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Case Study Report

Environment

GROWING MORE WITH LESS China's progress in agricultural water management and reallocation

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Acronyms

BRICS	Brazil, Russia, India, China and South Africa
CCP	Chinese Communist Party
ET	Evapotranspiration
EU	European Union
GDP	Gross Domestic Product
NGO	Non-governmental organisation
ODI	Overseas Development Institute
OECD	Organisation for Economic Co-operation and Development
PPP	Purchasing power parity
UN	United Nations
USD	US Dollar
WAB	Water affairs bureau
WUA	Water user association

Abstract

Since the early 1990s, China has experienced remarkable economic growth, lifting nearly 600 million people out of poverty. Investments in agricultural productivity post-1978 drove this growth, but also led to pollution and overuse of water resources. Nonetheless, China has since progressed toward more sustainable water management, particularly in agriculture. Here, we focus on China's ability to get 'more crop per drop' by improving agricultural water use.

China's water withdrawals per hectare of irrigated land have declined by 20% since the early 1990s, even in water-scarce northern China. This case study identifies four factors driving improvements: Chinese decision-makers' balancing of needs for water for food versus growth; institutional and policy reform; major government investment; and local technical, economic and regulatory programmes. Challenges remain, especially mismatched incentives between national and local decision-makers, frustrating the achievement of ambitious environmental targets.

China's progress offers lessons for other countries. For example, strong national leadership is necessary but not sufficient for environmental progress, even in a single-party state. Positive change requires ambition, innovation and investment of leaders and citizens at all levels. China's experience highlights the importance of a problem-focused approach: using rewards and incentives, and clarifying roles, responsibilities and accountabilities among different users.

Growing more with less

China's progress in agricultural water management

PROGRESS MADE

ECONOMIC GROWTH

China has raised nearly **600 million** people out of $2-a-day poverty since the early 1990s:

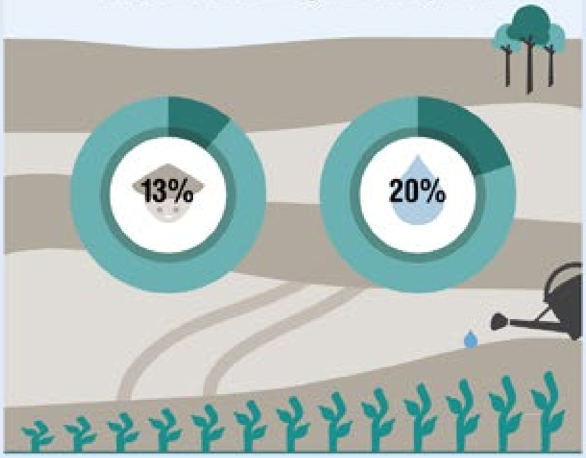
8% of the world's population.

China's per capita GDP has increased by 623%.

China's agricultural productivity has more than doubled (130%).

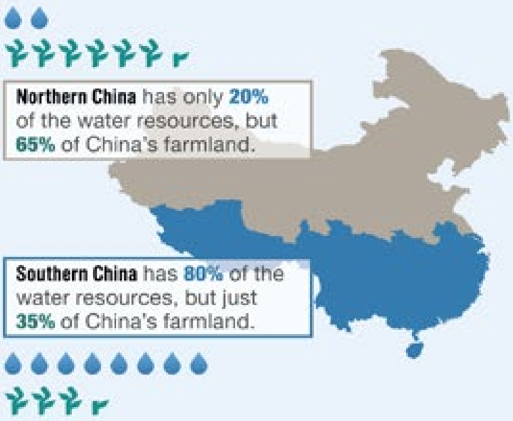
MORE CROP PER DROP

From 1990 to 2012, China's water withdrawals for agriculture per person declined by nearly **13%** and per hectare of irrigated land by **20%**.



CHALLENGES AHEAD

NORTH-SOUTH DISPARITIES

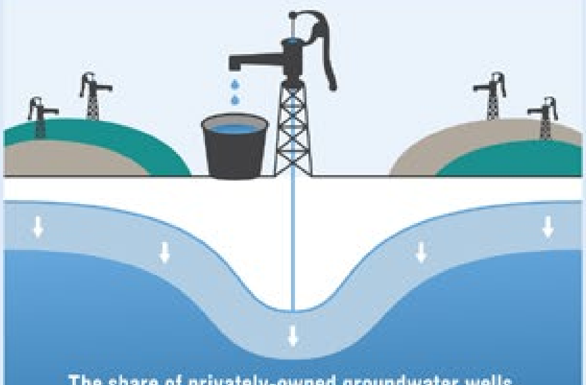


Northern China has only **20%** of the water resources, but **65%** of China's farmland.

