can be roughly divided into three types: single cropping, double cropping and triple cropping.[57] The single cropping zone mainly covers the northeast and northwest regions, as well as the hilly dryland areas of north and southwest China, where the growing season is relatively short. The double cropping zone refers to certain regions in north and southwest China, as well as the Yangtze and Huai River basins. The triple cropping zone covers the southwest basin, the mid and lower Yangtze River basin, as well as southeast and southern China. Climate change has seen a gradual shift northwards of climatic belts and crop suitability zones, particularly in the northern part of China.[58] Crop rotations are practised by farmers not only for the variety and quantity of products obtained, but also for their effectiveness in balancing soil nutrients and improving soil fertility. Other benefits include reducing weeds, pests and diseases, thus reducing the need for chemical fertilisers, pesticides and herbicides.

Triple cropping in southern China mainly involves a green manure–early rice–late rice rotation. The green manure (often alfalfa) is helpful in improving the physical, chemical and biological traits of soil and enhancing its fertility. The rapeseed–early rice–late rice rotation is another traditional approach which yields both food crops and edible oil. Returning rapeseed leaves, flowers and stalks to the soil enhances soil nutrients and soil structure. Vegetables have also become common as the third crop in these rotation systems.

Double cropping in southern China involves spring and summer crops with fallowing in autumn and winter. In the southern Yangtze River basin, double cropping of wheat and rice was the major practice in the past. Now the cultivation of two crops of (early and late) rice has become the norm, and in some areas triple cropping is practised by the addition of barley, wheat, rapeseed or green manure cultivation in the winter season. The southwest region used to rely solely on single cropping, but now includes winter crops like wheat, rapeseed, and broad beans. The southwest has also developed other double cropping practices such as rice-wheat, rice-rapeseed, vegetable-rice, and rotational cropping of cereals with beans or sweet potato. In recent years, a triple cropping system has been adopted for cultivating crops like wheat, corn, and sweet potato in dryland

[57] Zuo, L. *et al.* .2014. Developing grain production policy in terms of multiple cropping systems in China. *Land Use Policy* (40) 140–146; Li W. (ed.). 2003. *Ecological Agriculture: Theory and practices of sustainable agriculture in China.* Chemical Industry Publishing House [李文华（主编）. 2003年. 生态农业:中国可持续农业的理论与实践. 化学工业出版社]; Qiu, J. *et al.* 2003. Mapping single-, double-, and triple-crop agriculture in China at 0.5°× 0.5° by combining county-scale census data with a remote sensing-derived land cover map. *Geocarto International* 18(2) 3–13.
[58] Ye, D., Jiang, Y. and Dong, W. 2003. The northward shift of climatic belts in China during the last 50 years and the corresponding seasonal responses. *Advances in Atmospheric Sciences* 20(6) 959–967.

areas. In north China, triple cropping of wheat, corn, and sweet potato is practised in some areas. In Inner Mongolia, Shaanxi, and Gansu provinces, where double cropping is not practical due to limited water availability and low winter temperatures, inter-cropping of wheat and corn is practised. Cropping practices have changed in many areas due to the incorporation of cash crops. For example, in the Yangtze River basin and Huang-Huai-Hai regions, the inter-cropping of wheat with cotton has been introduced.

2.3 A variety of farm enterprises

Chinese agriculture is still dominated by small-scale household farming: more than 250 million households, with an average land size of 0.6 ha, contribute the majority of crop output.[59] However, several forms of larger-scale farming operation have also emerged, including specialised households and large-scale family farms, farmer cooperatives[60] and agribusinesses (all described in the sections below). More than 200 million land contracts have been issued, mostly to small-scale farmers, but more than 30% of the total contracted arable land area (i.e. 26.7 million ha) has been rented out to specialised farmers or other larger-scale operations due to out-migration or other factors. By the end of 2014, China had 3.41 million specialised households each cultivating over 3.3 ha of land; 870,000 large-scale farms (each cultivating an average of 13.3 ha); 1.29 million registered farmer's cooperatives; and more than 350,000 agricultural enterprises, including 125,000 large-scale agriculture firms which engage more than 125 million households in their supply chains.[61] This increase in land rentals and the scale of farm operations has been facilitated by large-scale migration to urban areas and the increase in off-farm employment. By the end of 2014, there were 274 million migrant workers. Of these, 106 million were employed off-farm in their local area and 168 million had migrated to towns and cities further away, leaving land available for cultivation by other households or enterprises.[62]

Small rural households

China's contract households are mostly small farming operations, with a small average farm size (ca. 0.6 ha) and low levels of investment in fixed assets.[63] Large numbers of farmers have migrated seasonally, temporarily or permanently to urban areas where wages are higher, and in some areas there is a significant shortage of labour for household farming operations.[64] Farming households tend to intensify labour inputs to maintain operations and improve incomes, using mainly family labour.[65] Some households have increased the cultivated area by renting land from other households, particularly those with insufficient labour resources to maintain their own farming operations. The vast majority of small farms still apply organic manure, though in smaller quantities than in the past,[66] and other production inputs (e.g. seeds, fertiliser, pesticides) are purchased from input suppliers. Agricultural products partly meet family consumption needs, but the food produced by the average household only contributes to about 15% of their calorific intake.[67] Most agricultural produce is sold, and foodstuffs purchased in nearby markets. While in the 1980s about two-thirds of household income derived from agriculture, with the growth of labour migration and other incomes (e.g. self-employment, rental income, welfare payments or other subsidies), agriculture now provides less than one-third of household income.[68] The majority of Chinese farming households are 'agriculture + wage labour' enterprises. This has significant impacts on their farming operations, including decisions about fertiliser and manure use, with a resulting impact on the sustainability of natural resources. With most young men and women working off-farm, farm work and domestic tasks are increasingly undertaken by elderly parents and children.[69] These trends have prompted some to ask who will do farming in the future?[70]

[59] Huang, J., Wang, X. and Qiu, H. 2012. *Small-scale Farmers in China in the Face of Modernisation and Globalisation*. IIED/HIVOS, London/The Hague.
[60] Formally named 'farmer specialized cooperative economic organizations'.
[61] Mai, T. 4 August 2015. Agricultural commercialization lets of more energy through innovation. *Farmer's Daily*, 1. [买天.2015年8月4日.农业产业化在创新中释放更大能量。农民日报,01版 http://szb.farmer.com.cn/nmrb/html/2015-08/04/nw.D110000nmrb_20150804_9-01.htm?div=-1]; State Administration for Industry and Commerce. 2015. National market actor development in the first half of 2015. SAIC, Beijing. [中国工商总局, 2015年.2015年上半年全国市场主体发展, www.saic.gov.cn/zwgk/tjzl/zhtj/xxzx/201507/t20150715_158914.html]. See also Ji, X. et al. 2016. Are China's farms growing? *China & World Economy* 24(1) 41–62.
[62] National Bureau of Statistics. 2015. Bulletin on GNP and social development in 2014. National Bureau of Statistics, Beijing [国家统计局, 2015年.2014年国民经济和社会发展统计公报].
[63] Huang, J., Wang, X. and Qiu, H. 2012. *Small-scale Farmers in China in the Face of Modernisation and Globalisation*. IIED/HIVOS, London/The Hague.
[64] Li, L. and Tang, Z. 2013, Rural-urban migration and its effects on social and economic development in China: A review. *Acta Prataculturae Sinica* 22(2) 300–306 [李丽华、唐增. 2013年. 我国农业劳动力转移及其影响的研究综述. 草业学报 22(2) 300–306].
[65] Van der Ploeg, J. *et al.* 2014. Peasant-managed agricultural growth in China: Mechanisms of labour-driven intensification. *International Journal of the Sociology of Agriculture and Food* 21(1) 155–171; Cook, S. 1999. Surplus labour and productivity in Chinese agriculture: evidence from household survey data. *Journal of Development Studies* 35(3) 16–44.
[66] Gao, L., Huang, J. and Rozelle, S. 2012. Rental markets for cultivated land and agricultural investments in China. *Agricultural Economics* 43(4) 391–403.
[67] Sun, Y. and Lin, W. 2014. Impact of income and market condition on the nutrition vulnerability of rural household in China: Evidence from CHNS. *Studies in Labor Economics* 2(3) 142–156 [孙颖, 林万龙. 2014年.收入水平、市场条件对中国农村家庭营养脆弱性的影响.劳动经济研究 2(3) 142–156].
[68] Huang, J., Wang, X. and Qiu, H. 2012. *Small-Scale Farmers in China in the Face of Modernisation and Globalisation*. IIED/HIVOS, London/The Hague.
[69] Chang, H., Dong, X. and MacPhail, F. 2011. Labor migration and time use patterns of the left-behind children and elderly in rural China. *World Development* 39(12) 2199–2210.
[70] Zhu, Q. and Yang, H. 2011. Who is going to till the land? Survey and thoughts on agriculture labor. *Journal of China Agriculture University (Social Science Edition)* 28(1) 162–169 [朱启臻, 杨汇泉. 2011年. 谁来种地—对农业劳动力的调查与思考. 中国农业大学学报（社会科学版）28(1) 162–169].

Larger-scale family farms and specialised households

With land fragmentation and the increasing off-farm employment of rural labour, specialised households and large-scale family farms began to be supported in the 1980s, and their promotion is now a major strand of agricultural development policy. Large-scale family farms are defined in government statistics as farms with more than 3.33 ha of land.[71] Their average size is about 13 hectares, with less than 2% larger than 33 ha.[72] Unlike small-scale farms, which use mainly family labour, specialised and large-scale farms use family labour supplemented by hired labour, and engage in large-scale, intensive and commercialised agricultural operations. They obtain the bulk of their income from agriculture.[73] Most of these farms rely primarily on modern technologies, including agricultural machinery, pesticides, fertilisers and other inputs. Specialised households are also common in the livestock sector, such as small and medium poultry and pig operations.[74] By the end of 2012, there were 877,000 formally recognised larger-scale family farms. Together, these farms cultivated 11.73 million ha, or about 10% of China's total farmland. In 2014, a specific policy was issued to support the further development of large-scale family farms (discussed further in Section 3.2).[75]

Farmers' specialised cooperatives[76]

Another way in which farmers overcome the limitations of small-scale production operations is by joining together in cooperatives. Farmers' specialised cooperatives refer to a mutually-supporting economic organisation, voluntarily built and democratically managed by a group of producers of similar agricultural products, or a group of providers and users of similar agricultural services. This definition highlights two elements. Firstly, cooperatives have to operate according to their registered specialisation. For example, rice cooperatives are required to focus on rice production. Secondly, their beneficiaries are clearly identified as cooperative members, to whom they may provide technical and information services, access to agricultural supplies, agricultural products sales, processing, transport and storage.[77]

Specialised cooperatives are regulated by a law issued in 2007. In 2008, there were 58,000 cooperatives with 770,000 members (households).[78] By the end of 2014, there were almost 1.29 million farmer cooperatives, with 92 million member households (about 35% of the total number of farming households).[79] There are three main factors driving this increase in cooperatives. First, with household division, average farm size has been decreasing over time, with a growing number of farmers working off-farm and increasing sales of farm produce, collaboration among farmers through cooperatives meets farmers' needs. Second, there has been very strong policy support, including legislation, tax breaks, financial support and credit, targeting cooperatives and direct support for farmer cooperative formation from local governments.[80] Third, with trends towards vertical integration in many agri-food supply chains, cooperatives provide an institutional framework for linking individual farmers to purchasers, markets and processors. Two-thirds of cooperatives have been initiated by government or by government together with farmers, one-fifth by farmers alone, and the remainder by agribusiness.[81]

About 40% of cooperatives are active in livestock and poultry production, and 40% in horticulture, while the remainder focus on grain crops or aquaculture.[82] The vast majority of cooperatives provide technology or information services, and about half supply production inputs to farmers.[83] About a third of cooperatives purchase farm produce from farmers, while just under half are involved in arranging marketing for farmers. About a third of cooperatives provide support to farmers through technology and input supply as well as marketing. In terms of marketing channels, about a third of cooperatives use modern supply chains (i.e. processors and retailers), and over 40% use wholesale

[71] With recent explicit fiscal support for large family farms, local governments are currently drafting definitions suited to different areas and different value chains in order to clarify eligibility for subsidies.
[72] Shi, R. 27 February 2014. Family farms exceed 870,000; Ministry of Agriculture says bigger is not necessarily better. Caixin.com [石睿, 2014年2月27日, 家庭农场超87万农业部称非越大越好 http://china.caixin.com/2014-02-27/100644214.html].
[73] Liu, H. and Wang, Q. 2014. Review of family farm research in China. *Journal of Jiangsu Agricultural Sciences* 42(5) 448–450 [刘惠芳, 王青. 2014年. 我国家庭农场研究综述. 江苏农业科学 42(5) 448–450]; Gao Q., Liu T., and Kong X. 2013. Institutional analysis of family farms: Features, mechanisms and impact. *Economist* 48–56 [高强, 刘同山,孔祥智. 2013年. 家庭农场的制度解析: 特征, 发生机制与效应. 经济学家 6(6) 48–56].
[74] Jia, X. 2014. Pig Production, Smallholders, and the Transformation of Value Chains in China. IIED Issue Paper. IIED, London
[75] Ministry of Agriculture. 2014. *Guiding Suggestion on Promoting the Development of Family Farms*. Ministry of Agriculture, Beijing [农业部.2014年.农业部关于促进家庭农场发展的指导意见.]
[76] Today's specialised cooperatives are not the same as the cooperatives established in the 1950s. Contemporary cooperatives are established under the 2007 Farmer Specialized Cooperative Law, and are focused on enabling cooperation among farmers for specific agricultural products.
[77] PR China. 2007. *Law on Farmer Specialized Cooperatives*. Xinhua News Agency, Beijing [中华人民共和国农民专业合作社法].
[78] Zhang, X. 2009. Exploration of the development trend in farmer specialized cooperatives. *Management World* (5) 89–96 [张晓山, 2009年. 农民专业合作社的发展趋势探析. 管理世界, (5) 89–96].
[79] Research Network for China Farmer Cooperatives. 15 July 2015. There are 1.4118 million farmer cooperatives in China with an investment of more than 3 billion CNY. [中国农民合作社研究网, 2015年7月15日. 全国实有农民专业合作社达141.18万家, 出资总额突破3万亿元, www.ccfc.zju.edu.cn/a/shujucaiji/20150717/20455.html].
[80] Deng, H. *et al.* 2010. Policy support and emerging farmer professional cooperatives in rural China. *China Economic Review* 21(4) 495–507.
[81] Jia, X. and Huang, J. 2011. Contractual arrangements between farmer cooperatives and buyers in China. *Food Policy* 36(5) 656–666.
[82] Jia, X. and Huang, J. 2011. *ibid.*
[83] Deng, H. *et al.* 2010. *op. cit.*.

markets, with sales to middlemen and consumers being a common secondary marketing channel.

While written or oral contracts are commonly used in sales through modern supply chains, contracts often do not have detailed specifications, and quality and safety requirements are rarely specified.[84] This suggests that the potential role of cooperatives in ensuring food safety is not always being brought into play, either due to the nature of contract relationships or the characteristics of the cooperatives themselves.[85] Some cooperatives have implemented some kind of production or product standard,[86] and can be effective in reducing the use of pesticides and adopting other improved practices.[87] A number of factors affect the extent to which cooperatives can influence or regulate production practices, such as whether cooperatives produce branded products.[88] However, most cooperatives implement conventional agriculture production methods, so cooperative formation by no means implies the promotion of ecological aspects of sustainable agriculture.

Agribusiness

Much as in many other countries, agribusiness operations in China are characterised by hired labour and significant capital investment. Agribusiness operations also include almost 1,800 state-owned farms that together manage 6.2 million ha of arable land.[89] Some non-state agribusinesses gain access to arable land through the transfer of land-use rights from farmers, or through contract farming, but the majority of agribusinesses are active in post-harvest stages, purchasing agricultural products from farmers and other land users. In the early 2000s, there were 580 national-level agribusinesses, and 4,800 provincial-level agribusinesses;[90] by 2014 this had risen to a total of 125,000 agricultural enterprises.[91] The increasing role of agribusinesses in farming operations has occurred alongside the vertical integration of supply chains, and is more common in some sectors, such as livestock feed, oil crops and livestock production. Agribusiness development has received strong policy support in recent decades.[92]

2.4 Changing marketing systems

Today farmers in China are well integrated into the cash economy. Most Chinese grain and cash crops are marketed. Farmers are responsive to prices, with prices around planting time having a clear impact on cultivation decisions.[93] So how are agricultural products marketed?