Southern China has **80%** of the water resources, but just **35%** of China's farmland.

Managing 'water for food' versus 'water for industry and growth' will continue to be challenging in the water-scarce north.

EXPLOITATION OF GROUNDWATER



The share of privately-owned groundwater wells increased from 42% to 70% from 1995–2004.

Groundwater levels are falling by 1–2 metres per year or more in some places. Government regulations are unable to keep pace.

Sources: World Bank 2014 | NBS 2014 | Shen 2014 | FAO Aquastat 2011 | Economy 2011 | Calow et al 2009 | Wang et al 2009a

infogr8

1. Introduction

Water melon farmers in Ningxia. Photo: © Bert van Dijk

苦尽甘来

It is always darkest before the dawn (Proverb)

1.1 Why focus on agricultural water management in China?

China finds itself at the centre of debates around the perceived trade-off between economic growth and environmental protection. High profile cases of environmental pollution and China's growing contribution to greenhouse gas emissions have affected its international reputation. A media narrative has emerged around its polluted air and water, growing consumer population, contaminated export products and overuse of natural resources – all supposedly driven by its 'growth at all costs' development model.

This case study challenges this narrative. China has undoubtedly suffered from – and will continue to suffer from – environmental degradation. Environmental damage in China is reducing the country's GDP growth by at least 2.3% per year (World Bank, 2007). However, the country has also made rapid and significant progress toward a greener and more sustainable future that deserves to be recognised. It has done this particularly by growing more crops to feed its growing population while using less water to do so – the focus of this case study. China has been able to feed 21% of the world's population with only 9% of the world's arable land and 6% of its freshwater. It has done so while lifting hundreds of millions out of poverty and maintaining some of the world's highest rates of economic growth.

In this case study, we investigate progress in the country's agriculture and water sectors since 1990. We explore changes in water use by China's agricultural sector and identify the extent to which these changes contribute to the country's sustainable development. We examine, in particular, China's progress toward the sustainable intensification of its agricultural outputs via its agricultural water management – specifically its ability to get 'more crop per drop'. We focus on the water-scarce region of northern China. Here, China increased its water use efficiency dramatically, reducing agricultural water withdrawals per hectare of irrigated land by around 20% since the early 1990s, while increasing its agricultural output and growing its economy.

We therefore examine the synergies and trade-offs in northern China where increases in agricultural output and poverty reduction were achieved alongside these improvements to water use efficiency, watershed management and water conservation. This enables improved understanding of the political, economic and technical drivers that promoted these practices. We recognise the impacts of the country's broader environmental dialogue on issues of agricultural water management, and consider this through the lens of sustainable development and green growth – concepts that China is increasingly embracing in its national policy discourse. We discuss these in the context of agricultural water management below. We then provide an overview of China's political and water resource context.

1.1.1 Sustainable development, green growth and agricultural water management

The concept of sustainable development became prominent in 1987 as a key theme of the *Our Common Future* report from the UN World Commission on Environment and Development. The term has since become a centrepiece of developmental and environmental discourse. That report's definition of the term remains in use today: '*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*' (WCED, 1987). It draws attention to two key concepts: needs and limitations. The former refers in particular to the essential needs of the world's poor, which it recommends prioritising over all else. The latter refers to the limitations imposed by current levels of technology and social organisation on the environment's ability to meet present and future needs.

The concept of green growth is more recent, originating in 1999 in a book by Paul Ekins. It took until 2008 for the term to gain popularity and policy acceptance though, rising in East Asia out of the global financial crisis – driven largely by the South Korean Government (Government of Korea, 2012). Though consensus on its definition and measurement are still lacking, the Global Green Growth Institute sees it as '*a model of economic growth that simultaneously achieves poverty reduction, job creation, social inclusion as well as environmental sustainability and resource security*' (GGGI, 2014). The term arose from the drive to recast environmental protection as a discourse of opportunity and reward, rather than one of costly restraint (Bowen and Fankhauser, 2011). The term is not conceived as a replacement for 'sustainable development', but rather a subset of it – narrower in scope and focused on building an operational policy agenda to achieve concrete progress on economic growth alongside resilient ecosystems (OECD, 2011).