For grain crops, in the early 1980s land contracts included quotas for the amount of grain that each household should supply to state grain procurement agencies at fixed prices.[94] In the mid-1980s, this was changed to a system of administrative set prices for the sale of within-quota grain and market prices for above-quota grain. This system was in operation until 2004. Now a minimum price for grain is set based on market prices; the grain purchased at minimum purchase prices is stored in the national grain reserves and used to influence market prices. The aim is to ensure price stability to maintain farmers' incentives to produce grain, and affordability for consumers. These reforms mean that most farmers no longer sell directly to state procurement agencies. In the main grain-producing areas, while smaller farmers may sell to local traders who then sell on to grain mills, the majority sell directly to grain mills. In areas where grain is not a major commodity, grain mills are less present and farmers mostly sell to private traders who then bulk their purchases and sell to grain mills elsewhere.[95] Some grain mills in the main grain-producing areas also engage in contract farming with producers. Large grain mills are the main suppliers to urban wholesale markets and supermarkets. Overall, grain supply chains have become more vertically integrated through the development of formal (e.g. contract) or informal relationships between actors at each stage, and more concentrated as small grain mills are declining and medium and large-scale grain mills take on an increasing

[84] Jia, X. and Huang, J. 2011. *op. cit.*
[85] Jia, X. and Huang, J. 2011. *op. cit.*; Chen, X. and Tan, Y. 2013. Functions and impact of farmer cooperative services based on food safety: Example of fruit cooperatives in Guangdong Province. *Journal of Agrotechnical Economics* (1) 120–128 [陈新建,谭砚文, 2013年. 基于食品安全的农民专业合作社服务功能及其影响因素——以广东省水果生产合作社为例. 农业技术经济 (1) 120–28].
[86] Jin, S. and Zhou, J. 2011. Adoption of food safety and quality standards by China's agricultural cooperatives. *Food Control* 22(2) 204–208.
[87] Cai, R. and Han, H. 2012. The effect of farmer cooperatives on farmer use of pesticides and its mechanisms: analysis based on survey data from apple cultivators in Shandong Province. *Journal of China Agriculture University* 17(5) 196–202 [蔡荣, 韩洪云, 2012年. 农民专业合作社对农户农药施用的影响及作用机制分析: 基于山东省苹果种植户的调查数据. 中国农业大学学报 17(5) 196–202].
[88] Jia, X. and Huang, J. 2011. *op.cit.*
[89] National Bureau of Statistics National Data Database (http://data.stats.gov.cn).
[90] Rural Economy Research Center of the Ministry of Agriculture (ed.). 2008. *Report on China Agricultural Commercialization*. China Agriculture Publishing House, Beijing [农业部农村经济研究中心（编）, 2008年.中国农业产业化发展报告.中国农业出版社].
[91] Mai, T. 4 August 2015. Agricultural commercialization lets of more energy through innovation. *Farmer's Daily*, 1. [买天.2015年8月4日.农业产业化在创新中释放更大能量。农民日报,01版 http://szb.farmer.com.cn/nmrb/html/2015-08/04/nw.D110000nmrb_20150804_9-01.htm?div=-1]; State Administration for Industry and Commerce. 2015. National market actor development in the first half of 2015. SAIC, Beijing. [中国工商总局, 2015年.2015年上半年全国市场主体发展, www.saic.gov.cn/zwgk/tjzl/zhtj/xxzx/201507/t20150715_158914.html].
[92] Gale, F. 2013. *Growth and Evolution in China's Agricultural Support Policies*. USDA Economic Research Report 153. US Department of Agriculture, Washington DC.
[93] Brockhaus, J. *et al.* 2015. Rice, wheat and corn supply response in China. Paper presented at the 2015 Agricultural & Applied Economics Association and Western Agricultural Economics Association Annual Meeting, San Francisco, California, 26–28 July 2015.
[94] Li, X., Wang, S. and Yan, J. 2012. Grain market and policy in China. In: Alpermann, B. (ed.). *Politics and Markets in Rural China*. Routledge, London.
[95] Reardon, T. *et al.* 2014. The quiet revolution in Asia's rice value chains. *Annals of the New York Academy of Sciences* 1331(1) 106–118.

proportion of total output, increasingly providing branded products to retail markets.

The transformation of supply chains has also affected marketing patterns for other crop types. Studies have found that the majority of fruit producers sell to local spot markets, where traders and wholesalers purchase goods for supply to traditional food markets and supermarkets in urban areas.[96] For vegetables, most farmers sell to small traders or wholesalers.[97] While these marketing arrangements mean that poorer and wealthier farmers alike are able to access markets, and urban food supply is ensured in a relatively cheap and efficient way, there are some significant shortcomings. Foremost among these is the lack of quality assurance in horticultural supply chains, as purchasers are unable to monitor production practices.[98] Consumers therefore have little trust in the quality or safety of food they purchase.[99] Secondly, farmers and buyers both face difficulties in forecasting supply and thus prices.

In this context, some alternative marketing and procurement arrangements have emerged. In supply chains where quality assurance is an objective (e.g. export markets), forms of vertical integration have emerged, including direct involvement in production by processors, packers or retailers;[100] contract farming,[101] including contract relationships between purchasers and farmer cooperatives;[102] and intermediate supply companies that manage production bases for retailers.[103] Such vertical integration facilitates quality assurance by retailers,[104] and in some cases enables product traceability for retailers and consumers.[105] Quality assurance and profitability have also been key drivers of vertical integration in the livestock sector.[106] For these reasons, direct procurement by retailers (e.g. major supermarket brands) has also been supported by government.[107] As the modern retail sector develops, and with continued institutional innovations to improve and ensure food safety in the country, marketing arrangements will continue to evolve.

[96] Huang, J. *et al.* 2008. Small holder incomes, food safety and producing, and marketing China's fruit. *Applied Economic Perspectives and Policy* 30(3) 469–479.
[97] Huang, J. *et al.* 2007. *Production, Marketing and Impacts of Market Chain Changes on Farmers in China: Case study of cucumber and tomato in Shandong province.* IIED Regoverning Markets Agri-food Sector Study. IIED, London.
[98] Huang, J. *et al.* 2008. Small holder incomes, food safety and producing, and marketing China's fruit. *Applied Economic Perspectives and Policy* 30(3) 469–479.
[99] FORHEAD. 2014. *Food Safety in China: A mapping of problems, governance and research.* www.forhead.org
[100] Michelson, H. *et al.* 2013. Supermarket supply chains with Chinese characteristics: The case of Walmart's Direct Farms. Paper presented to 2013 Annual Meeting of the Agricultural and Applied Economics Association, Washington, DC, 4–6 August 2013.
[101] Miyata, S., Minot, N. and Hu, D. 2009. Impact of contract farming on income: Linking small farmers, packers, and supermarkets in China. *World Development* 37(11) 1781–1790.
[102] Jia, X., Huang, J. and Xu, Z. 2012. Marketing of farmer professional cooperatives in the wave of transformed agrofood market in China. *China Economic Review* 23(3) 665–674; Deng, H. *et al.* 2010. Policy support and emerging farmer professional cooperatives in rural China. *China Economic Review* 21(4) 495–507.
[103] Michelson, H. *et al.* 2013. Supermarket supply chains with Chinese characteristics: The case of Walmart's Direct Farms. Paper presented to 2013 Annual Meeting of the Agricultural and Applied Economics Association, Washington, DC, 4–6 August 2013.
[104] Han, J. 2009. *Supply Chain Integration, Quality Management and Firm Performance of Pork Processing Industry in China.* Wageningen Academic Publishers, Wageningen; Miyata, S., Minot, N. and Hu, D. 2009. Impact of contract farming on income: Linking small farmers, packers, and supermarkets in China. *World Development* 37(11) 1781–1790; Backhouse, C. *et al.* 2014. Sustainable food supply networks in the Chinese supermarket sector. Paper presented at 2014 International Conference on Industrial Engineering and Operations Management, Bali, Indonesia, 7–9 January 2014.
[105] Miyata, S., Minot, N. and Hu, D. 2009. Impact of contract farming on income: Linking small farmers, packers, and supermarkets in China. *World Development* 37(11) 1781–1790.
[106] Han, J. 2009. *Supply Chain Integration, Quality Management and Firm Performance of Pork Processing Industry in China.* Wageningen Academic Publishers, Wageningen.
[107] Michelson, H. *et al.* 2013. Supermarket supply chains with Chinese characteristics: The case of Walmart's Direct Farms. Paper presented to 2013 Annual Meeting of the Agricultural and Applied Economics Association, Washington, DC, 4–6 August 2013.

Agricultural sustainability issues

Today agriculture in China faces a number of environmental and socio-economic challenges. Environmental challenges include pressures on the quantity and quality of land and water resources, unsustainable nutrient management and soil and water pollution. Many of these challenges are tied in with socio-economic and institutional shifts, such as rural-urban migration, and changes in land tenure, farming institutions and agricultural extension services.

3

As documented in the previous chapter, China's growth in agricultural output has been accompanied by the development of high external-input agriculture as the prevalent, conventional form of agriculture. Environmental, and to a lesser extent, socio-economic, challenges to the sustainability of this approach are increasingly recognised in policy circles. The current consensus is that agriculture should meet the need for safe, quality food products while also limiting its environmental impacts.[108] This chapter reviews selected resource and environmental challenges (land degradation, water use and pollution of soils and water)[109] and socio-economic challenges associated with demographic change and land tenure.

3.1 Resource and environmental challenges

Land loss and degradation

At 0.1 ha per person on average,[110] arable land resources are limited in China. With limited endowments of suitable land, both the availability and quality of arable land resources are a major concern. In recent decades, the amount of arable land has declined, mainly lost to urban and industrial construction. Between the mid-1990s and 2008, land used for urban and residential construction increased from 29.6 million ha to 33.1 million ha, while the arable land area decreased from about 130 million ha to 122 million ha.[111] These losses have not only been due to the growth of China's mega-cities, but also expanding urbanisation around small towns.[112] Loss of arable land has been particularly rapid in the eastern coastal areas, including the Huang-Huai-Hai region and the mid and lower Yangtze River agricultural zones.

Much of the remaining arable land is of limited fertility. A recent census[113] classified all arable land on the basis of site conditions, topsoil physical and chemical properties, soil management, and production constraints. Of a total of 122 million ha:

- 27.3% were classed as high fertility soils. These were mostly located in the northeast, Huang-Huai-Hai, mid and lower Yangtze River and southwest regions.
- 44.8% were classed as moderate quality, indicating suitable conditions for further development of production, mostly located in the Southwest, Mid and Low Yangtze River, Huang-Huai-Hai and GanXin zone, and in the agro-pastoral transition area.
- 27.9% were classed as poor quality with no potential for improvement in the short term. Most of this was located in the Yellow Plateau, mid and lower Yangtze River, southwest and agro-pastoral transition zones.

Notably, however, all classes of land were identified in all of the nine agricultural zones, indicating that soil degradation is a widespread problem.

In addition to general fertility constraints, other forms of land degradation are prominent in certain regions. Official reports state that in 2009, 2.62 million square kilometres (sq km) were affected by desertification, equating to about 27% of China's total land area.[114] About three-quarters of the area affected by desertification are located in arid and semi-arid regions, mostly in the north and west of the country. About 70% of land affected by desertification is susceptible to wind erosion, 10% to water erosion, 7% to salinisation and 14% to desertification resulting from loss of permafrost. Arable land susceptible to wind erosion covers 44,600 sq km, but accounts for only 2.6% of the affected area. Wind erosion mainly affects natural grasslands and livestock raising in pastoral regions, where cultivation of grassland and overgrazing have been among the main causes of degradation.[115] Water erosion mainly affects areas where rainfall is high and topography leads to high water flow rates. Such areas are concentrated in the Loess Plateau, watersheds in the western part of northeast China and parts of Xinjiang. Salinisation affects about 3.6 million sq km of land, including about 92,000 sq km of arable land – more than 6.5% of the total arable land area. Salinisation is mostly found in the northwest, north, northeast and coastal areas of China.[116] Arid and semi-arid regions are susceptible to

[108] Garnett, T. and Wilkes A. 2014. *Appetite for Change: Social, Economic and Environmental Transformations in China's Food System*. Food Climate Research Network, Oxford.
[109] A more detailed discussion of environmental aspects of China's agri-food system is provided in Garnett, T. and Wilkes A. 2014. *Appetite for Change: Social, Economic and Environmental Transformations in China's Food System*. Food Climate Research Network, Oxford.
[110] Wang, Z. 30 December 2013. Ministry of Land and Resources: China's per capita arable land fell to 1.52 mu and is less than half the global per capita level. People.cn [王泽.2013年12月30日.国土部：我国人均耕地降至1.52亩 不足世界人均水平一半, 人民网 http://politics.people.com.cn/n/2013/1230/c1001-23977290.html].
[111] Li, Y. *et al.* 2015. Urban–rural transformation in relation to cultivated land conversion in China: Implications for optimizing land use and balanced regional development. *Land Use Policy* (47) 218–224.
[112] Deng, X. *et al.* 2015. Impact of urbanization on cultivated land changes in China. *Land Use Policy* 45 1–7.
[113] Ministry of Agriculture. 2014. *Report on the National Arable Land Quality Grade Situation*. Ministry of Agriculture, Beijing [农业部, 2014年.全国耕地质量等级情况公报].
[114] State Forestry Administration. 2010. *China Desertification Report*. State Forestry Administration, Beijing. [国家林业总局, 2010年.中国荒漠化和沙化状况公报].
[115] Liu, J. *et al.* 2010. Spatial patterns and driving forces of land use change in China during the early 21st century. *Journal of Geographical Sciences* 20(4) 483–494.
[116] Wang, J. *et al.* 2012. Research summary on salinization and sustainable use. *Journal of Geographical Science* (66)5 673–684 [王佳丽、黄贤金、钟太洋、陈志刚, 2011年.盐碱地可持续利用研究综述. 地理学报 66(5) 673–684].

salinisation in part because of high evapotranspiration rates.

Temperate and humid areas may also be affected by land degradation. In parts of southwest China, for example, karst desertification is a major threat to agricultural production. Karst landscapes typically have thin soil layers, and loss of vegetation cover due to human activities exposes soils to erosion, soon exposing the bedrock. About a quarter of China's karst region (mainly on the Yunnan-Guizhou Plateau) is affected by erosion, totalling 120,000 sq km.[117] In the black soil region of the northeast, where peat soils predominate, the depth of the soil layer and its soil organic matter have declined significantly, mainly due to improper land management practices.[118] In both semi-arid and humid regions, high-intensity rainfall events in the monsoon season can have significant impacts on exposed soils in mountainous areas.[119] Land-use change, such as cultivation of grassland or former forest land followed by abandonment, often leads to soil degradation.[120] During the 1990s alone, more than 6 million hectares of grassland or forest were converted to cropland, mainly in northeast China and Inner Mongolia.[121] Finally, a range of management practices has contributed to land degradation, including the widespread use of crop residues for fuel instead of being returned to the soil, reductions in organic manure application, and inappropriate management of irrigation water in arid areas.[122]

After many decades of expansion of the area affected by desertification,[123] official reports suggest that the net area affected by desertification and land degradation has begun decreasing in recent years following the implementation of effective conservation and restoration programmes (see Section 4.2).[124] This conclusion is also supported by several academic studies.[125]

Water resources and climate change

China has just over 5% of the Earth's renewable water resources,[126] but its available water resources are unevenly distributed: 70% of the country's groundwater resources are in the south, with the remaining 30% in the dryland areas of northern China, which produce about 40% of total crop output.[127] The agriculture sector accounts for about 55% of total water use,[128] but the proportion has been falling rapidly as urbanisation increases. Urbanisation not only decreases the availability of water for agricultural use, but also decreases the area of irrigated arable land and thus affects yields. This may decrease the total national output of crops such as rice, wheat and vegetables.[129] It is notable that more than half of the water used in China's agriculture is used to produce animal feed.[130] Future agricultural water use (and China's overseas water footprint) will depend on future consumption trends, because meat and dairy product production is water-intensive.[131]

[117] State Forestry Administration. 2012. *China Karst Desertification Report*. State Forestry Administration, Beijing [国家林业总局，2012年.中国石漠化状况公报].
[118] Lian, Y., Gao, C. and Ren, H. 2001. Climate change and expansion of desertification in northeast China in the 1990s. *China Meteorological Bulletin* 59(6) 730–736. [廉毅，高枞亭,任红玲. 2001年. 20世纪90年代中国东北地区荒漠化的发展与区域气候变化. 气象学报 59(6) 730–736].
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[120] Rao, E. et al. 2014. Spatial patterns and impacts of soil conservation service in China. *Geomorphology* (207) 64–70.
[121] Tian, G. *et al.* 2002. Spatial characteristics and ecological background of new cultivated land in China. *Resources Science* 24(6) 1–6 [田光进，周全斌，赵晓丽，张增祥，2002年. 中国新开垦耕地资源空间分布特征及生态背景研究. 资源科学 24(6) 1–6].
[122] LADA Project Team. 2010. *China National Level Report of Land Degradation Assessment in Drylands (LADA)*. FAO, Rome.
[123] Wang, T. 2004. Spatial and temporal changes in desertification in Northern China in the past 50 years. *Journal of the Geographical Science* (2) 203–212 [王涛，吴薇，薛娴，孙庆伟，张为民, 韩致文. 2004年. 近50年来中国北方沙漠化土地的时空变化. 地理学报 (2) 203–212].
[124] State Forestry Administration. 2015. *The Desertification and Sandification State of China*. State Forestry Administration, Beijing [国家林业局, 2015年.中国荒漠化与沙化状况公报].
[125] Lü, Y. *et al.* 2012. A policy-driven large scale ecological restoration: quantifying ecosystem services changes in the Loess Plateau of China. *PloS One* 7(2):e31782; Liu, J. *et al.* 2008. Ecological and socioeconomic effects of China's policies for ecosystem services. *Proceedings of the National Academy of Sciences* 105(28) 9477–9482; Yin, R., Yin, G. and Li, L. 2009. Assessing China's ecological restoration programs: What's been done and what remains to be done? In: Yin, R. (ed.). *An Integrated Assessment of China's Ecological Restoration Programs*. Springer, Netherlands; Liu, J. *et al.* 2014. Spatiotemporal characteristics, patterns, and causes of land-use changes in China since the late 1980s. *Journal of Geographical Sciences* 24(2) 195–210; Zhang, J., Wang, T. and Ge, J. 2015. Assessing vegetation cover dynamics induced by policy-driven ecological restoration and implication to soil erosion in Southern China. *PloS One* 10(6): e0131352.
[126] Renewable water resources are defined as the long-term average annual flow of rivers and groundwater. FAO. 2003. *Review of Water Resources by Country*. FAO, Rome.
[127] Wang, J. *et al.* 2007. Agriculture and groundwater development in northern China: Trends, institutional responses, and policy options. *Water Policy* 9(S1) 61–74.
[128] Ministry of Agriculture. 2015. *National Plan for Sustainable Development of Agriculture (2015–2030)*. Ministry of Agriculture, Beijing [农业部, 2015年。全国农业可持续发展规划纲要（2015–2030）].
[129] Yan, T., Wang, J. and Huang, J. 2015. Urbanization, agricultural water use, and regional and national crop production in China. *Ecological Modelling* 318: 226–235.
[130] Qin, W. *et al.* 2012. Urbanization affects water and nitrogen use in the food chain in China. Conference paper presented at Agro Environ 2012, Wageningen. http://edepot.wur.nl/218156.
[131] See Garnett, T. and Wilkes, A. 2014. *Appetite for Change: Social, Economic and Environmental Transformations in China's Food System*. Food Climate Research Network, Oxford.

Within the agriculture sector, water-use efficiency is low. More than half of pumped irrigation water is lost to leaks or evaporation and is not effectively used. Increasing water-use efficiency has become a key target of national agricultural policy.[132] Groundwater is the main source of irrigation water for most of northern China. Groundwater extraction has increased ten-fold since the 1950s, and the number of tube wells more than doubled between 1978 and 2003.[133] The water table is falling significantly in much of northern China,[134] which increases the financial costs of irrigation, as well as damaging water quality.

Climate change may also exacerbate China's water resource challenges. Regional climate models predict an increase in the frequency of heat waves and intense rainfall events across most of China.[135] There have already been significant regional shifts in precipitation, with a decrease in summer-autumn precipitation in northeastern areas and increases in summer and winter precipitation in southeastern areas. In some areas (e.g. northwestern China and the mid to lower reaches of the Yangtze), the increase in precipitation involves greater rainfall intensity, implying higher flood and drought risks. Each year, large areas of crops are lost to flood, drought and other extreme events. Over the last 20 years, an annual average of 28% of the total sown area has been affected to some extent by natural disasters, half of which are caused by drought. On average 15% of the affected area experiences a total loss of crop output.[136] Although there has been a significant decrease in the sown area affected by disaster over time (mainly due to better infrastructure), climate change alters production conditions for crops, and changing patterns of disaster risk as well as potential impacts on crop yields are major concerns.[137]

Unsustainable nutrient management

Intensive soil fertility management was the defining characteristic of traditional Chinese agriculture for centuries. Today, however, conventional agricultural practice is heavily dependent on high-external inputs, in particular chemical fertilisers. Controlled experiments across China clearly show that the combined application of inorganic and organic fertilisers benefits soil fertility and crop yields in rice, wheat and maize production systems.[138] Yet, organic manure application is declining, with one study reporting a decrease from 13 tonnes per ha in 2000 to 5 tonnes per ha in 2008.[139] While around half the small-scale pig farmers use livestock waste as manure, a significant proportion of large operators do not, and often abandon livestock waste untreated, because they have no land to cultivate or because of the high costs of transporting it to other sites for use as manure.[140] Nationwide, about 85% of households apply human excreta as manure, but in some regions (e.g. Jiangsu in eastern China) excreta is increasingly discharged into septic tanks for sanitation reasons.[141] Human excreta is more likely to be used in areas with lower incomes, lower population density, and larger families and farm land area.

There are a number of barriers to farmers adopting appropriate organic manure management practices. Firstly, increasing off-farm wages and the rising opportunity cost of farm labour make labour-intensive manure management less attractive.[142] Secondly, fertiliser prices have been falling, particularly since China's entry to the World Trade Organisation in 2005. Thirdly, farmers tend to apply more organic manure on plots to which they have contract rights compared to plots that are rented from others (in fact up to one-third more), although this effect may be decreasing as tenure reforms give greater clarity to rental rights.[143] Fourthly, livestock on-farm were traditionally the main source of farmyard manure, but livestock are increasingly raised in livestock production zones or in large-scale confined animal operations, from where it is not practical to transport manure.[144]

[132] National Development and Reform Commission. 2009. *Medium and Long-term Food Security Plan (2008–2020).* National Development and Reform Commission, Beijing [国家发展与改革委员会. 2009年. 国家粮食安全中长期规划纲要(2008–2020]**;** Ministry of Agriculture. 2015. *National Plan for Sustainable Development of Agriculture (2015–2030).* Ministry of Agriculture, Beijing [农业部，2015年。全国农业可持续发展规划纲要（2015–2030）].
[133] Wang, J. 2007. Agriculture and groundwater development in northern China: Trends, institutional responses, and policy options. *Water Policy* 9(S1) 61–74.
[134] Liu, C., Yu, J. and Kendy, E. 2001. Groundwater exploitation and its impact on the environment in the North China Plain. *Water International* (26) 265–272; Yuan, Z. and Shen, Y. 2013. Estimation of agricultural water consumption from meteorological and yield data: A case study of Hebei, North China. *Plos One* (8) e58685.
[135] Piao, S. *et al.* 2010. The impacts of climate change on water resources and agriculture in China. *Nature* 467(7311) 43–51.
[136] National Bureau of Statistics National Data Database (data.stats.gov.cn).
[137] Wang, J., Huang, J. and Yang, J. 2014. Overview of impacts of climate change and adaptation in China's agriculture. *Journal of Integrative* Agriculture 13(1) 1–17; Li, K. *et al.* 2016. Feeding China. In: Nadin, R., Opitz-Stapleton, S. and Xu, Y. (eds). *Climate Risk and Resilience in China.* Routledge, London.
[138] Zhang, H., Xu, M. and Zhang, F. 2009. Long-term effects of manure application on grain yield under different cropping systems and ecological conditions in China. *Journal of Agricultural Science* 147(1) 31–42.
[139] Gao, L., Huang, J. and Rozelle, S. 2012. Rental markets for cultivated land and agricultural investments in China. *Agricultural Economics* 43(4) 391–403.
[140] Zhang X., Liu, Y. and Wang, L. 2009. An empirical study on non-point pollution of livestock and poultry raising in western rural areas. *Ecological Economy* 7: 98–100, 173 [张雪梅、刘永功. 王莉. 2009年. 西部农村养殖非点源污染实证研究. 生态经济 (7) 98–100,173].
[141] Liu, Y., Huang, J. and Zikhali, P. 2014. Use of human excreta as manure in rural China. *Journal of Integrative Agriculture* (2) 024.
[142] Chao, G., Bo, S. and Zhang, T. 2006. Sustainable nutrient management in Chinese agriculture: challenges and perspective. *Pedosphere* 16(2) 253–263.
[143] Gao, L., Huang, J. and Rozelle, S. 2012. Rental markets for cultivated land and agricultural investments in China. *Agricultural Economics* 43(4) 391–403.
[144] Chadwick, D. *et al.* 2012. Improving Manure Nutrient Management towards Sustainable Intensification in China. SAIN Policy Brief 6. http://sainonline.org

Application of crop residues also improves soil fertility and crop yields.[145] Prior to the 1980s, most crop residue was used for fuel or animal feed, or returned to soils, but since the 1980s an increasing proportion of crop residues are being burned in the fields as alternative energy and feed sources have become available and the opportunity cost of labour-intensive crop residue management practices have increased.[146] In the mid-2000s, it is estimated that about 25% of crop residues were returned to soils, with about 30% used as animal feed and 35% burned.[147] Factors such as whether household members work off-farm, whether the household raises livestock, and the strength of local enforcement of bans on biomass burning are key in determining the treatment of crop residues. A range of factors has also been identified as associated with the adoption of green manure cultivation by farmers, including site biophysical conditions as well as socio-economic factors.[148]

Today the application of chemical fertilisers is ubiquitous across China. Overall application rates have been increasing, but the marginal returns to fertiliser use have been declining.[149] Nitrogen fertiliser has been a particular concern because of the potential for pollution of water resources as well as greenhouse gas emissions from over-application. Overuse of phosphorous – a limited resource – is also a concern.[150] For nitrogen fertilisers, there are regional differences in application rates as well as differences among crops.[151] Studies have identified a number of factors at the household level related to fertiliser use, such as farm size (with higher fertiliser application rates on smaller farms).[152] Some studies find a relationship between seasonal migration and greater fertiliser use, while others report no relationship.[153] While some studies found no reliable predictors of fertiliser use intensity,[154] significant variation in fertiliser management practices and yields among farmers in any given region suggests that there is potential to improve nutrient management.[155]

Reforms to fertiliser marketing in the 1980s explicitly allowed grassroots extension agencies to accept payments for their role in agro-input product marketing and to sell fertiliser during extension activities.[156] This has also served to increase chemical fertiliser use. In the current context of farmer reliance on external inputs to maintain soil fertility, markets have arisen for nutrient services and products. New types of fertiliser – such as inoculants and slow-release fertilisers – are increasingly being adopted, particularly by commercial enterprises. Organic microbial fertiliser product markets are also growing, as are organic fertiliser markets generally.[157]

Cropping systems and nutrient management practices are thus changing in response to a range of factors. Some of these factors reflect broader trends in China's development, such as rural-urban migration and rising labour costs, while others reflect responses to specific policies in the agriculture sector. It is important, however, to remain aware of the diversity of agricultural practices across the country, and even within specific regions and local areas. Recognition of this diversity underscores the importance of locally tailored approaches to addressing issues in agriculture and rural development, and the need for demand-driven agricultural extension.[158]

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Pollution of the production environment

The growing dependence on high external-input agriculture, rapid growth of livestock production, a recent history of rural industrialisation and an active mining sector are all major contributors to pollution in the agricultural production environment. Pollution from dispersed sources (i.e. agricultural non-point pollution) is a main cause of water pollution across large parts of the country. In the mid-2000s, more than 40% of rivers were severely polluted and more than 80% of lakes were eutrophic.[159] In areas with high nitrogen application rates (e.g. major vegetable production areas), nitrate pollution in groundwater is also a problem.[160] The main contributors to non-point pollution are livestock waste, excess or improper use of nitrogen fertilisers and pesticides. An estimated 3,060 million tonnes of livestock waste were produced in 2010, representing 14 million tonnes of nitrogen (compared to 32 million tonnes of manufactured chemical fertiliser nitrogen). The amounts of potassium and phosphorous emitted in waste from livestock are comparable to the amount of nutrients in inorganic fertiliser applied in the country.[161] However, one survey in 2007 reported that about two-thirds of livestock waste are applied to fields, a small proportion is composted or used for biogas, and the rest (about 20%) is abandoned, thus polluting soils and watersheds.[162] Average nitrogen fertiliser application rates in China are among the highest in the world, at about 200 kg N per ha common in the main grain crops, and 300–500 kg N per ha in vegetable and fruit production. The area under vegetables and fruit has also expanded significantly in recent years.[163] With such high application rates – in excess of plant nutrient needs – large amounts of nitrogen are lost to the environment through volatilisation (contributing to greenhouse gas emissions), leaching and runoff.[164] Overuse of chemical fertilisers has also contributed to soil acidification.[165]

China is the world's largest pesticide producer and consumer, with an average application rate of 14 kg per ha. Application rates are higher in wealthier and warmer areas – i.e. southeast and central China – than in the north and west.[166] The main pesticides currently used are insecticides (in particular, organophosphates), herbicides, and fungicides. Pesticides used historically but that are now banned (e.g. organochlorines such as DDT and HCH) are still detectable in soil, freshwater sediment and freshwater fish.[167] As well as environmental pollution, significant health impacts of pesticide management have been recorded among farmers,[168] and high levels of residues found in fruit and vegetables at retail outlets.[169]

In addition to agricultural non-point pollution, China's particular form of industrialisation and mining development has also resulted in major environmental challenges for agricultural production.[170] Since the 1950s, China has developed significant industrial activity in rural areas, a pattern that accelerated after the economic reforms initiated in the late 1970s. Both rural industrialisation and weak management of mine tailings have led to the significant pollution of soils by heavy metals at landscape scale. More than 3 million ha are now moderately or seriously polluted, particularly in the Yangtze and Pearl River Deltas, the northeast, and parts of Hunan province. Health effects on local populations and high levels of heavy metals in retail food have been found. Along with other sources of food contamination, such as adulteration and fake goods, pesticide and heavy metal contamination of foods are one focal aspect of concerns with food safety in China today.[171] Addressing consumers' food safety concerns has been a major driver of recent changes in the regulation of food safety, which is likely to have major impacts on agricultural production and the marketing of agri-food products (see Section 4.1).

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3.2 Socio-economic and institutional challenges

Urbanisation and changes in agricultural population structure

Demographic patterns in China have changed substantially in recent decades and in ways that present challenges for agricultural development. While in 1980, 191 million Chinese people lived in cities, in 2014 there were 749 million urban residents, accounting for more than 50% of China's population.[172] Urbanisation and industrialisation have provided off-farm employment for hundreds of millions of people, including those who were previously farmers. In the mid-1990s, about a third of rural people were employed off-farm; by the mid-2000s this had risen to more than 50%, and to 61% in 2011 (i.e. about 300 million people).[173] Initially, most migration was within the local area or province, but by the mid-2000s almost half of migrants (particularly younger migrants) were working outside their province. However, this decreased after the financial crisis in 2007.

This large-scale migration has important implications for the agricultural workforce. In many areas, farm workers tend to be older than the average worker, are more likely to be female and may be part-time farmers. As more men and women have become engaged in off-farm employment, a declining proportion of households is engaged in farm work (89% in 1991, and 65% in 2009). Furthermore, among farming households, total hours per year allocated to farming fell significantly in the 1990s and 2000s, from 3,500 hours to about 1,400 hours.[174] Of this farm work, the share done by women increased from 53% in 1991 to 59% in 2009. The proportion of farms on which women do all the farm work has increased, and women are more likely to do farm work than men, across all age groups. Although studies have found differences between the land area, capital assets and fertiliser use in female versus male-headed farms, there are no significant differences in productivity.[175] Feminisation therefore seems not to have affected agricultural productivity. More generally, studies have found the impacts of migration on output and yield to be mixed: some studies report negative effects on yields, others positive effects and still others found no effect.[176] However, other studies did find impacts of off-farm employment on specific farming practices, including investment in farm operations, and applications of organic manure and inorganic fertilisers,[177] although these are also affected by other factors such as tenure and tenure security.[178] The proportion of farm work undertaken by those over 50 years old has also increased, to more than 60% in 2006. Farms where elderly people are the main workforce are likely to have lower net incomes, and less likely to cultivate cash crops than other farms.[179]

There have been concerns that these changes in the farm workforce have affected the welfare of those remaining behind to work on the farm. Studies in the 1990s reported an increase in the 'double burden' of women responsible for both farm work and domestic duties.[180] A more recent study has identified an increase in time use in both farm work and domestic duties for the elderly (especially women) and for children.[181] Although migrants (including women) remit finances to their homes, this does not translate into increased status for women in managing collective affairs, such as water management, and traditional gender relations in such spheres are unchanged in many areas.[182] There have also been concerns for the well-being of the children left behind to be cared for by others. Although there appears to be no impact on nutritional status and physical development,[183] children whose parents are absent for longer and who visit less regularly are likely to have lower health-related quality of life as measured in terms of physical, emotional and social functioning.[184] Elderly parents of migrants may also be at higher risk of poverty.[185]

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The push for larger-scale farming

The institutional context of farming in China has changed several times in recent decades. Faced with the environmental, demographic and economic transitions and their related challenges described above, China's policy makers today are again promoting initiatives to adjust the institutional framework to meet the needs of rural, agricultural and farmer development. Recent policy documents set out a major change in rural land tenure and the organisation of agriculture.[186] Transfer of land-use rights to family farms, specialised households, rural cooperatives and agribusinesses is explicitly encouraged, and a number of supporting policies have been announced, including regulatory reforms linking land tenure rights to capital markets, subsidies, loan finance instruments and taxation policies.

There have long been debates in policy and academic circles on the appropriateness of large-scale agriculture in China. Several arguments have been made in favour of increasing the scale of farm operations.

- A shift towards larger-scale farms is inevitable in light of the shortage of rural labour due to out-migration.
- Larger-scale operations may facilitate mechanisation and increases in output. However, mechanisation substitutes between factors of production, and evidence suggests that total factor productivity is not correlated with farm size.[187]
- Farm size may be positively associated with unit area yields or unit area value of output, though there is variable evidence on this question.[188] The more relevant argument, however, is that there is a positive relationship between farm size and output per number of hours worked or output per number of family members engaged in agriculture. That is, smaller farms have a lower labour productivity, hence the main economic argument for promoting land transfers is that it enables an increase in off-farm employment and enhances the productivity of farm labour, thus contributing to rural income rises.[189]
- Large-scale farming may be more profitable than small-scale farming. The evidence for this is not conclusive, but some studies find that when small-scale farms account for family labour input at local wage rates, they are not as profitable as larger farms.[190]
- Small plot and farm size has been associated with increased environmental emissions, with several studies showing that soil carbon stocks are higher in larger plots than smaller plots;[191] the carbon footprint of large-scale rice farms is lower than that of small-scale farms mainly due to improved nitrogen use efficiency and low methane emissions;[192] and nitrogen fertiliser application rates have been found to be negatively associated with farm size.[193]
- The large numbers of smallholders involved in urban food supply chains are often cited as a risk for food safety. The available evidence, however, suggests that food safety risks are more related to the nature of supply chain relationships than to the scale of production.[194]

On the other hand, several risks and shortcomings of large-scale farming have been highlighted, including:

- The increased risk of non-voluntary transfer of land-use rights (i.e. 'land grabbing' by governments and/or companies) when policy promotes increased farm scale. Non-voluntary land rights transfers were documented in studies in the 1990s,[195] and presumably are still a risk, as reflected in the exhortations in recent policy documents to ensure that transfers are voluntary.[196]

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- Increased risk of transfer to non-agricultural and non-grain production, with one report suggesting that in some areas the majority of transferred land has been used for non-grain production.[197] While economically rational, there is a concern that this trend may pose a threat to grain supply.
- Possible contribution of large-scale farming to inequality within villages.[198]
- Inequity in access to government support. As government policy actively promotes large-scale farming, large-scale farmers are better placed to benefit from public funds in the form of subsidies and other public investments.[199]

The policy promoting large-scale farming is not limited to the cropping sector. An increase in scale of livestock production operations has been promoted for several years as a means to address productivity, profitability, and disease and food safety risks.[200] However, large-scale livestock production has significant environmental impacts due to the challenge of livestock waste treatment. It also poses new health risks, such as zoonotic disease, and brings new animal welfare challenges.

Thus, while the push to increase the scale of production may help to address some indicators of sustainability, it poses new challenges for other aspects of sustainability.