Good management of water resources, particularly those used for agriculture, is central to achieving the principles of sustainable development and green growth. As the World Bank (2014) emphasises, '*water is the common denominator across economic sectors, including agriculture*'. Globally, over 1.3 billion people are still involved in agriculture (one-third of the total working population), including the majority of the world's poorest people (FAOSTAT, 2014). The challenge posed by sustainable development is to meet their needs through agricultural growth while recognising the limitations of this growth on the environment's ability to meet future needs. Global population growth, urbanisation and rising wealth are rapidly creating new patterns of consumption, shifting diets, and creating a surging demand for raw materials and energy (ERD, 2012). Agricultural total factor productivity has increased in response to this – growing about 2% per year since 2000. However, other individual indicators, such as crop yields, are less positive, with growth rates of major crops declining (Fuglie, 2012).

Agricultural growth has often come at a huge environmental cost. Intensive agricultural production, especially when using chemical fertilisers and pesticides, can degrade soils, reduce biodiversity, and pollute and overuse water resources. Agriculture currently accounts for at least 70% of global water withdrawals and is the largest consumptive user of water. Looking ahead, Pretty et al. (2010) predict that the world will need to produce 70-100% more food by 2050 to meet expected demands. To avoid expansion onto remaining non-agricultural land and further encroachment on fragile ecologies, most of this growth will need to happen via the intensification of production on existing agricultural land, avoiding management practices that degrade the land and water systems upon which future production depends (FAO, 2011).

1.1.2 China's ethos, political context and water

China presents a complex and interesting case study of progress on agricultural water management. As one of the world's oldest continuous civilisations, its history and political economy have heavily influenced this progress, particularly the impact of early Confucian and Taoist ideals and the activities of the Chinese Communist Party (CCP) since 1949. China's economy has adapted well to the rapidly changing global political economy and its government has put physical and human infrastructure in place to move aggressively up the value chain, offering lessons for developed and developing countries alike. It has done so through the CCP – China's governing party that has held power through authoritarian means since 1949. We will not debate the merits or demerits of China's single-party government in this report, but acknowledge the complexity it adds in terms of concerns about restricted civil liberties with respect to water management issues. China's huge population and land mass add additional diversity and complexity to the case study. Despite its single-party government, China's political–economic, cultural and environmental conditions vary greatly across the country, and so require focus on specific progress metrics and regions within the country.

Box 1: China's water resource profile

China suffers physical water scarcity relative to its population. The country contains only 6% of the world's total amount of freshwater resources, yet 21% of its total population (FAO Aquastat, 2011). Northern China is particularly water-scarce (see Map 1 overleaf). 'Northern China' is generally defined as the area north of the Yangtze River basin and contains only 20% of the country's total water resources. Nonetheless, it has been the focus of much of China's agricultural and economic growth since the 1970s, due in part to the flat plains of the north being more conducive to growth than the mountains of the south. The north currently contains 40% of the country's total population, around 65% of its farmland and generates around 50% of China's GDP (Calow et al., 2009; Economy, 2011).

Agriculture accounts for roughly 65% of total water withdrawals in China, followed by industry (22%) and municipal use (12%), with environmental flows (2%) accounting for remaining 'use'(MWR, 2012). While still the dominant user, agriculture's share has decreased from previous levels of around 70% in the year 2000 and 97% in 1949 (Amarasinghe et al., 2005; Kendy et al., 2007). These are relative figures, however; total water withdrawals have increased since these early years. For example, total water use per capita has increased from 190 cubic metres per year in 1949 to 458 in 2012. According to government data, roughly 81% of withdrawals are from surface water sources, with groundwater accounting for the remaining 19% (MWR, 2012). Official data may under-estimate the growth in rural groundwater abstraction, however, since groundwater development is increasingly opportunistic and village- or farmer-led (Wang et al., 2007; Calow et al., 2009).