Cooperatives have emerged as an institution to enable cooperation among farmers. However, it is often noted that a significant proportion of cooperatives were formed through government initiative; only a very small proportion were initiated by small or medium farmers, possibly due to a lack of entrepreneurial skills and the ability to bear the significant transaction costs involved in collective action.[201] As an institutional form with significant government support, farmer cooperatives are often more associated with rural elites. Questions of the control of capital, cooperative governance and the distribution of benefits have been a concern.[202] Reducing the transaction costs of accessing market information and negotiating trade is one of the main arguments for cooperatives. A number of studies have investigated the capacity of cooperatives to undertake marketing functions, finding that several aspects of marketing capacities are relatively low for a significant proportion of cooperatives.[203]

Weakening public agricultural research and extension

Adoption of new technologies has been one of the key drivers of the growth in agricultural output in China.[204] The public extension system has played a major role in this. By 1990, there were 7,761 extension agencies at county level and 46,249 at township level, with more than 275,000 staff in total.[205] Reforms in the 1990s to address the rising cost of extension services led to the collapse of grassroots (township-level) extension institutions as extension agencies turned to agricultural input sales for revenue generation.[206] Studies showed that unless there was project-based funding for extension services, extension workers did not go to the countryside.[207] Low salaries for extension workers provided weak incentives for service delivery,[208] and institutional arrangements have not been supportive of demand-driven service delivery.[209]

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[208] Shen, H., Chou, X. and Wang, Z. 2010. Income distribution and extension performance of grassroots agricultural extension workers. *China Rural Economy* (2) 57–67 [申红芳, 廖西元、王志刚, 2010年. 基层农技推广人员的收入分配与推广绩效. 中国农村经济 (2) 57–67].
[209] Gong, T. and Wang, W. 2013. Literature review on problems in China's agricultural technology extension system. *Rural Economic Research* (1) 126–131 [宫同瑶, 王蔚, 2013年. 关于我国农业技术推广体系问题研究的文献述评. 农业经济研究 (1) 126–131].

There have been two main responses. Firstly, reforms introducing new forms of accountability were piloted,[210] and the organisational structure of extension agencies reformed.[211] However, there has been no significant national approach to improving extension services. Service provision at local level is thus variable, with diverse forms including government-led, research institute-led, company-led and entrepreneur-led all emerging in response to opportunity and demand.[212] Farmers' cooperatives, rural associations (i.e. non-profit technology associations), agribusiness and agricultural research institutions are all engaged in providing extension services. This raises several concerns about the effectiveness of the public extension system. Supply-driven extension (e.g. government extension programmes) may not meet farmers' real and diverse needs. Furthermore, with extension increasingly commercially-driven, it is not certain whether public service provision focuses more on companies and large-scale farm owners, to the neglect of small and medium-scale farmers. In addition, much extension work is focused on the delivery of available technologies, with relatively less attention paid to supporting farmers to develop, pilot and adapt farming methods using local knowledge and resources.

The second response has been the emergence of commercial agricultural input supply and private agricultural research to meet farmers' needs. Research by China's agricultural science academies and universities has provided many agricultural technologies that are now widely applied. After a decline in funding in the mid-1980s to mid-1990s, total investment in agricultural research increased once again and commercial funding became an important source of finance for research.[213] In 2006 (the latest year for which data are available), private investment in agricultural research and development (R&D) was about 17% of total investment in agricultural R&D.[214]

Public funding for agricultural research has increasingly focused on applied-basic and basic research, and research institutes have been encouraged to generate their own funding for research with commercial potential. In the early 2000s, a special fund was established to support the application of research results.[215] However, the low rate of adoption of agricultural research results has been a continuous concern for some years.[216] Scholars working in the agricultural research system cite a number of reasons for this, including an excessive funding focus on basic science rather than practical applications and an imperfect intellectual property rights system.

Meeting farmers' technology requirements is further complicated by the increasingly diverse needs and conditions of a market-oriented agricultural sector involving hundreds of millions of smallholders. More fundamentally, agricultural researchers have little incentive to undertake research through a farmer-centred approach. For many years, the number of academic publications in Scientific Citations Index journals or national 'core' journals has been the main indicator used for assessing research staff, although patents and government prizes are also valued. Farmer-centred and participatory research can be difficult to conduct and to publish, however. There are few mechanisms for conducting genuinely multi-disciplinary research that crosses categories established in project funding guidelines. Research on extension itself is seen as 'soft science', which attracts much less funding than more traditional agricultural sciences. Much of the exemplary farmer-centred, participatory research in China has been conducted in the scope of international donor-funded projects.

[210] Hu, R. *et al.* 2012. Effects of inclusive public agricultural extension service: Results from a policy reform experiment in western China. *China Economic Review* 23(4) 962–974.
[211] Babu, S. *et al.* 2015. A comparative analysis of agricultural research and extension reforms in China and India. *China Agricultural Economic Review* 7(4) 541–572.
[212] Zhang, W. *et al.* 2014. Problems and solutions regarding innovation in county agricultural technology services. *Journal of Shanxi Agricultural University (Social Sciences Edition)* 13(7) 736–740 [张文明, 刘飞翔, 陈融航, 丘秀珍, 林丹丹, 甘小烨. 2014年. 县域农业科技服务创新存在的问题及对策分析. 山西农业大学学报: 社会科学版 13(7) 736–740].
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[214] Hu, R. *et al.* 2011. Privatization, public R&D policy, and private R&D investment in China's agriculture. *Journal of Agricultural and Resource Economics* 36(2) 416–432.
[215] See Agriculture Science and Technology Achievement Transfer Fund website, www.agrifund.cn/www/agro/index.html.
[216] Wang, S. and Li, C. 2005. Analysis of constraints and solutions in the transformation of agricultural technology research findings in China. *Science & Technology and Economy* 18(5)27–29 [王树进, 李彩霞, 2005年. 我国农业科技成果转化的障碍分析与对策. 科技与经济 18(5) 27–29]; Shi, M. and Chen, H. 2009. Current problems existing and solutions in the transformation of agricultural technology research findings in China. *Agricultural Science and Technology Management* 28(2) 83–85 [石明权, 陈宏, 2009. 目前农业科技成果转化中存在的问题及其解决的对策. 农业科技管理 *28*(2) 83–85]; Xiao, X. *et al.* 2015. The measurement and comparative analysis of transformation efficiency of agricultural science and technology achievements. *China Science and Technology Forum* 8(8) 139–149 [肖娴, 毛世平, 孙传范, 胡小鹿, 2015. 农业科技成果转化效率测度及分析. 中国科技论坛, (8), pp.139–144].

The policy framework for sustainable agriculture

Numerous plans, policies and programmes are being implemented to address specific environmental and socio-economic challenges to agricultural sustainability. Diverse forms of sustainable agriculture are being promoted by government. The recent *National Plan for Sustainable Development of Agriculture (2015–2030)* sets out the framework for government actions in the coming years.

4

In recent years, national development policies supportive of more sustainable agricultural practices have emerged. In 2005, the 16th Chinese Communist Party Congress identified the need to hasten the development of resource-conserving and environmentally friendly economic development models. In 2012, at the 18th Party Congress, environmental objectives were put on an equal footing with other development objectives in the higher political framework for national development – a move that has been taken to signify the priority given to environmental issues.[217] In April 2015, the Chinese Communist Party and State Council issued *Opinions on Hastening Construction of Ecological Civilization*, which stressed that green development, circular economy development and low-carbon development are basic approaches for constructing an 'ecological civilisation'.[218] These overarching approaches to development now provide the broader political framework for specific policies and plans in each sector and across sectors.

Since the turn of the century, the central government has given high priority to rural, agriculture and farmers' issues. Many of the challenges discussed in the previous chapter have been the target of specific policies and programmes in the agriculture and related sectors. The *National Plan for Sustainable Development of Agriculture (2015–2030)* has recently been issued by the Ministry of Agriculture together with seven other ministries. It sets out the framework for government actions in the coming years.

This chapter begins by describing China's general agricultural development policies and then outlines more specific policies to address particular sustainability challenges. It concludes by exploring policies and measures to support specific forms of sustainable agriculture, including the *National Plan for Sustainable Development of Agriculture*.

4.1 Key elements of China's national agricultural policy

Food security

Meeting the needs of the nation for food security is one of China's primary agricultural policy objectives. Framework policies and plans were issued in 1996 and in 2008; they state the aim of maintaining 95% self-sufficiency in the supply of the most important cereal grains.[219] Specifically, the *Medium and Long-term Plan for National Food Security (2008–2020)* set the objective of achieving self-sufficiency in rice, wheat, and animal and aquatic products, and 'basic self-sufficiency' in maize. A number of policies have been put in place to meet this target, including support to grain production, development of marketing and logistics systems, a grain reserve policy and support for the development of grain processing industries.

In the last two decades, China's food consumption patterns have changed significantly. The per capita direct consumption of cereal grains has begun to decrease, while consumption of meat, milk and other non-staple food products has increased.[220] Correspondingly, the use of cereal grains has changed, with an increasing proportion of grain now destined for livestock feed and industrial uses. Net imports of grain have increased in recent years, led particularly by imports of soy bean, though maize imports have also been large in some years (Figure 7). To put these imports in perspective, however, in 2012 wheat and maize imports were equivalent to about 2–3% of national output of these crops. On the other hand, soybean imports were more than two times larger than domestic output. This reflects China's comparative advantage in trade, as the country is a major importer of land-intensive agricultural products (e.g. soybean, maize), rather than labour-intensive crops such as vegetables. 'Making use of two markets [i.e. domestic and international markets] and two resources [i.e. domestic and overseas resources]' has long been a tenet of Chinese international trade policy.[221] The potential for Chinese demand to influence global food

[217] Hu, J. 8 November 2012. Report at the Eighteenth Congress of the Communist Party of China (8th November 2012).People.cn [胡锦涛.2012年11月8日. 胡锦涛在中国共产党第十八次全国代表大会上的报告. http://cpc.people.com.cn/n/2012/1118/c64094-19612151.html].
[218] Chinese Communist Party and State Council. 2015. *Opinions on Hastening Construction of Ecological Civilization.* Xinhua News Agency, Beijing [中共中央、国务院, 2015 年. 关于加快推进生态文明建设的意见].
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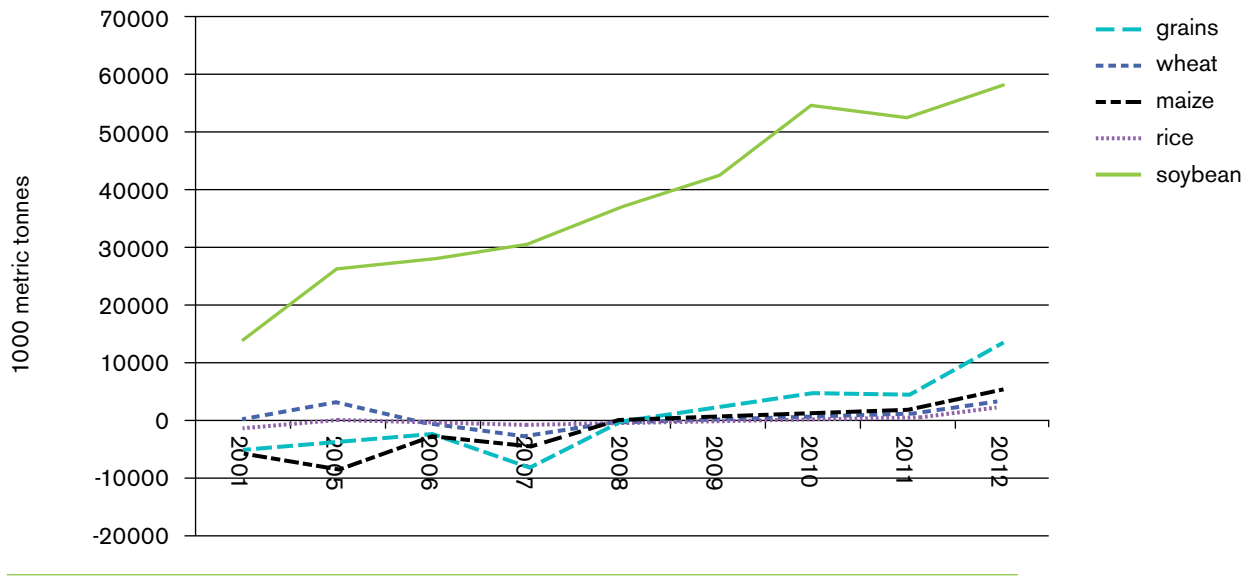
[220] Cao, L. *et al.* 2013. Recent food consumption trends in China and trade implications to 2020. *Australasian Agribusiness Review* (21) 15–44.
[221] Hu, Y. 1982. On foreign economic relations. In: Communist Party Center Archive Editorial Committee (ed.). 2015. *Selected Works of Hu Yaobang.* People's Press, Beijing. [胡耀邦 1982年.关于对外经济关系问题. 中共中央文献编辑委员会（编）. 胡耀邦文选.人民出版社, 北京].

prices on international markets has been a concern of analysts and policy makers for many years. Most recent analysis suggests that China is likely to continue to be able to meet its food supply needs in the short and medium term, while continuing to rely on imports of land-intensive products such as soy bean and animal feed stock.[222] The recently issued *National Plan for Sustainable Development of Agriculture (2015–2030)* continues to stress the importance of ensuring an increase in national grain supply, while also prioritising improvement in the quality and safety of food products, and in resource use efficiency, sustained increase in farmers' incomes and reductions in environmental impacts.[223] According to the plan, imports are expected to continue to play a role in maintaining market stability and making best use of comparative advantage in China.

Food quality and safety

Supply of basic grains is not the only focus of China's food security policy. While initial policies in the 1990s focused significantly on securing food supply,[224] national policies in agriculture and related sectors have responded to the shift in the structure of food demand and changes in agri-food supply chains.[225] Consumption of livestock products, sugars and edible oils has increased in both rural and urban populations,[226] and consumption of processed food products is now common.[227] Restaurants, supermarkets and convenience stores account for an increasing share of food retail, in both urban and rural areas.[228] National nutritional policy now focuses on meeting people's needs for diverse, quality foods, and the need to improve food safety.[229] Policies and plans relate not only to agricultural production, but also

Figure 7. Net imports of major grain crops, 2001–2012



Source: Ministry of Agriculture. 2013. Ten key points that must be borne in mind in selection of agricultural trade policy. Beijing. [农业部，2013年。农业贸易政策选择需要注意把握的十大要点。北京].

[222] Norse, D., Lu, Y. and Huang, J. 2014. China's food security: Is it a national, regional or global issue? In Brown, K. (ed.). *China and the EU in Context*. Palgrave, London; Keats, S. and Wiggins, S. 2012. *China: Are changes afoot for cereals?* Working Paper. Overseas Development Institute, London.
[223] Ministry of Agriculture. 2015. *National Plan for Sustainable Development of Agriculture (2015–2030)*. Ministry of Agriculture, Beijing [农业部, 2015年.全国农业可持续发展规划（2015–2030年）].
[224] State Council. 1993. *Food Structure Reform and Development Masterplan for the 1990s*. State Council of the PRC, Beijing [国务院, 1993年. 九十年代中国食物结构改革与发展纲要].
[225] Garnett, T. and Wilkes, A. 2014. *Appetite for Change: Social, Economic and Environmental Transformations in China's Food System*. Food Climate Research Network, Oxford
[226] Cao, L. *et al.* 2013. Recent food consumption trends in China and trade implications to 2020. *Australasian Agribusiness Review* (21) 15–44.
[227] Zhou, Y. *et al.* 2015. The food retail revolution in China and its association with diet and health. *Food Policy* (55) 92–100.
[228] Zhai, F. *et al.* 2014. Dynamics of the Chinese diet and the role of urbanicity, 1991–2011. *Obesity Reviews* 15(S1) 16–26.
[229] Health and Family Planning Commission. 2014. *Development Masterplan for Food and Nutrition in China (2014–2020)*. Health and Family Planning Commission, Beijing [卫生和计划生育委员会, 2014年. 中国食物与营养发展纲要（2014–2020年）].

to the development of logistics systems, processing sectors, food safety diagnostic technologies and other aspects of modern food production and distribution systems.[230]

In recent years, food safety has become a dominating concern. Polls indicate it ranks among the top concerns of China's citizens.[231] Several studies indicate the willingness of middle-class, urban consumers to pay a premium for traceable or certified food, such as 'green' or organic foods (see Section 4.3).[232] In 2012 the State Council issued its *Twelfth Five Year Plan for Food Safety Regulation*.[233] The plan sets out new institutional arrangements for the monitoring and regulation of food safety; proposes to increase the proportion of products labelled as hazard-free, green, organic or with a geographical indication (see Section 4.3) and proposes traceability systems be developed for milk powder, meat products, vegetables, alcohol and health foods. Considerable challenges are faced in implementing these systems,[234] but in the longer term traceability requirements may fundamentally change producers' market access conditions and affect relationships between farmers and other supply-chain actors involved in food production and marketing.

In response to a number of food safety scandals in recent years, the *Food Safety Law* was amended in 2013.[235] This amendment established the China Food and Drug Administration (CDFA) as the main central government authority responsible for food safety. Its role is to supervise and administer the safety of food production, food trade and consumption processes, as well as to conduct inspections and testing. The National Health and Family Planning Commission is responsible for food safety risk evaluation and food safety standards development, while the Ministry of Agriculture is responsible for the quality and safety of agricultural products. The 2013 amendment also created a new food production and operation licensing system, increased food companies' responsibilities for food safety, and introduced severe penalties for illegal activities.

Following the newly amended law, nearly 5,000 national food quality and hygiene standards have been reviewed, clarified or merged to eliminate contradictions.[236] Efforts have also been made to strengthen food quality and safety monitoring capabilities at the local level throughout the country, although many institutional, standardisation and capacity issues have yet to be resolved.

Financial support to agriculture

The national policy objectives of ensuring the provision of sufficient, diverse, quality and safe food while also improving farmers' incomes are supported by substantial fiscal investment in the agriculture sector. Support to agricultural production is delivered through farm subsidies and grants to agricultural development programmes. Together, these public expenditures have been estimated at about US$ 87 billion in 2011, which is equivalent to about 10% of the value of agricultural output.[237]

In 2006, agricultural taxes and levies were abolished, and China initiated a set of subsidy policies to support agricultural production. Subsidies to grain farmers increased from about US$ 12 million in 2002 to almost US$ 22 billion in 2011.[238] The vast majority of rural households (53–97% of households, depending on the province) receive subsidy payments. For grain farmers, subsidies include grain production subsidies, agricultural input subsidies, quality seed subsidies and agricultural machinery subsidies. On a per-household basis, the subsidies paid are a very small proportion of total income (agricultural income being less than one-third of total household income, on average). On a per-unit area basis, however, the subsidies are substantial, amounting to several hundred Yuan per hectare. These levels are similar to farming subsidies in the USA. A 2008 dataset suggests that the subsidies

[230] E.g. National Development and Reform Commission and State Grain Administration. 2011. *Twelfth Five Year Plan for the Grain Industry*. National Development and Reform Commission and State Grain Administration, Beijing; National Development and Reform Commission and Ministry for Industry and Information. 2012. *Twelfth Five Year Plan for the Food Industry*. National Development and Reform Commission and Ministry for Industry and Information [国家发改委、国家粮食局.2011年.粮食行业十二五发展规划纲要；国家发改委、工业信息部,2012年.食品工业十二五发展规划].
[231] Zhang, D., Gao, Y. and Morse, S. 2015. Corporate social responsibility and food risk management in China; a management perspective. *Food Control* (49) 2–10.
[232] E.g. Ortega, D. *et al.* 2011. Modeling heterogeneity in consumer preferences for select food safety attributes in China. *Food Policy* 36(2) 318–324; Zhang, C., Bai, J. and Wahl, T. 2012. Consumers' willingness to pay for traceable pork, milk, and cooking oil in Nanjing, China. *Food Control* 27(1) 21–28; Xu, P. *et al.* 2012. Chinese consumers' willingness to pay for green-and eco-labeled seafood. *Food Control* 28(1) 74–82.
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[234] Tang, Q. *et al.* 2015. Food traceability systems in China: The current status of and future perspectives on food supply chain databases, legal support, and technological research and support for food safety regulation. *Bioscience Trends* 9(1) 7–15.
[235] FORHEAD. 2014. *Food Safety in China: A mapping of problems, governance and research*. www.forhead.org.
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[237] Garnett, T. and Wilkes, A. 2014. *Appetite for Change: Social, Economic and Environmental Transformations in China's Food System*. Food Climate Research Network, Oxford ; Gale, F. 2013. *Growth and Evolution in China's Agricultural Support Policies*. Economic Research Report 153. USDA Economic Research Service, Washington, DC.
[238] Huang, J., Wang, X. and Rozelle, S. 2013. The subsidization of farming households in China's agriculture. *Food Policy* (41) 124–132.

offset between 2% and 13% of the total production costs, depending on crop type.[239] The payment of farm subsidies has little impact on the grain area sown (except among cash-constrained households) or the use of inputs such as fertilisers, however, and thus raises farmers' income without contributing significantly to national food security objectives.

There are substantial indirect subsidies to fertilisers. The energy use and transportation costs of fertiliser factories are heavily supported through direct subsidies and tax breaks.[240] To the extent that these subsidies are passed on in lower fertiliser prices, they encourage fertiliser use and contribute to the severe adverse environmental impacts of excess nitrogen use in Chinese agriculture (Chapter 3). There are also subsidies for pig production for smallholders (e.g. subsidies for raising sows, for insurance and for improved breeds), as well as subsidies and tax breaks for large-scale pork, poultry, beef and dairy producers.[241]

In addition to direct subsidies, the central government makes substantial investments in agricultural development programmes. Many of these programmes are specified in 'Document No. 1', the annual statement of central government policy priorities for the year. Ministries use this document to approach the Ministry of Finance for funding to implement the policies and programmes outlined. Every year since 2004, Document No. 1 has focused on rural, agricultural and farmers' issues. In 2010, it confirmed a gradual increase in total investment in the sector, with subsidy programmes for a number of crops and for water-saving irrigation equipment, as well as expansion of the role of the Agricultural Development Bank. In 2011, it focused on improving irrigation infrastructure, while in 2012 the focus was on agricultural technology. In 2013, it stressed support for developing new agricultural economic institutions, such as farmer cooperatives and specialised farming households. In 2014 and 2015, the document called for an increase in financial products targeting rural areas and agriculture, and preferential financial access for farmers and agribusiness.[242] A number of public finance programmes target large farms, farms introducing 'standardised' production techniques and key enterprises in agri-food supply chains.[243] The extent to which public support for large-scale agriculture subsidises otherwise inefficient and unprofitable production is not known, but has long been a concern.[244]

The banking sector also provides finance to farmers and agricultural enterprises. Major financial service providers include the Agricultural Bank of China, Agricultural Development Bank of China, Rural Credit Cooperatives and the Postal Savings Bank of China. The Agriculture Bank of China has specific loan products for agricultural investments, and preferential loans for certain categories of farmer.[245] The Agricultural Development Bank and China Development Bank are policy banks providing major loans to government and the private sector for infrastructure and agricultural development. In recent years, reforms to rural finance have focused on strengthening the Rural Credit Cooperatives,[246] and since 2006 on relaxing constraints on other forms of financial institution in rural areas.[247] By the end of 2014, rural commercial banks, rural cooperative banks, and credit cooperatives had total assets of more than US$ 3.2 trillion.[248] In the last decade, the banking sector has generally shifted its focus towards sectors with higher rates of return and lower risk than agriculture. Despite rural finance sector reforms, many farmers, and poor farmers in particular, remain credit constrained.[249] In some poorer parts of western China, formal financial institutions take significantly higher deposits from farmers than the volume of credit made available to

[239] Huang, J. *et al.* 2011. Subsidies and distortions in China's agriculture: Evidence from producer-level data. *Australian Journal of Agricultural and Resource Economics* 55(1) 53–71; Yi, F., Sun, D. and Zhou, Y. 2015. Grain subsidy, liquidity constraints and food security: Impact of the grain subsidy program on the grain-sown areas in China. *Food Policy* 50 114–124.
[240] One study estimates these subsidies to total US$ 7.46 billion in 2008–9 alone. Heffer, P. and Olegario, A. 2010. Fertiliser subsidy situation in selected countries: 2008/9. International Fertiliser Industry Association, cited in Zhang, W. *et al.* 2013. New technologies reduce greenhouse gas emissions from nitrogenous fertiliser in China. *Proceedings of the National Academy of Sciences* 110(21) 8375–8380.
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[242] Chinese Communist Party and State Council. 2014. *Several Opinions on Deepening Rural Reform to Hasten Promotion of Agricultural Modernization.* Xinhua News Agency, Beijing; Chinese Communist Party and State Council. 2015. *Several Opinions on Increasing Reform Innovation to Hasten the Construction of Modern Agriculture.* Xinhua News Agency, Beijing [中共中央、国务院. 2014年. 关于全面深化农村改革加快推进农业现代化的若干意见; 中共中央、国务院. 2015年. 关于加大改革创新力度加快农业现代化建设的若干意见].
[243] State Council. 2012. *State Council Opinion on Support for Agricultural Commercialization 'Dragon-head' Enterprise Development.* State Council of the PRC, Beijing [国务院, 2012年. 国务院关于支持农业产业化龙头企业发展的意见].
[244] Prosterman, R., Hanstad, T. and Li, P. 1996. *Large-scale Farming in China: An appropriate policy?* Report on Foreign Aid and Development 90. Rural Development Institute, Seattle.
[245] www.abchina.com.
[246] State Council. 2003. *Circular Regarding Pilot Programs for Deepening Rural Credit Cooperatives Reform.* State Council of the PRC, Beijing [国务院, 2003年. 关于印发深化农村信用社改革试点方案的通知].
[247] China Banking Regulatory Commission. 2006. *Some Opinions on Adjusting and Relaxing the Access Policies for Banking Financial Institutions in Rural Areas and Better Supporting the Construction of New Socialist Countryside.* China Banking Regulatory Commission, Beijing [中国银行业监督管理委员会, 2006年. 关于调整放宽农村地区银行业金融机构准入政策更好支持社会主义新农村建设的若干意见].
[248] Boao Review. 26 March 2015. Boao Review issues '2015 Rural Finance Development Report' [博鳌观察.2015年3月26日. 博鳌观察《农村金融发展报告2015》发布. www.boaoreview.org/html/boaoyazhouluntan2015nianhui/nongcunjinrong/zu/2015/0326/3723.html].
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them.[250] There is evidence, however, that microcredit providers allowed to enter the rural market after the 2006 reforms may be able to compete effectively with other sources of formal and informal credit.[251]

4.2 Policies to address key sustainability challenges

Policies to tackle land loss and degradation

Section 3.1 discussed China's challenges in maintaining both the quantity and quality of arable land. Protection of arable land is defined in law as a basic national strategy,[252] and a series of regulations have been put in place to regulate the conversion of arable land to construction land. The *National Land Use Masterplan (2006–2020)* sets a target of maintaining 120 million ha of arable land, including 104 million ha of 'basic farmland' (i.e. arable land that should be protected from conversion to other uses).[253] This is to be achieved by implementing an arable land balance system at the provincial level, in which areas lost to non-agricultural uses have to be replaced by new (or reclaimed) arable land, as mandated in the *Land Management Law*.[254] In the 2008 ministerial restructuring, the Ministry of Land Resources was given the mandate for macro-level planning of land resources.

However, analysis suggests that these measures have not been successful in limiting arable land conversion.[255] A key obstacle is that local governments depend on revenues from land-use right auctions – contributing as much as 50% of their fiscal revenues in some cases. This gives them strong incentives for land-use conversion.[256] Moreover, the arable land balance system has been criticised for leading to replacement of high quality land with poor quality land.[257] Further regulations issued in 2014 aim to tighten the supervision of land-use plans, regulate the approval of construction, take both the size and quality of arable land into account, strictly identify and permanently protect arable land, prevent collective land from being transferred and used for non-agricultural purposes, and promote land-sparing practices in urban construction.[258] In addition, China has developed a system of finance for land consolidation, which also helps to offset the impact of arable land conversion on agricultural output (Box 2).

BOX 2. FINANCIAL SOURCES FOR LAND CONSOLIDATION IN CHINA[259]

The *Land Management Law* of 2005 states that construction companies can obtain use rights to state-owned land through the payment of fees, including a fee for the compensated use of newly increased construction land. Of the revenue from this fee, 30% must be submitted by local government to a central government fiscal account, while the remaining 70% remains in the local government fiscal account. However, both shares must be used for developing arable land resources. In 2009, the total national revenue from compensatory payments for land-use right transfers was US$ 205 billion. Of this, US$ 13.5 billion (i.e. 6.5% of the total revenue) was from the fees for acquiring new building land.[260] The current regulations explicitly encourage the use of funds for land consolidation projects. Land consolidation involves land levelling, improvements in irrigation infrastructure and farm access roads, as well as ecological conservation measures (e.g. wind break plantations). The central government-managed portion of the levied revenues is largely used to fund key national land consolidation projects, while the local government portion funds local projects. One main focus of land consolidation activities is the improvement of irrigation and drainage infrastructure across 26.7 million hectares of arable land.

[250] Song, H. 2009. Analysis of the current financial environment in agro-pastoral areas of Qinghai. *Journal of Qinghai Nationalities Institute (Social Sciences Edition)* 35(2) 104–107 [宋慧, 2009年. 青海农牧区金融生态现状分析. 青海民族学院学报: 社会科学版 (2):104–107]; Song, H. 2010. Current status of micro-credit in agro-pastoral areas of Qinghai and recommendations for development. *Qinghai Social Sciences* 2010(4) 82–85 [宋慧, 2010. 青海农牧区小额信贷现状与发展对策. 青海社会科学 (4) 82–85].
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[255] Xu, G. *et al.* 2015. Assessment on the effect of city arable land protection under the implementation of China's National General Land Use Plan (2006–2020). *Habitat International* (49) 466–473.
[256] Lu, Y. and Sun, T. 2013. *Local Government Financing Platforms in China: A fortune or misfortune?* Working Paper 13/243. International Monetary Fund, Washington DC.
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There have been a number of major policies and programmes established to tackle land degradation and desertification. These include large forestry programmes, particularly in northern China.[261] The largest programme directly affecting arable land is the Sloping Farmland Conversion Programme (also known as 'Grain for Green'). Implementation began in 1999 following severe flooding in the Yangtze River basin the year before. The programme pays farmers subsidies to convert marginal arable land (e.g., land on slopes steeper than 25°) to forest or grassland, and has afforested large areas of degraded and abandoned cropland. As of 2008, 26.7 million ha were enrolled in the programme, including 9.3 million ha of afforested arable land and 15.8 million ha of afforested wasteland. The programme is one of China's largest payment for ecosystem services schemes.[262] Despite some reports of low tree survival rates and inappropriate species selection in some areas,[263] most assessments of the programme's environmental impacts are favourable and include ecological restoration, carbon sequestration, water retention and reduced soil erosion.[264] At the same time, the programme's impacts on rural incomes, income inequality, local food production, and also biocultural heritage have been more varied.[265] In general, farmers have avoided adverse impacts on incomes by increasing their participation in off-farm work, but not all households have been able to benefit to the same extent, and the risk remains that converted lands will be taken back into cultivation. Since 2007, the programme has been in a 'consolidation' phase aimed at ensuring the goals are met in existing target areas, rather than expanding the area covered.[266] Large-scale land rehabilitation programmes have also targeted remediation of land degradation in areas affected by desertification, karst regions, and northeast China's black soil region.[267]

Beyond specific forms of land degradation, soil fertility management is relevant across the country to maintain and improve arable land quality. Some local governments have piloted incentive programmes to encourage farmers to incorporate crop residues in fields and to promote composting, and in some areas there are subsidies for machinery to process crop residues for composting. So far there have been few assessments of these policy impacts.[268] Similarly, conservation agriculture has been widely promoted in China, involving improved vegetation cover and reduced or zero tillage. In 2007, the Ministry of Agriculture announced a target of 4 million hectares under conservation agriculture by 2010.[269] Despite controlled experiments showing its benefits for soil fertility and yields,[270] there have been few studies of adoption rates or barriers to adoption by farmers.[271] Most research has been conducted on experimental or demonstration farms.[272] The *National Plan for the Sustainable Development of Agriculture (2015–2030)* also promotes activities such as conservation tillage, crop residue management, application of organic manure, and cultivation of green manure in order to increase soil fertility, as well as

[261] China National Committee for the Implementation of the UNCCD. 2006. *China National Report on the Implementation of the United Nations Convention to Combat Desertification*. UNCCD, Bonn.
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[270] E.g. Chen, H. *et al.* 2008. Traffic and tillage effects on wheat production on the Loess Plateau of China: 1. Crop yield and SOM. *Soil Research* 46(8) 645–651.
[271] But see Cai, R. and Cai, S. 2012. The adoption of conservation agricultural technology and the impact on crop yields based on rice farms in Anhui Province. *Resources Science* 34(9) 1705–11 [蔡荣, 蔡书凯. 保护性耕作技术采用及对作物单产影响的实证分析:基于安徽省水稻种植户的调查数据. 资源科学. 34(9) 1705–11]; Wang, J. and Zhang, L. 2010. The impact of conservation tillage technology on agricultural production: empirical research in the Yellow River Basin. *Management Review* 22(06) 77–84 [王金霞, 张丽娟 (2010) 保护性耕作技术对农业生产的影响: 黄河流域的实证研究. 管理评论 *22*(06): 77–84].
[272] E.g. He, J. *et al.* 2010. The adoption of conservation tillage in China. *Annals of the New York Academy of Sciences 1195*(s1): E96–E106; Brouder, S. and Gomez-Macpherson, H. 2014. The impact of conservation agriculture on smallholder agricultural yields: A scoping review of the evidence. *Agriculture, Ecosystems & Environment* (187) 11–32.

processing of crop residues into fertiliser and animal feed in order to increase utilisation rates.[273]

Policies to improve water resources management

Over-extraction, low efficiency and poor water quality are recognised by the government as major challenges. In 2010, the government issued its 'Three Red Lines' policy, which sets out the following targets to be achieved by 2030:

- reducing total national water consumption to less than 700 billion m3 per year
- achieving irrigation use efficiency of 60%
- reducing water consumption to 40 m3 per 10,000 CNY of GDP produced
- improving water quality so that 95% of key hydrological zones exceed minimum standards.[274]

In 2011, central government committed to doubling state investment in water infrastructure over ten years to address multiple water-related issues, including climate change adaptation, drought and flood management, as well as food security. Investment in small-scale irrigation facilities has amounted to 300 billion CNY per year since the policy announcement,[275] with further investments in rural reservoirs and drinking water supplies.