Imperial China's Confucian and Taoist roots emphasised an ethos of protecting all life, with the world's oldest known ecological commentary attributed to Confucian philosopher Meng Zi some 2,300 years ago (Palmer, 2013). This ethos changed dramatically with the rise of Mao Zedong though, who declared 'war against nature' and worked to convert China from an agrarian to an industrial society (Shapiro, 2001). During this period, Mao's attempts at agrarian reform and the disbandment of the imperial feudal system and its replacement with a communal one caused massive productivity declines and, along with a drought in the late 1950s, led to the deaths of over 30 million people during the so-called Great Leap Forward (1958-1961). The Cultural Revolution witnessed the recentralisation of farming practices and Deng Xiaoping's 'household responsibility system' subsequently re-introduced household-level farming from 1978 onwards. Despite the devastation caused by Mao's *Great Leap Forward*, the focus on rural industrialisation did provide a long-term platform for investment. It was particularly successful in developing the irrigation infrastructure that would power the country's agricultural progress beyond 1978 (Bramall, 2008).

Under Deng Xiaoping, the period from 1978 to 1992 saw economic revival, market reforms and poverty reduction, but with sharp increases in pollution and environmental degradation (Bauer et al., 2013). For example, by the early 1990s, over 70% of China's major rivers passing through cities were deemed unsuitable as a source of drinking water (ibid.). Throughout this period, Mao's industrial/material ethos continued, with little regard for the environment. Deng Xiaoping's ideological framework of 'material civilisation' focused on industrialisation, economic growth and mass consumption. It also became the basis for the CCP's continued political legitimacy – based previously on ideology and nationalism under Mao (d'Alançon, 2014).

Water has played a central role in this growth story. Water in China is a story of general scarcity and of regional extremes (see Box 1), with a belief in massive state development to solve these problems (Wouters et al., 2004). In the water sector, Molle et al. (2009) define Mao's ethos as the 'hydraulic mission' – the 'harnessing [of] water resources for human needs as typified by major dams and irrigation systems' (Swatuk, 2008). Until recently, China has focused on 'hard' supply development, rather than 'soft' demand management. A clear example is the country's South–North Water Transfer Project, which we highlight in Box 2 overleaf. As a result, much of the country's current hydraulic infrastructure that powered its economic growth was built or conceived from the 1950s to 1970s. In the early 1980s, however, China's investment in water infrastructure stagnated due to the national government focusing on other priorities and providing few incentives for local governments to invest. As a result, much of the existing infrastructure suffered from a lack of maintenance, as the Government preferred to focus on new projects (Lohmar et al., 2003). Within this context, China passed its original Water Law in 1988 to address these shortfalls and to reprioritise investment in agricultural water infrastructure. This was one of its early political drivers of progress toward improved agricultural water management. From here, we can begin to discuss the period from 1990 to the present in the following sections.

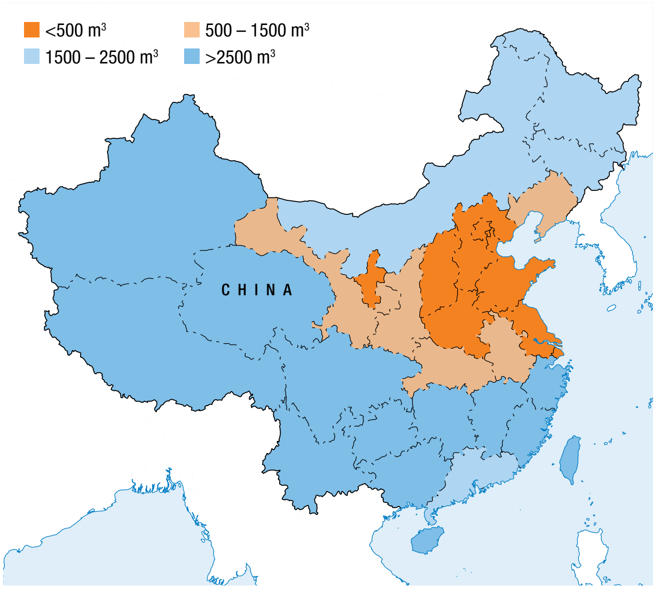
1.2 About this case study

This case study report examines China's progress toward more sustainable agricultural water management since 1990. It assesses the major drivers toward achieving 'more crop per drop' while improving rural incomes.