Several institutional reforms have also been introduced in order to improve agricultural water management. After villages inherited irrigation infrastructure from the former collectives in the 1980s, infrastructure ownership and management rights were often unclear and water management was inefficient. In the 1990s, the government began to promote water user associations (WUAs) to facilitate collective management. It promoted the contracting of management responsibilities by the village collective to individuals, on the theory that contracts would provide incentives for improved management. The number of WUAs grew rapidly nationwide in the 2000s, reaching more than 30,000 WUAs by 2006.[276] WUAs continue to be promoted in recent policies.[277] In some cases, WUAs and contracting have provided positive incentives for water managers, and water resource management has improved. However, many WAUs are reportedly not functioning effectively.[278] This is probably because of their top-down process of establishment. Farmers' incentives to join them are affected by individual and group characteristics and by resource scarcity, and gender.[279,280] Despite the increasing role of women in agricultural production and management, women tend to be marginalised from active participation in WUAs. During the 1990s, water pricing and water use-rights transfers began to be used in some local areas, but a national policy to do so has not emerged because of concerns about impacts on agricultural production.[281] However, a policy announcement in January 2016 indicates the government's intention to develop a national water pricing policy within the coming decade.[282]

Adoption of water-saving technologies has expanded significantly, particularly in land sown to high-value cash crops where investment in technology has a higher return. Adoption of technologies and farming techniques at household level (e.g. intermittent irrigation, mulching, drought-resistant varieties) has been faster than those technologies that are implemented at the community level (e.g. drip irrigation, canal lining). A 2010 survey of seven provinces across the country found that 73% of households (farming 32% of the crop area) had adopted a water-saving technology, but only 17% of households (farming 4% of the crop area) were benefiting from a community-based technology.[283] Government financial and extension service support for improved irrigation technologies has had a positive impact on adoption at both household and community level. While water pricing has had a positive impact on adoption at household level, it has had the opposite

[273] Ministry of Agriculture. 2015. *National Plan for Sustainable Development of Agriculture (2015–2030)*. Ministry of Agriculture, Beijing [农业部，2015年。《全国农业可持续发展规划（2015–2030年）》。北京].
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[277] Ministry of Water Resources *et al.* 2014. *Guiding Opinion on Encouraging and Supporting Innovation and Development of Farmer Water User Organizations*. Ministry of Water Resources, National Development and Reform Commission, Ministry of Civil Affairs and Ministry of Agriculture, Beijing [水利部、国家发展与改革委员会、民政部、农业部, 2014年. 关于鼓励和支持农民用水合作组织创新发展的指导意见].
[278] Huang, Q. *et al.* 2010. Empirical assessment of water management institutions in northern China. *Agricultural Water Management* 98(2) 361–369.
[279] Qiao, G., Zhao, L. and Klein, K. 2009. Water user associations in Inner Mongolia: Factors that influence farmers to join. *Agricultural Water Management* 96(5) 822–830; Zhang, L. *et al.* 2013. Water users associations and irrigation water productivity in northern China. *Ecological Economics* (95) 128–136.v
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[282] Xinhua News Agency. 30 January 2016. China works for more efficient water use in agriculture. See www.china.org.cn/china/Off_the_Wire/2016-01/30/content_37701769.htm.
[283] Cremades, R., Wang, J. and Morris, J. 2015. Policies, economic incentives and the adoption of modern irrigation technology in China. *Earth System Dynamics* (6) 399–410.

effect for community-based technologies.[284] This is most likely because rising water prices stimulate households to adopt their own water-saving technologies and these substitute for community-based initiatives. Public investment in irrigation has not increased the irrigated area, but has mostly served to improve the efficiency of water use in the existing irrigated area.[285]

Policies to prevent pollution of the production environment

Addressing water quality is an equally significant challenge. The government's main approach has been to strengthen regulations, monitoring and enforcement. The 2008 *Water Pollution Law* introduced harsher penalties for enterprises polluting water resources, and national water quality standards have been updated to include a wider range of pollutants. The Ministry of Environmental Protection has established Regional Supervision Centres to improve monitoring of enterprise discharges, and the Ministry of Water Resources has established water quality agencies in the main river basins. More than 10,000 monitoring stations have been established nationwide. Their success at tackling environmental pollution has also been included in the job assessment criteria for government officials, a measure that reportedly has had some effect.[286]

Fertiliser use and livestock waste management are the two largest sources of non-point water pollution in China (Section 3.1).[287] The main policy to reduce overuse of nitrogen fertiliser is the National Soil Testing and Fertiliser Programme (STFR). The STFR covers all 2,498 agricultural counties and about US$ 1 billion has been invested to date. The programme involves testing soil properties and crop fertiliser needs to make location and crop-specific fertiliser recommendations. Specialised NPK mixture fertilisers are then produced by 100 participating fertiliser firms and supplied to farmers along with guidance for their application. There has not yet been any comprehensive assessment of the effectiveness of this policy. One study using provincial data suggested that synthetic nitrogen (N) application rates for cereal crops decreased from 179–203 kg N/ha in 1998 to 157–175 kg N/ha in 2008, with annual reduction rates of 3.2 kg N/ha/year for rice, 2.5 kg N/ha/year for wheat, and 5.1 kg N/ha/year for maize.[288] However, farmer-level studies of the impact of agricultural extension and training as part of this programme produce a more varied picture, with impacts ranging from insignificant to positive.[289,290] The effectiveness of training has been found to vary depending in part on whether it is delivered by fertiliser companies, sales shops, extension agencies, NGOs or research institutes.[291] Training alone may be insufficient to change fertilisation practices,[292] in some cases because recommended nutrient management practices may reduce profitability.[293]

Biogas has been widely promoted for many years as a way of dealing with livestock waste. By the end of 2011, 41 million biogas units had been built across the country, mostly for individual household use.[294] However, this is reportedly only a small fraction of the technical potential. A number of constraints have been identified, including farmers' preferences for alternative energy sources, limited availability of fermentation materials and financial barriers to household investment.[295] Even where biogas is made, the slurry is often not used. Although most farmers know that biogas slurry is a good fertiliser, few are able or willing to take on the costs of transporting it to their fields. Instead it is abandoned.

Although policies promote the use of livestock waste, use rates are often low for reasons discussed in Section 3.1 above. Easier treatment of livestock waste has been one of the reasons behind a policy to shift dispersed livestock production to concentrated livestock-raising areas. Fiscal support for concentrated livestock-raising

[284] Cremades, R., Wang, J. and Morris, J. 2015. *ibid.*
[285] He, F. *et al.* 2015. Irrigation investment in China: Trends, correlates and impacts. *China Agricultural Economic Review* 7(3) 344–359.
[286] Yu, W., Gao, N. and Zha, J. 2015. Political achievement demands of local officials, government intervention and regional environmental pollution: Empirical analysis based on Chinese city-level data. *China Economic Studies* (5) 35–45 [于文超，高楠，查建平，2015年. 政绩诉求、政府干预与地区环境污染:基于中国城市数据的实证分析. 中国经济问题 (5) 35–45].
[287] Ministry of Environmental Protection. 2015. *China Environment Report 2014.* Ministry of Environmental Protection, Beijing [环境保护部, 2015年.中国环境状况公报2014年].
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[290] Huang, J. *et al.* 2012. Impacts of training on farmers' nitrogen use in maize production in Shandong, China. *Journal of Soil and Water Conservation* 67(4) 321–327.
[291] Li, S. and Ma, J. 2015. Assessment of the effectiveness of training by different actors and policy implications: The example of soil fertiliser testing. *Science & Technology and Economy* 28(3) 50–54 [李莎莎，马骥，2015年. 不同技术培训主体的效果评估及政策启示:以测土配方施肥为例. 科技与经济 28(3) 50–54].
[292] Jia, X. *et al.* 2013. Farmer's adoption of improved nitrogen management strategies in maize production in China: An experimental knowledge training. *Journal of Integrative Agriculture* 12(2) 364–373.
[293] Ha, N. *et al.* 2015. The effect of simple nitrogen fertiliser recommendation strategies on product carbon footprint and gross margin of wheat and maize production in the North China Plain. *Journal of Environmental Management* (163) 146–154.
[294] Xia, Z. 2013. *Domestic Biogas in a Changing China: Can Biogas Still Meet the Energy Needs of China's Rural Households?* IIED, London.
[295] Chen, Y. *et al.* 2010. Household biogas use in rural China: A study of opportunities and constraints. *Renewable and Sustainable Energy Reviews* 14(1) 545–549.

areas began in 2006, and has been listed as a key measure in recent government regulations.[296] Gradual progress has also been made in developing laws and regulations to improve livestock waste management on the increasing number of large livestock farms. The *Environment Law (1989)* established regulatory measures to enforce the adoption of pollution abatement measures. These include the 'Three Simultaneous' system, which (1) requires that pollution abatement is addressed in the design and construction of facilities; (2) requires that these abatement measures are used when the facility goes into production; and (3) established a waste permission application system, so that polluting enterprises have to apply for permission to emit pollutants. Since 2001 these regulations have been applied to pig farms with more than 500 animals, chicken farms with more than 30,000 chickens and cattle farms with more than 100 cows.[297] However, some commentators have noted that the emission standards were extremely lax, providing no incentive to reduce emissions.[298] Exhortations for livestock farms and local environment bureaus to comply with these regulations have been frequent. In 2013, new regulations were issued that apply to large-scale facilities (e.g. >500 pigs), but there are still no standards or regulations applicable to small-scale producers.[299]

In recent years there has been closer collaboration between the environment and agriculture ministries. This is illustrated by their joint publication of the *Twelfth Five Year Plan on Prevention and Treatment of Livestock Waste* in 2011.[300] The plan proposed to clarify the situation of livestock waste pollution by 2015; establish a regulatory, standardisation and monitoring system; and to define locations that should be free from livestock production in order to reduce non-point pollution risks. The plan sets the target of installing waste treatment facilities on 50% of large-scale livestock production farms (as defined above) by 2015 – a goal that is supported by subsidy programmes.

Despite these measures, surveys often still report low rates of treatment for waste discharge, and a range of problems in implementing the livestock waste treatment regulations are often raised. Multiple agencies are involved in the enforcement of regulations, and there is often a need for stronger coordination in planning and approvals,[301] particularly since the environment agency is often not in a strong administrative position in local governments. Pig and dairy enterprises are already operating on low profit margins, so they have little economic potential or incentive to take on the costs of prevention and treatment of pollution.[302] On the other hand, some companies have recouped heavy investments in environmental impact assessments and treatment facilities by establishing organic compost enterprises.

Heavy-metal contamination of soils has only begun to be addressed by government plans and programmes in the last few years. The *Twelfth Five Year Plan for Comprehensive Prevention and Treatment of Heavy Metal Pollution* was approved in 2011, but only released in 2014.[303] A national survey of heavy metal contamination of soils was completed in 2009, but partial results were only released at the end of 2013.[304] A *National Soil Pollution Action Plan* was drafted by the Ministry of Environment in early 2014, but only submitted to the State Council in mid-2015 and had still not been formally approved by early 2016.[305] Media reports suggest that these delays reflect not only the complexities of consultation among several ministries, but also uncertainty about technical measures to address the problem.[306] Other media reports suggest that the action plan will be implemented in the coming

[296] Ministry of Agriculture. 2006. *Standardized Poultry and Livestock Raising Area Pilot Project Guide*. Ministry of Agriculture, Beijing [农业部，2006年. 标准化畜禽养殖小区试点项目指南]; State Council. 2013. *Regulations on the Prevention of Pollution from Scale-Production of Livestock and Poultry*. State Council of the PRC, Beijing [畜禽规模养殖污染防治条例].
[297] State Environmental Protection Administration. 2001. *Livestock and Poultry Pollution Prevention Management Method*. State Environmental Protection Administration, Beijing [环境保护总局，2001年. 畜禽养殖污染防治管理办法].
[298] Su, Y. 2005. Analysis and countermeasures against the obstacles of waste treating of intensive livestock and poultry farms in China. *Ecology and Environment* 14(2) 271–274 [苏杨, 2005年.我国集约化畜禽养殖场污染治理障碍分析及对策. 生态环境14(2) 271–274].
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[301] Gu, X. *et al.* 2011. Problems and suggestions regarding treatment of livestock waste pollution in Taihu, Suzhou City. *Shanghai Journal of Animal Husbandry and Veterinary Medicine* (1) 55–57 [顾旭萍, 许国平, 陈刚, 俞小红, 2011年. 苏州市环太湖畜禽养殖污染治理存在问题及建议. 上海畜牧兽医通讯 (1) 56–57].
[302] Miao, D. *et al.* 2013. Current status and development of standardized large-scale dairy production. *China Animal Husbandry*, 9 [缪冬梅，张院萍，李胜利，姚琨等，2013年。奶牛标准化养殖现状与发展。中国畜牧业，9：http://mall.cnki.net/magazine/Article/MYTX201309014.htm].
[303] Ministry of Environmental Protection. 2011. *Twelfth Five Year Plan for Comprehensive Prevention and Treatment of Heavy Metal Pollution*. Ministry of Environmental Protection, Beijing [环境保护部, 2011年.重金属污染综合防治十二五规划].
[304] Ministry of Land and Resources. 2013. *National Soil Pollution Situation Survey Report*. Ministry of Land and Resources, Beijing [国土资源部, 2013年.全国土壤污染状况调查公报].
[305] Wangyi Caijing. 18 May 2015. Market: Ten Land Rules has been submitted to State Council, land restoration concept leads to several shares rising. [网易财经.2015年5月18日. (市场)"土十条" 已上报国务院, 土壤修复概念多股大涨. http://money.163.com/15/0518/10/APT1KMCC00253B0H.html#from=keyscan].
[306] Xinhua Net. 26 November 2015. Ten Land Rules will set the timetable for soil pollution treatment – hopes that it will catalyse markets worth billions [新华网.2015年11月26日.土十条" 将定土壤污染治理时间表 望催生万亿级市场 http://news.xinhuanet.com/energy/2015-11/26/c_128469505.htm]; Hsu, A. and Moffat, A. 4 August 2014. China's soil pollution crisis still buried in mystery. China Dialogue. See www.chinadialogue.net/blog/7189-China-s-soil-pollution-crisis-still-buried-in-mystery/en.

five-year plan period (2016–2020).[307] They also suggest there will be significant financial support for implementing soil remediation pilot programmes in six regions, to apply and test technical measures for soil remediation. This will most likely involve forms of public-private partnerships and other fiscal incentives. Until the plan is released, one key concern is whether farmers will be allowed to continue cultivating severely polluted farmland. Recent technical guidance from the Ministry of Agriculture suggests that they will, with measures to adjust crop structure away from rice cultivation in regions where heavy metal uptake by rice is a significant risk.[308] Emissions of key heavy metals are being monitored, and recent results reportedly indicate a reduction of emissions in many provinces, but a continued increase in some others.[309]

4.3 Policy support for sustainable agriculture

National plan for the sustainable development of agriculture

In an attempt to address a range of environmental and other issues, in 2015 the Ministry of Agriculture and seven other ministries jointly issued the *National Plan for Sustainable Development of Agriculture (2015–2030)*. This medium-term plan can be expected to guide the development of legislation, government policy and funding programmes for the agriculture sector in the coming years.

The national plan addresses – to varying extents – many of the environmental challenges described in this report. Targets for maintaining the quantity of arable land are restated, and measures to promote soil nutrient management practices, manage soil pollution and redress land degradation are highlighted. Water-use efficiency targets are set, to be met through promoting water-saving technologies. Prevention of non-point pollution from fertiliser, pesticide and livestock waste receives significant attention. Links with food safety are also made through initiatives to monitor the agri-production environment and regulate agricultural production in locations where environmental parameters do not meet standards.

Among other things, the plan identifies the following key tasks:

- to promote ecological and circular agriculture (see next section), with targets to develop relevant models by 2020 in the national modern agriculture demonstration areas and main grain producing counties, and by 2030 to be on a path towards zero waste and emissions from agriculture;
- to protect and improve the quality grading of existing arable land, and to control pollutants from other sectors (e.g. industry, urban waste);
- to increase water-use efficiency in agriculture;
- to reduce agricultural non-point pollution by promoting soil nutrient testing and improved nutrient and pest management practices, with a goal of achieving zero increase in pesticide use by 2020, and promoting recycling of plastic mulch sheeting and pesticide packaging;
- to support large-scale livestock production farms to improve waste management so that 75% of livestock waste is reused by 2020 and 90% by 2030;
- to implement programmes to increase forest cover in desertified areas of northern China, protect grassland ecology, restore marine ecosystems and conserve biodiversity, including agrobiodiversity (Box 3).

[307] China Environment Online. 13 January 2016. Issue of the Ten Land Rules is imminent: analysis of soil remediation sector development trends. [中国环保在线. 2016年1月13日. "土十条" 出台在即 土壤修复行业发展趋势分析. http://www.hbzhan.com/news/Detail/103818.html].
[308] Information Office of the Ministry of Agriculture. 22 July 2015. China's agricultural resources and environment protection achieves positive progress [农业部新闻办公室.2015年7月22日.我国农业资源环境保护取得积极进展 http://www.moa.gov.cn/zwllm/zwdt/201507/t20150722_4758354.htm].
[309] Ministry of Environmental Protection. 19 November 2015. Ministry of Environmental Protection releases "Heavy metal pollution integrated prevention and treatment Twelfth Five Year Plan" 2014 assessment results. [环境保护部.2015年11月19日. 环境保护部公布《重金属污染综合防治 "十二五" 规划》2014年度考核结果. http://www.mep.gov.cn/gkml/hbb/qt/201511/t20151119_317343.htm].

BOX 3. THREATS TO AGROBIODIVERSITY IN CHINA

China is recognised as one of the centres of origin of domesticated crop species. Eleven globally important crops have native wild relatives in China, including rice, wheat, soybean, millet, yam, buckwheat, tea, apple and pear.[310] Southern and southwest China in particular have been identified as areas of high diversity in both crop wild relatives and local landraces.[311] The main threats to agrobiodiversity have been identified as land-use change,[312] and the rapid adoption of hybrid varieties of some of the main crop types.[313]

For example, maize is now the grain crop with the largest sown area across China; by the mid-1990s, 83% of the area was sown with hybrid varieties.[314] Although there are about 16,000 recorded varieties, in the early 2000s, more than half the sown area used just five hybrid varieties.[315] Research clearly shows a decline in the use of local landraces.[316] Local landraces and underutilised crops are more likely to continue being used in topographically diverse environments in the mountainous areas of southwest China. Agrobiodiversity is also intimately related to cultural diversity and biocultural heritage.[317] In some cases, the transformation of agricultural landscapes (e.g. due to the implementation of national agri-environment conservation policies which ban swidden cultivation) has been shown to lead to the loss of local agrobiodiversity.[318] When traditional farming systems are fundamentally changed, the traditional knowledge systems and culture underpinning the maintenance of agrobiodiversity may also be lost.

Conservation of agrobiodiversity is promoted in the National Biodiversity Strategy and Action Plan (2010),[319] which is now being translated into provincial action plans.[320] The topic receives a mention in the *National Plan for Sustainable Development of Agriculture (2015–2030)*.[321] Ex-situ conservation methods are widely applied, but there are many more challenges associated with in-situ conservation, including inconsistencies between different policies, laws and regulations, and lack of incentives for the public plant breeding and extension system to support the in-situ conservation and use of agrobiodiversity.[322]

The *National Plan for Sustainable Development of Agriculture (2015–2030)* also identifies those regions with better production conditions where agricultural development is to be further optimised, regions where 'appropriate development' is encouraged (i.e. improving basic infrastructure while balancing development with conservation), and regions where conservation is a high priority (Table 4).

Since 2014, Document No. 1 has also highlighted the promotion of sustainable agricultural practices. Since programmes listed in the document are more likely to receive funding from the Ministry of Finance, this illustrates one mechanism through which the national plan for sustainable agriculture will be implemented. For example, the 2014 Document No. 1 listed 'promoting environmentally-friendly agricultural development' as a priority, including measures and programmes to

[310] Kell, S. *et al.* 2015. China's crop wild relatives: Diversity for agriculture and food security. *Agriculture, Ecosystems & Environment* (209) 138–154.
[311] Crop Wild Relatives and Climate Change. 2013. Interactive map. Online resource. Accessed on 29 January 2016. www.cwrdiversity.org/distribution-map/.
[312] Guo, H. *et al.* 2002. Economic development, land use and biodiversity change in the tropical mountains of Xishuangbanna, Yunnan, Southwest China. *Environmental Science & Policy* 5(6) 471–479; Shen, S. *et al.* 2010. Agrobiodiversity and biocultural heritage in the Dulong Valley, China: Impacts of and responses to the sloping land conversion program. *Mountain Research and Development* 30(3) 205–211.
[313] Song, Y. 1999. Formal system and farmers' system: the impact of CIMMYT maize germplasm in South-western China. PhD dissertation. Wageningen Agricultural University.
[314] Song, Y. 1999. Formal system and farmers' system: the impact of CIMMYT maize germplasm in South-western China. PhD dissertation. Wageningen Agricultural University.
[315] Vernooy, R. and Song, Y. 2004. New approaches to supporting the agricultural biodiversity important for sustainable rural livelihoods. *International Journal of Agricultural Sustainability* 2(1) 55–66.
[316] Zhang, S., Huang, K. and Song, Y. 2010. Maize and the formal agricultural research and development system: evolution, challenges and alternatives. In: Song, Y. and Vernooy, R. (eds). *Seeds and Synergies: Innovating Rural Development in China*. Practical Action Publishing and IDRC, Rugby and Ottawa.
[317] Xu, F. *et al.* 2012. On-farm conservation and utilization of paddy rice, wheat and maize landrace varieties in 15 unique ethnic groups in Yunnan, China. *Hereditas* 34(11)1466–1474 [徐福荣, 杨雅云, 张恩来, 阿新祥, 汤翠凤, 董超, 张斐斐, 刘旭, 戴陆园. 2012年. 云南15各特有少数民族当前农家保护的稻、麦、玉米地方品种多样性. 遗传 34(11): 1466–1474].
[318] Wilkes, A. and Shen, S. 2007. Is biocultural heritage a right? A tale of conflicting conservation, development, and biocultural priorities in Dulongjiang, China. *Journal of Policy Matters* (15) 76–82.
[319] PR China. 2010. *China National Biodiversity Conservation Strategy and Action Plan (2011–2030)*. Convention on Biodiversity, Montreal.
[320] Wu, J. *et al.* 2015. Progress in elaborating provincial biodiversity strategy and action plans (BSAP) and strategies for implementation. *China Population, Resources and Environment* (S1) 555–557 [武建勇, 于之的, 刘海鸥, 刘纪新, 赵富伟, 薛达元, 2015.省级生物多样性保护战略与行动计划(BSAP)编制进展和实施策略. 中国人口·资源与环境 (S1期) 555–557].
[321] Ministry of Agriculture. 2015. *National Plan for Sustainable Development of Agriculture (2015–2030)*. Ministry of Agriculture, Beijing [农业部, 2015年.全国农业可持续发展规划纲要（2015–2030）].
[322] Vernooy, R., Zhang, Z. and Song, Y. 2011. *Policies of Plant Genetic Resources for Food and Agriculture: China and the World.* Bioversity International, Rome.

Table 4. Designated areas for sustainable agricultural development

DIVISION		AREA COVERAGE
Optmized Development Area	Northeast	Heilongjiang, Jilin, Liaoning, east parts of Inner Mongolia
	Huang-Huai-Hai	Beijing, Tianjin, middle and southern Hebei, Henan, Shandong, Anhui and northern Jiangsu
	Mid and lower Yangtze River	Jiangxi, Zhejiang, Shanghai, Jiangsu, middle and southern Anhui, Hubei, most of Hunan
	Southern areas	Fujian, Guangdong, Hainan
'Appropriate Development' Area	Northwest and along the Great Wall	Xinjiang, Ningxia, most of Gansu, Shanxi, central and northern Shaanxi, central and northern Inner Mongolia, northern Hebei
	Southwest	Guangxi, Guizhou, Chongqing, southern Shaanxi, eastern Sichuan, most of Yunnan, Hubei, western Hunan
Conservation and Development Area	Qinghai-Tibetan Plateau	Tibetan, Qinghai, Tibetan area of Gansu, western Sichuan and northwest Yunnan
	Ocean and fishery areas	Ocean areas under Chinese management

Source: Ministry of Agriculture (2015) *National Plan for Sustainable Development of Agriculture (2015–2030)* [农业部，2015年.全国农业可持续发展规划（2015–2030年）]

support improvements in water-use efficiency and crop residue management; subsidies for measures to improve soil fertility (e.g. soil amendments, crop residue management, nutrient management), and to reduce pollution from fertiliser, pesticides and plastic sheeting. Document No. 1 issued in 2015 added further regulation of livestock waste impacts and promotion of circular economy models to the list of environmentally-friendly measures. Many of these measures were again highlighted in 2016, along with measures to address food safety. Most of the specific measures listed in these documents and in the national plan build on existing regulations, policies and programmes. Learning lessons from implementing these measures will be one key to ensure progress towards the targets.

Ecological and circular agriculture[323]

Ecological and circular agriculture, which have been promoted in China since the 1980s, aim to transform the conventional high resource-use, high waste emission and low material and energy re-use system to a low resource-use, low waste, high material and energy re-use system. Unlike some forms of ecological agriculture or agro-ecology in other countries, these approaches do not aim to eliminate external inputs, such as fertilisers, but to make use of technology to improve the efficiency of resource use and re-use so as to support agro-ecosystem sustainability. Circular and ecological agriculture approaches in the Chinese context are still being explored, and models and experiences are gradually being summarised and disseminated. There is significant overlap between 'ecological' and 'circular' approaches, and no attempt is made to distinguish them in this report.

Ecological and circular agriculture initiatives involve technological and institutional innovations to adjust the structure of production and agro-ecological relationships, and link production with downstream processes so as to increase the re-use of material and energy within supply chains.[324] At the production level, examples of ecological agriculture models promoted by the Ministry of Agriculture include integrated crop and livestock production linked with use of waste by processing enterprises; agroforestry and silvopastoral

[323] See *Rural Renewable Energy and Ecological Environment Trends*, 2015, Issue 1. China Association of Rural Energy Industry, Beijing www.carei.org.cn/index.php?c=article&a=type&tid=20 [农村可再生能源及生态环境动态，第1期.中国农村能源行业信息网 www.carei.org.cn/index.php?c=article&a=type&tid=20].
[324] *ibid.*

systems in which individual farmers are linked with processing and marketing enterprises; crop-livestock systems based around the use of crop residues for silage fodder and production of organic fertiliser; and crop-livestock systems based around the use of biogas slurry or composting to support production of speciality crops. Although models of ecological agriculture and circular agriculture may be feasible at field and farm level, policy also promotes material flows at a regional and supply-chain level, integrating the roles of different agricultural operations in the use and re-use of agricultural resources. For example, while individual farms may be unable to make use of crop residues or biogas slurry, by building commercial linkages within a region between farms that supply these resources and processors and farms that use these resources, resource-use efficiency may be improved.

Promotion of ecological and circular agriculture aims to address multiple challenges in the Chinese context, including:

(1) Labour scarcity: the loss of labour to off-farm occupations, the evolution of part-time agricultural workers and the ageing workforce. This is addressed for example by creating commercial relationships that enable resources (e.g. crop residues, livestock waste) to be used when labour scarcity means that smallholders are unable to use them.

(2) Resource scarcity: Pressure on agricultural resources and the need for more efficient use of limited resources with minimal environmental impact.

(3) Institutional change: Promoted models often respond to the recent changes in agricultural production institutions (e.g. development of large-scale farms, cooperatives and commercial agri-business) and supply chain relationships (e.g. vertically integrated supply chains), and the higher degree of specialisation, larger-scale and more intensive farm operations that are accompanying these changes. They do this by promoting models based on changes in the inter-relationships between supply chain actors (e.g. by establishing commercial relationships between agriculture sector actors who were previously not linked).

Policy statements have supported the development of ecological and circular agriculture since the 1980s.[325] Several State Council documents issued in the 1990s and early 2000s explicitly indicated support for ecological agriculture and for initiating pilot activities. In 2008, the *Decision of the Chinese Communist Party Center on Several Major Issues regarding Promotion of Rural Reform and Development* stated the objective of establishing by 2020 a 'resource-conserving, environmentally friendly agricultural production system', involving 'resource conserving agriculture, circular agriculture and ecological agriculture and protection of the agricultural environment'.[326] Successive issues of Document No. 1 (between 2010 and 2016) also repeated these intentions.

The National Ecological Agriculture Counties Construction Programme was initiated in 1993, and provided policy and financial support to 51 counties in the first phase (1994–1999) to establish pilot and demonstration models. In 2000, the Ministry of Agriculture issued management regulations for the establishment of National Ecological Agriculture Demonstration Counties.[327] This led to the selection of more than 100 national-level demonstration counties, 500 provincial-level ecological agriculture demonstration counties, 2,000 ecological agriculture demonstration sites and 10 circular agriculture demonstration sites. Some of these demonstrations are county-wide and some are limited to specific villages, while others focus on linking value chain actors in a broader geographic area. In 2014, the Ministry of Agriculture initiated pilot projects in 11 provinces to establish ecological agriculture and clean production technology pilot sites. At each site, farmer cooperatives, family farms and enterprises will be linked to demonstrate ecological and clean production processes.[328] In 2015, 16 provinces were selected to establish circular agriculture pilot counties and cities, with central government investing US$ 1.6–1.9 million in each pilot site.[329] The pilot sites include major grain and livestock-producing counties and water source areas. The objective in each site is to implement circular agriculture involving areas of at least 667 hectares, achieve increases of at least 10% in farmers' incomes and realise land rights transfers on at least 50% of land. Based on the experience of the pilots, successful models will be promoted in other suitable areas.

From the practice of ecological and circular agriculture in China, one can discern two general approaches. The first focuses on macro-level trends in practices that affect resource-use efficiency and environmental impacts of agriculture within a region (Box 4).

[325] *Rural Renewable Energy and Ecological Environment Trends*, 2015(1): 1–2; [生态农业有关政策汇编。农村可再生能源及生态环境动态，1：1–2].
[326] Chinese Communist Party. 2008. *Decision of the Chinese Communist Party Center on Several Major Issues Regarding Promotion of Rural Reform and Development*. Xinhua News Agency, Beijing [中共中央, 2008年. 中共中央关于推进农村改革发展若干重大问题的决定].
[327] Ministry of Agriculture. 2000. *National Ecological Agriculture Demonstration County Management Method*. Ministry of Agriculture, Beijing [农业部, 2000年. 全国生态农业示范县建设管理办法].
[328] www.21food.cn/html/news/35/1444119.htm.
[329] www.scagri.gov.cn/ywdt/hydt/201505/t20150507_339754.html.

BOX 4. A REGIONAL APPROACH TO ECOLOGICAL AGRICULTURE: ZHEJIANG PROVINCE

Zhejiang province has recently begun implementing a national pilot project that primarily aims to reduce non-point pollution from crop and livestock production. On the one hand, restrictive regulations are enforced in target areas (e.g. local governments define areas where livestock raising is prohibited), and on the other hand, practices to reduce environmental impacts are promoted, such as soil nutrient testing for targeted fertiliser formulation, and organic fertiliser substitutes and green manure cultivation.[330] Since household conditions vary greatly, a range of farm and household characteristics and external factors (e.g. availability of financial support) have been found to influence adoption among farmers.[331] How such programmes address farmers' constraints to adopting environmentally-friendly practices will be the key to scaled-up impacts.

A second approach focuses on developing particular material flows within the production enterprise or within specific value chains or regions. In the 2000s, the Ministry of Agriculture promoted ten models of ecological and circular agriculture. These included pig raising integrated with greenhouse vegetable production and biogas production; pig-biogas-fruit production models; pasture-livestock and silvo-pastoral models and so on. There have been few published evaluations of the adoption or effectiveness of these models. However, some commentators have noted that when such models are implemented at the regional scale, the development of industry clusters and related infrastructure is critical to enable commercially profitable material flows to develop. This requires significant government involvement.[332] As with government support to large-scale, commercialised farming, the efficiency of the use of public funds, and the distribution of benefits among farmers and enterprises may be relevant concerns.

Certification schemes

Another approach to transforming agricultural production practices has involved the certification of production conditions and processes. There are three main certification schemes supported by the government:[333]

- 'Green food' certification, which began in the early 1990s, is awarded to foods that meet standards issued by the Ministry of Agriculture for the use of pesticides, production methods and residue testing. Green foods may receive a price premium compared to conventional produce.[334] In 2014 the value of green food-certified produce stood at US$ 89 billion, with an export value of US$ 2.5 billion.[335] In 2014, 23 million hectares were farmed to Green food standards by more than 20,000 certified enterprises.[336]
- 'Hazard-free' certification was introduced in 2001, in response to concerns over health incidents and contaminated food. The standards, developed by the Ministry of Agriculture, focus on controlling the illegal use of highly toxic agricultural chemicals and violations of pesticide residue standards. Today about 16 million hectares are farmed to hazard-free standards.[337]
- Organic certification[338] was introduced to China in the 1990s, initially using international accreditation processes. In 2002 an organic certification body, the China Organic Food Certification Center, was set up as a non-profit governmental enterprise to promote organic farming. National regulations for organic certification and accreditation and organic product standards were issued by the General Administration of Quality Supervision, Inspection and Quarantine in 2005. By the end of 2014, more than 9,000 producers had been certified,[339] mostly in northeast China (cereals, bean, sunflower and pumpkin seeds), coastal areas (vegetables) and southeast China (tea). Nevertheless, the total area under organic

[330] Chen, R. and Chen, Y. 2015. Feasibility of chemical fertiliser user reduction in Zhejiang's agriculture. Zhejiang Agri*cultural Sciences* 6: 769–770 [陆若辉, 陈一定. 2015 年. 浙江农业施用化肥减量可行性分析. 浙江农业科学 (6) 769–770].
[331] Deng, Q., Hu, J. and Huang, Z. 2013. Research on willingness of farmers to participate in high-efficiency ecological agriculture in an economically developed region. Fujian For*um (Humanities and Social Science Edition)* (5) 22–28 [邓启明, 胡剑锋, 黄祖辉, 2013 年. 经济发达地区农户参与现代高效生态农业建设的意愿研究. 福建论坛: 人文社会科学版 (5) 22–28].
[332] Zhang, F. 2013. Exploration of the economic effect of ecological agriculture industry clisters and the role of government. Agricultural Modernization Research (2) 011 [张芬昀 (2013) 生态农业产业集群发展中的经济效应与政府行为探究. 农业现代化研究 (2) 011].
[333] Garnett, T. and Wilkes, A. 2014. *Appetite for Change: Social, Economic and Environmental Transformations in China's Food System.* Food Climate Research Network, Oxford.
[334] Paull, J. 2008. The greening of China's food: Green food, organic food, and eco-labelling. Paper presented to Sustainable Consumption and Alternative Agri-food Systems Conference, Liege University, Arlon, Belgium, 27–30 May 2008.
[335] China Green Food Development Center. 2016. Report of Annual Statistics. See www.greenfood.agri.cn/zl/tjnb/ [中国绿色食品发展中心, 统计年报。查看 www.greenfood.agri.cn/zl/tjnb/].
[336] *Ibid.*
[337] Ministry of Agriculture, 9 July 2015. Response to suggestion No. 3012 from the Twelfth National People's Congress Third Meeting. Ministry of Agriculture, Beijing. [农业部.2015年7月9日. 对十二届全国人大三次会议第3012号建议的答复.查看: www.moa.gov.cn/govpublic/KJJYS/201507/t20150709_4739217.htm].
[338] FIBL. 2011. *The World of Organic Agriculture: Statistics and Emerging Trends 2011.* Research Institute of Organic Agriculture, Frick, Switzerland.
[339] FIBL. 2016. *World Organic Agriculture 2016. FIBL, Frick, Switzerland.*

production is still far below 1% of the total arable land area.[340] Certification costs are a major barrier to entry, although some local governments have supported the costs of certification for organic producers.[341] The Ministry of Commerce and other ministries also have supportive policies.[342] Recently, the ministries of environment and agriculture jointly selected 67 new National Organic Production Bases, providing financial support for adoption of practices such as crop residue re-use, recovery of plastic mulch sheeting and waste water treatment.[343]

In principle, there should be considerable scope for the increased production of organic food in China. Not only is China a major exporter of organic food ingredients, but a portion of middle-class urban Chinese consumers shows a willingness to pay the price premium that organic production requires. Studies have found that willingness or intent to purchase organic food is related to factors such as income and consumers' degree of concern with food safety or health, rather than their awareness of environmental issues.[344] Their degree of trust in organic certification is also an important factor, as poor governance is widely perceived to be pervasive in China's food system.[345]

Farmers' interest in organic production is affected by a number of factors. In the case of organic production bases, companies lease farmers' land, and farmers provide their labour. Labour income is the main financial benefit in this case, as the price premium is not passed on to farmers. Independent producers, on the other hand, are more likely to benefit financially from a price premium.[346] The future development of organic agriculture in China will therefore most likely be intertwined with land tenure policy reforms, and other policies promoting the upscaling of production through farmer cooperatives and agri-business development.

Various forms of Community Supported Agriculture have recently developed in China, partly as an alternative to the high costs of certified organic production and the lack of trust in certification schemes (see Box 5). To date, these initiatives have mostly been developed without government support.

BOX 5. COMMUNITY SUPPORTED AGRICULTURE[347]

Community Supported Agriculture (CSA) is a growing form of sustainable agriculture in China. CSA is an alternative to industrial agriculture, and focuses on direct, small-scale exchanges between producers and consumers based on trust. In China, concerns over food safety are a major motivator for urban consumers to engage with CSA initiatives. Many of the farms involved adopt low external input agriculture and/or organic methods, as exemplified by the '3 lows and 3 highs' slogan (i.e. low energy consumption, low pollution, low investment, high standards, high yield, and high quality).