Box 2: China's South–North Water Transfer Project

China's challenge of regional water extremes has been recognised since Mao's era. Mao himself suggested the idea to move water from the south of the country to the north in 1952 (Guerringue, 2013). It took until 2002 for construction of this 'South–North Water Transfer Project' to begin though, and construction will continue for several decades. The project is a feat of massive engineering to transfer water from the southern Yangtze basin to the northern Yellow River basin along three main routes, to help alleviate northern scarcity (see Map 2). As of 2014, the project's eastern route is beginning to come online, though its western and central routes are still in development (Yue, 2014). The project is a clear example of China's historic engineering-led approach to its water resources management problems.

Map 1: Water resources per capita, 2012 (m^3 per person)



Source: Based on NBS, 2014; World Bank, 2007

The report sets out four key drivers that help explain improved agricultural water management: the balancing act by Chinese decision-makers on the need for water for food versus water for growth; institutional and policy reforms; major investment by the Government; and local programmes to incentivise progress using technical, economic and regulatory interventions.

The research team of UK- and China-based researchers reviewed and analysed published materials, including government policies, surveys, project reports, journal articles and grey literature, along with publicly available datasets on agricultural production, water use and other related indicators. The team also carried out a field visit to Beijing and Inner Mongolia in June 2014 to interview a range of experts working on China's water and agriculture sectors. These included academics in Beijing and water resource department and irrigation district officials in Inner Mongolia. Team members also drew upon their past field and research experience in China to inform the analysis.

We framed the analysis around five main research questions, focusing in particular on irrigated agriculture in northern China in the context of growing and competing demands for water:

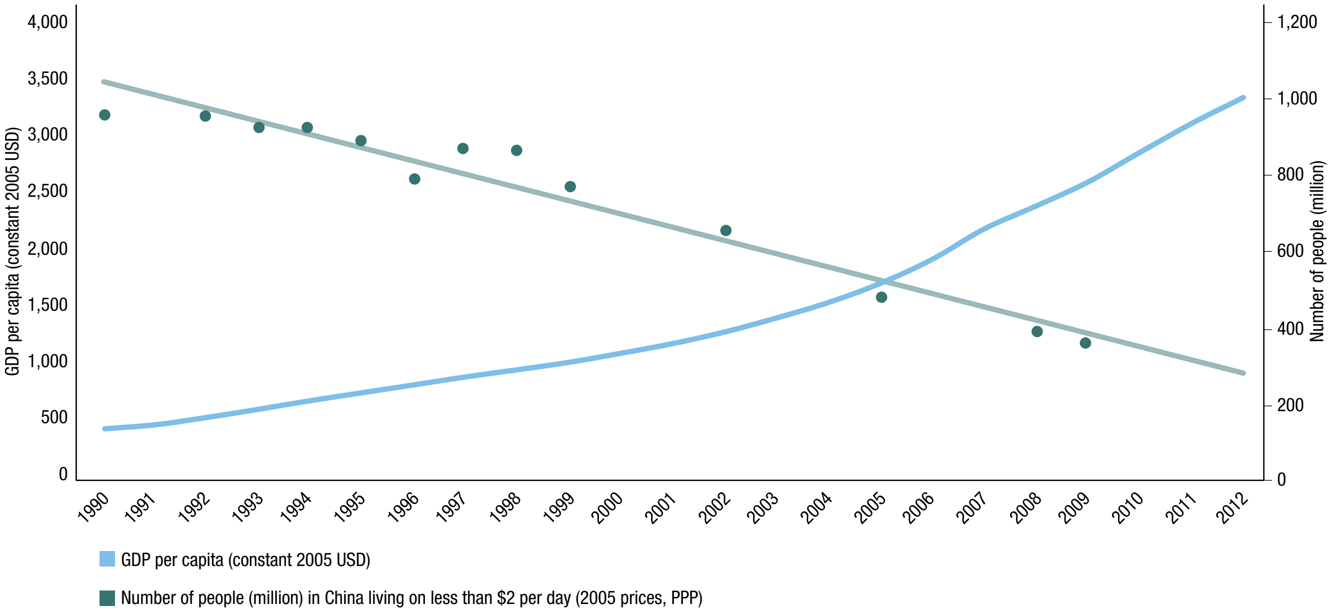
- What has been the nature and extent of China's progress toward sustainable agricultural water management?
- What mechanisms have enabled progress?
- What motivated (or blocked) change?
- What lessons have been learned about China's financing of sustainable agricultural water management?
- Have there been any trade-offs or unintended impacts arising from progress in sustainable agricultural water management?