The CSA approach began on Little Donkey Farm near Beijing in 2008 and has since spread rapidly. Today there are about 300 CSA farms nationwide. They are mostly located near large cities and developed regions such as Beijing, Shanghai, Guangzhou and Hangzhou. There are three main types of CSA: those with small farmers as the main producers (e.g. Meitian Sunshine Farmland and Xinnongfu Farm); those with cooperatives as the main producers (e.g. members of the Green Alliance Cooperative that is spreading across China, supported by the Rural Reconstruction Movement Network); and those where individuals or cooperative members produce for their own consumption rather than for sale (e.g. Lehexiangu Organic Farm and Sanfendi Organic Farm in Beijing).

[340] Ministry of Agriculture, 9 July 2015. Response to suggestion No. 3012 from the Twelfth National People's Congress Third Meeting. Ministry of Agriculture, Beijing. [农业部.2015年7月9日. 对十二届全国人大三次会议第3012号建议的答复.查看：www.moa.gov.cn/govpublic/KJJYS/201507/t20150709_4739217.htm].
[341] FIBL. 2011. *op. cit.*
[342] Ministry of Commerce *et al.* 2004. *Several Opinions on Promoting Organic Food Sector Development.* Ministry of Commerce, Beijing [商务部等, 2004年.关于积极推进有机食品产业发展的若干意见]; National Development and Reform Commission. 2007. *Modern Agriculture Demonstration Project Plan (2007–2010).* National Development and Reform Commission, Beijing [国家发改委, 2007年.现代农业示范项目建设规划（2007–2010年）].
[343] Kong, Y. 26 March 2015. Assessment results released of the fifth batch of national organic food production bases. *China Environment News* [孔源.2015年3月26日.第五批国家有机食品生产基地考核结果公布.查看： www.cenews.com.cn/xwzx2013/hjyw/201503/t20150326_789910.html].
[344] Yin, S. *et al.* 2010. Consumers' purchase intention of organic food in China. *Journal of the Science of Food and Agriculture* 90(8) 1361–1367; Chen, J., Lobo, A. and Rajendran, N. 2014. Drivers of organic food purchase intentions in mainland China: Evaluating potential customers' attitudes, demographics and segmentation. *International Journal of Consumer Studies* 38(4) 346–356.
[345] Mol, A. 2014. Governing China's food quality through transparency: A review. *Food Control* (43) 49–56.
[346] Chen, A. 2014. China's path in developing organic agriculture: Opportunities and implications for small-scale farmers and rural development. PhD dissertation. University of Waterloo, Ontario, Canada; Wang, J. 2012. Organic vegetable value chain study: Emerging organic market and opportunities for smallholder farmers in China. Master's dissertation. Humboldt University.
[347] Cook, S. and Buckley, L. 2015. *Multiple Pathways: Case Studies of Sustainable Agriculture in China.* IIED, London.

Conclusions: the many stepping stones to agricultural sustainability

The policy environment for sustainable agriculture is increasingly supportive. However, developments beyond agricultural policy – such as land tenure, reforms to urban citizenship rights and increasing vertical integration – will also determine opportunities and outcomes for farmers. Collaborative relationships among farmers, companies and government will enable the further innovation and promotion of sustainable agricultural practices.

5

Deng Xiaoping is credited with the famous dictum that reform and development are like a process of groping for stones as you cross the river. A river with many stones provides several potential pathways towards sustainability. This final chapter highlights some of the issues and options that may determine the course of efforts to pursue agricultural sustainability in the coming years.

5.1 A unique approach to sustainable agriculture

The scope of 'sustainable agriculture' in China does not easily map onto concepts commonly used in western countries. The concept overlaps with the term 'sustainable intensification', but there are also some potential differences. As it is commonly used, sustainable intensification is often taken to mean 'producing more with less', and is often addressed through technical approaches.[348] In China, sustainable approaches not only focus on resource-use efficiency, but also on reducing the adverse environmental impacts of agricultural production and emphasising the importance of waste minimisation and re-use, as in circular agriculture. Innovations in market linkages and supply-chain integration (e.g. cooperatives, vertical integration, regional circular agriculture models) are also given relatively more emphasis in many contexts, being seen as essential conditions for enabling and incentivising the adoption of more sustainable practices. And while 'sustainable intensification' commonly addresses only challenges in food production, in China food safety is a much more ubiquitous concern and draws attention to the need for sustainable practices and relationships throughout supply chains.

At the same time, 'sustainable agriculture' in China has no single definition or defined scope. There is general consensus among many groups on the scope of the challenges to be addressed, but significant diversity in the range of specific approaches being promoted to address those challenges.

5.2 An increasingly supportive policy environment

Every year since 2004, Document No. 1 has focused on rural, agriculture and farmer issues. Many of the specific measures outlined each year relate to key sustainability challenges, or the need to adjust national institutional and policy frameworks in order to enable more sustainable agricultural production. Environmental aspects of agricultural production have also been highlighted in recent years. The *National Plan for Sustainable Development of Agriculture (2015–2030)*[349] clearly indicates that environmental concerns will be an integral part of national agricultural development strategy in the coming 15 years. The plan sets out ambitious targets for waste reduction and re-use, and also addresses institutional aspects of agricultural production, promoting farmer cooperatives, specialised producers and other forms of agriculture that are seen as better suited to the changing broader conditions. It is also worth noting that as central government receives 80% of all fiscal revenues, it has considerable influence on government spending on stated policy goals.[350]

Aside from direct financial support for adopting improved agriculture practices, the regulatory role of government in the agri-food sector is also gradually strengthening. For example, food safety and traceability regulations are an increasingly important part of the operating environment for agri-food businesses and the farmers who supply them, although many difficulties in formulating and enforcing regulations remain. The joint release by several ministries of national plans to address multi-sectoral issues related to agriculture (e.g. livestock waste, heavy metal contamination of soils, food safety regulation) also indicates a potential for more coordinated government action to address significant sustainability challenges.

[348] Tittonell, P. 2014. Ecological intensification of agriculture: Sustainable by nature. *Current Opinion in Environmental Sustainability* 2014(8) 53–61.
[349] Ministry of Agriculture. 2015. *National Plan for Sustainable Development of Agriculture (2015–2030).* Ministry of Agriculture, Beijing [农业部2015年.全国农业可持续发展规划（2015–2030年）].
[350] World Bank and Development Research Center of the State Council. 2013. *China 2030: Building a modern, harmonious, and creative society.* World Bank, Washington, DC.

While these observations are based on national policy documents, suggesting policies driven by a primarily top-down agenda, China's policy formulation and implementation process has long been characterised by experimentation.[351] Approaches to ecological and circular agriculture, programmes and projects targeting particular issues, and specific policy instruments are often tested, piloted and gradually replicated or upscaled. Top-down policies may also be adapted to local conditions through local implementation regulations. Increasing knowledge of the effectiveness and impacts of policies in different regions and on different types of farmers and other stakeholders, and increasing farmers' voice and influence in decision-making processes, will be critical to incremental improvement in policies and policy implementation.

5.3 Clearer, more secure and longer term land tenure

Innovations by farmers in the late 1970s led to the development of the current land-use system based on household contracts for use and management rights over arable land. The relatively equitable distribution of land use rights played a key role in enabling widespread increases in rural incomes in the early 1980s. Subsequently, however, the constraints of high levels of land fragmentation became increasingly recognised. As an ever-growing number of farmers engaged in off-farm work, the question of how to balance access to land and efficient operation of arable land came to the fore. Again, land rental markets emerged as a local innovation, and regulations providing a supportive environment for land management rights transfers have subsequently begun to be put in place.

Land management rights over one-third of arable land have now been transferred, either to specialised households, cooperatives or companies. Land transfers may increase labour productivity, enabling both higher participation in more remunerative off-farm employment and more efficient use of agricultural labour resources. Unlike privatisation, however, allowing farmers to retain land-use right contracts while participating in rental markets ensures their access to land is not lost. This is particularly important in China, where rural people lack the same rights as urban residents and the rural social security system is still under development.

In addition to a legal framework for land rights transfers, government policy now explicitly supports local government to encourage land rights transfers. There are a number of concerns with how this system operates and the outcomes for farmers. Local government and village cadres are often actively involved in organising and negotiating land rights transfers. The outcome for farmers is not always beneficial, as the implementation of laws and policies, as well as governance and accountability, remain problematic at the local level.[352] The current direction of reform is towards clearer and more secure, long-term land tenure rights.[353] Much more needs to be done – not only in terms of land rights, but also to address rural social security and the rights of rural residents in urban areas. In the longer term, reforms in these domains will have major impacts on farmers' livelihood options, the values they attach to land, and their investment decisions.

Beyond land tenure itself, some commentators perceive that a fundamental transformation in the relations of production is now taking place in rural China. An increasing number of farmers are renting out their land, and either earning a rent or working as labourers for cooperatives or agribusiness companies, or farming under contract.[354] Some are concerned that agribusinesses (representing 'capital') are influencing policy and government action to obtain unfair access to resources, including land, cheap labour and government subsidies. However, others note that collective land ownership can play a key role in enhancing farmers' bargaining power, limiting the ability of capital to dominate, exploit or dispossess farmers.[355] Some commentators see farmer cooperatives as strengthening farmers' ability to influence the forms of exchange they engage in, while others see that in some cases, cooperatives play a similar role to companies in rural transformation.[356] These issues also interact with other changes, such as food safety regulations, which have been generally moving in directions that imply increased vertical integration in agri-food supply chains. On the one hand, this may provide farmers with increased access to markets. On the other hand, regulations (e.g. requirements for food product traceability) may imply greater influence by downstream firms over supply chain

[351] Heilmann, S. 2008. From local experiments to national policy: The origins of China's distinctive policy process. *China Journal* (59) 1–30; Heilmann, S. 2008. Policy experimentation in China's economic rise. *Studies in Comparative International Development* 43(1) 1–26.
[352] Yan, W. and Klein, K. 2013. Transfer of land use rights in China: Results from a survey of rural households in 8 counties of Hebei Province. *International Journal of Agricultural Science and Technology* 1(3) 33–42; Han, S. 2012. Problems occurring in land rights transfer as part of new countryside construction and their solution. *China Law* (1) 19–32 [韩松, 2012. 新农村建设中土地流转的现实问题及其对策. 中国法学 (1) 19–32].
[353] World Bank and Development Research Center of the State Council. 2013. *China 2030: Building a modern, harmonious, and creative high-income society.* World Bank, Washington, DC.
[354] Huang, P. 2013. The dynamics of capitalization in Chinese agriculture: private firms, the state, or peasant households? *Rural China* 10(1) 36–65 [黄宗智, 2013. 中国农业资本化的动力：公司、国家还是农户？ 中国乡村研究10(1) 36–65]; Han, S. 2012. Problems occurring in land rights transfer as part of new countryside construction and their solution. *China Law* (1) 19–32 [韩松, 2012. 新农村建设中土地流转的现实问题及其对策. 中国法学 (1) 19–32].
[355] Zhang, Q. and Donaldson, J. 2008. The rise of agrarian capitalism with Chinese characteristics: Agricultural modernization, agribusiness and collective land rights. *China Journal* (60) 25–47.
[356] Gürel, B. 2014. Changing relations of production in Chinese agriculture from decollectivization to capitalism. *McGill Sociological Review* (4) 67–92.

operations. The implications for the roles of farmers and the distribution of benefits deserve greater attention. The outcomes for farmers will thus be affected not just by policies on land and agricultural production, but also by changes originating elsewhere in China's food system.

5.4 Scaled up and increasingly integrated supply chains

Government policy also promotes larger-scale production in both the crop and livestock sectors and significant public funds are being spent to support the development of large-scale operations. Large-scale crop cultivation may increase crop output, efficiency and profitability, and may reduce the intensity of environmental impacts, although the evidence for several of these claims is not conclusive. In the livestock sector, large-scale operations have also been promoted to better manage livestock waste, improve disease control and enhance food safety. Again, evidence to support this is not always conclusive. Very large pig farms in China do not on average make more efficient use of production inputs than smaller farms, and waste treatment remains a problem. In addition, concentration of livestock production in large farms decouples feed production from the use of manure – a key nutrient flow that has supported Chinese agriculture for millennia. Though there are opportunities for circular agriculture models (see Section 4.3) – for example, where livestock producers supply waste to processors that produce fertilisers for feed and crop producers – pathways to achieving commercially viable material flows still remain to be developed throughout most of the country.

However, the push to increase the scale of crop and livestock production may simply shift the spatial location of agri-environment pollution and the location of food safety risks in the food system.[357] While the large number of producers, processors and other supply-chain actors may be a challenge for regulators, large-scale producers have also been documented to be the source of pollution and food safety risks.

These policies to promote large-scale operations also interact with other policies. Again, taking the example of food safety measures, many measures can only be implemented throughout the supply chain with some degree of vertical integration between supply chain actors. This may change the conditions under which smallholders access markets. In some cases this may be to farmers' benefit, if they are able to gain a fair share of the final product value. Cooperatives may also find a growing role in linking supply chain actors. Some farmers may change to other crops or products, or leave agriculture altogether. As China's experience over the last 35 years shows, there will be a multitude of answers to the questions of whether the outcomes of these changes are beneficial or not, and for whom?

5.5 Increasingly market-led development

While much of the focus of this report has been on government and its policies, markets provide an equally important context for farmers and the agriculture sector. Yet the operation of markets for the benefit of farmers is not independent of the roles of government. On the one hand, government has played key roles in investing in infrastructure to enable markets to work more efficiently, and in creating regulations to govern market transactions. On the other hand, farmers across the country face very different conditions for access to markets, and the current regulatory environment is insufficient to enable markets to function perfectly.

In recent decades, the expansion of physical infrastructure in rural China has been impressive. Most rural villages – even in many poorer parts of the country – now have access to roads, electricity and various forms of telecommunications. Research has shown that road access enables both poorer and richer farmers to benefit from increased non-farm income and greater specialisation in crop production.[358] In areas that remain remote (and many ethnic minority areas), physical access to agricultural and labour markets is still a challenge, however.[359] Government has also made significant investments in other critical market infrastructure, such as agri-food product storage and logistics networks.

Perhaps the biggest challenge for sustainable agriculture lies in the 'soft' infrastructure that can make markets work. The considerable emphasis on food safety by consumers and in official policy reflects less the actual scale of the problem, than a widespread lack of trust in the safety of food products, the ability of government to enforce regulations and the motivations of food producers. The development of organic food consumption in China has also been affected by

[357] Holdaway, J. 2015. *Urbanisation, Rural Transformations and Food Security: The View from China*. IIED Working Paper. IIED, London.
[358] Qin, Y. and Zhang, X. 2016. Road to specialization in agricultural production: Evidence from rural China. *World Development* (77) 1–16.
[359] Harwood, R. 2009. *Negotiating Modernity at China's Periphery: Development and policy interventions in Nujiang Prefecture*. Routledge, London.

a lack of trust in certifications and the retail chain. Community Supported Agriculture is emerging (albeit at a very small scale) as one reaction to this. Trust also affects farmers' responses to local government implementation of policies,[360] their expectations of commercial relationships with buyers,[361] and their ability to join in collective action, whether in cooperatives or other community-based institutions. Yet trust also underlies the ability of farmers to use social networks to access information, innovate and invest,[362] to access government support for investments at household or community level,[363] and to reduce information and negotiation costs when marketing their products.[364] While continued development of the 'soft' infrastructure for markets can provide a supportive environment for sustainable agriculture, China's food system will continue to undergo rapid change. The opportunities for farmers and companies to engage in, innovate and promote sustainable agricultural practice will depend on the collaborative relationships that they are able to build with each other and with government agencies.

This report has surveyed a range of approaches to sustainable agriculture in China, reflecting the multi-dimensional challenges facing the sector. Some of these challenges are due to agricultural practices (e.g. low soil fertility due to limited organic inputs), while others are influenced by wider development trends (e.g. large-scale rural-urban migration, and industrial development). Shifts in consumption patterns and concerns with food safety also place new demands on agriculture, posing new challenges and opportunities. National policies to promote sustainable agricultural development are responding to the broad scope of issues and trends, and include changes to agronomic practices, institutional and technological innovations, and economic incentives. Farmers' and consumers' responses also reflect a range of factors related to both the agricultural sector and the wider context. Across China's diverse regions, farmers, companies, consumers and local governments will continue to respond to new challenges and opportunities, with each innovation representing a stepping stone on one of a multitude of pathways towards sustainability.

[360] Li, L. 2008. Political trust and petitioning in the Chinese countryside. *Comparative Politics* 40(2) 209–226.
[361] Guo, H. and Jolly, R. 2008. Contractual arrangements and enforcement in transition agriculture: Theory and evidence from China. *Food Policy* 33(6) 570–575.
[362] Wu, B. and Pretty, J. 2004. Social connectedness in marginal rural China: The case of farmer innovation circles in Zhidan, north Shaanxi. *Agriculture and Human Values* 21(1) 81–92; Turvey, C. and Kong, R. 2010. Informal lending amongst friends and relatives: Can microcredit compete in rural China? *China Economic Review* 21(4) 544–556.
[363] Tsai, L. 2007. Solidary groups, informal accountability, and local public goods provision in rural China. *American Political Science Review* 101(2) 355–372; Chen, H., Wang, J. and Huang, J. 2014. Policy support, social capital, and farmers' adaptation to drought in China. *Global Environmental Change* (24) 193–202.
[364] Lu, H. *et al.* 2008. Influence of guanxi, trust and farmer-specific factors on participation in emerging vegetable markets in China. *NJAS-Wageningen Journal of Life Sciences* 56(1) 21–38.

In only a few decades, agriculture in China has evolved from a diverse “agriculture without waste” to one involving specialised, high-external input, resource-intensive, commercially-oriented models. This report charts this evolution, with a focus on sustainability – economic, environmental and social. It asks how China’s modern development is affecting sustainability in farming and the rural environment, and looks in detail at the influence of policies and measures to transform agricultural production systems in more sustainable ways. The report concludes by considering some of the challenges and opportunities that could shape sustainable agriculture in China in the future.

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International Institute for Environment and Development
80-86 Gray’s Inn Road, London WC1X 8NH, UK
Tel: +44 (0)20 3463 7399
Fax: +44 (0)20 3514 9055
email: info@iied.org
www.iied.org

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