The report is organised as follows: Section 2 describes China's progress toward more sustainable agricultural water management since 1990, focusing on water-scarce northern China. Section 3 explores the factors that have made the greatest contribution to this progress. Section 4 highlights the remaining challenges. Section 5 provides conclusions, and draws out policy lessons from China's experience over the past two decades.

Map 2: China's South–North Water Transfer Project

2. What progress has been achieved?

Figure 1: China's rising GDP per capita and falling levels of poverty



Source: World Bank, 2014

一步一个脚印
Every step leaves its print, work steadily and make solid progress (Proverb)

This section describes improvements in China's agricultural water management outcomes over the past two decades, focusing particularly on agricultural production and water use for achieving 'more crop per drop'. We first situate these key outcomes within the country's broader enabling environment, particularly its political progress on elements of sustainable development and its legislative progress on water and agricultural policy. We then discuss the agricultural water management outcomes in more detail, focusing on northern China.

2.1 China's broader economic progress and enabling policy environment

Since the early 1990s, China has experienced some of the world's highest rates of economic growth. Almost every macroeconomic metric for the country illustrates its rapid transformation from a low-income to an upper-middle-income country during this period. China's rates of growth have also far surpassed those of comparable countries in the 'BRICS' alliance (Brazil, Russia, India, China and South Africa). From 1990 to 2012, China's per capita GDP growth rate averaged an impressive 8.9%, while India's was 4.7%, Brazil's 1.3%, Russia's 0.9% and South Africa's 0.8% (World Bank, 2014). This helped lift nearly 600 million people out of $2-a-day poverty, even while the country's population grew by over 200 million people. By contrast, in India, 60 million more people lived in poverty in 2012 than in 1990, driven by the country's growth of nearly 400 million people. Figure 1 illustrates these trends for China and Table 1 (page 19) compares them for the BRICS countries. In this same period, China's national life expectancy rose from 69.5 years to 75.2 years and its UN Human Development Index rose from a 'low' score of 0.502 (ranking 101 of 141 listed countries) to a 'high' score of 0.715 (ranking 93 of 187 listed countries) (UNDP, 2014). The proportion of total income spent on food by its population also fell from around 55% to 37% (NBS, 2014).

From an environmental perspective, however, the 1990s were not much better than the 1980s. Bauer et al. (2013) describe the period 1992-2000 as China's second major development stage, post-1978, when industrialised economic development accelerated, but so too did environmental degradation, including water pollution and overuse. China's rapid economic development revealed its associated environmental challenges more quickly than experienced in other developed countries – where they had been able to deal with them over a much longer period. By the mid-1990s, Chinese policy-makers began to react to these increasingly serious challenges with the beginnings of an environmental agenda.[1] In 1994 and 1996, the Government tabled sustainable development strategies and implementation rules in official documents such as the 'Ten Key Responses to Environment and Development of China' and 'China's Agenda 21: White Paper on China's Population, Environment and Development in the 21st Century' (Zhang, 2012). These served as early strategic guidelines for sustainable economic and social development planning in the country, with the Government integrating their principles into other national plans over the subsequent years.

This national policy ambition began in earnest from 2000 until the present, a period which Bauer et al. (2013) describe as China's third major development stage post-1978 – typified by a greater integration of economic development, environmental protection and poverty reduction. Since 2000, the country's most important national planning documents and policy agendas – the Five-Year Plans and No. 1 Documents – have illustrated these shifting priorities at the highest level. The 11 No. 1 Documents[2] that the CCP has issued since 2004 have all focused on rural agricultural development, including water conservation (Xinhua, 2014a). For example, the 2011 Document took 'accelerating development of water conservation' as its theme and aimed to double the Government's annual investment in water conservation infrastructure for the next 10 years.

The 10th Five-Year Plan for the period from 2001 to 2005 made an initial foray into an environmental agenda, setting several targets on pollution reduction, forest coverage and resource use, though many were not achieved (Hilton, 2011). The 11th Five-Year Plan (2006-2010) was more ambitious. It changed direction from a sole emphasis on economic growth toward principles of 'putting people first', promoting sustainable development and constructing a 'harmonious', 'all-around well-off' society. It included targets on energy and water use efficiency, pollution reduction and forest coverage. For example, it aimed to decrease water consumption per unit of industrial value added by 30%. It achieved some success, but, overall, its measurement framework was problematic. Its targets focused only on the final achievement of outputs by 2010, rather than having interim targets. This incentivised a last-minute rush by officials to meet these targets – often through short-term or perverse methods (Fuqiang et al., 2011).

The current 12th Five-Year Plan (2011-2015) has shifted even more explicitly toward 'harmonious development' and rebalancing the country's economy toward scientific progress, social harmony and inclusive green growth (Bauer et al., 2013). By far the 'greenest' development plan to date, it sets out to transform the development ethos away from Deng Xiaoping's 'material civilisation' toward an 'ecological civilisation' – as conceived by former president Hu Jintao (Boyd, 2012). This approach aims to balance the relationship between humanity and nature to create a 'beautiful China'. This expresses both a national development strategy for socialist modernisation and an ideological framework for sustainable development and green growth (d'Alançon, 2014; Ke, 2013). The Plan incorporates hard environmental targets into the country's 'target responsibility system', which is the CCP's main tool for implementing policies of high priority (Kostka, 2013). There are nine binding targets in this Plan on energy, water, pollution and forests, which indicates the Government's seriousness in tackling these challenges (Wang, 2013). For example, the Plan again commits the Government to decrease water consumption per unit of industrial value added by 30% over the previous reductions in the 11th Plan.

Alongside these plans has come a variety of increasingly ambitious laws and regulations at national and local level. An important moment for China's water policy came with the country's revision of its Water Law in 2002. For the first time, the Law explicitly addressed the need to reduce inefficient water use and poor water management (Lohmar et al., 2003). The Law focused on seven key water resource issues, which included the establishing and linking of national water permit and quota systems with river-basin-level planning, along with other conservation and pollution reduction mandates (Wouters et al., 2004). It also added new regulatory authority to the Ministry of Water Resources to manage river basins more comprehensively and to establish nationwide systems of water pricing to promote conservation. These regulatory reforms also led to the strengthening of river basin management agencies, the consolidation of local

1 At this broad policy level, China thus illustrates the environmental Kuznets curve hypothesis, whereby an economy grows at the expense of the environment until a certain average income is reached. Thereafter, environmental concerns are taken more seriously and levels of environmental degradation begin to decrease. From the perspective of environmental quality, this is not an ideal growth model, as the period of environmental degradation can permanently degrade environmental assets (e.g. through species extinction). The principles of sustainable development and green growth instead espouse a growth model that balances economic and environmental needs more effectively over time. However, few regions of the world have yet been broadly able to 'leapfrog' the phase of environmental degradation in their growth paths.

2 No. 1 Documents are the first policy documents released by the CCP at the start of a new year – they typically symbolise the issues of highest priority for the Government that year.

water-related bureaus into water affairs bureaus and the growth of water user associations for agricultural water management. Section 3 will discuss these further.

Another important moment came with the development of the 'three red lines' policy by the State Council in 2010. This ambitious policy established clear and binding limits on total water use, water use efficiency and ambient water quality for a number of benchmark years to 2030 (Moore, 2013a; State Council, 2012). The policy limits total national water consumption to under 700 billion cubic metres per year by 2030 – about three quarters of China's total annual exploitable freshwater resources. On water use efficiency, it reaffirms the 30% efficiency target from the 12th Five-Year Plan and also aims to increase irrigation efficiency[3] to 60% by 2030. The 'red line' on water quality is slightly less clear in the policy, but broadly aims to bring 95% of key rivers and reservoirs with specific usage functions for drinking, agriculture and industry 'up to standard on quality' by 2030 – from a baseline of 46% in 2011 (*China Daily*, 2012). The policy also added government investment of nearly $300 billion in 2011-2015 for irrigation infrastructure improvements, rural clean water delivery and reservoir enhancements.

Two other, more recent, examples of policy progress include the 2013 Agricultural Law and China's new 'war on pollution' through its 2014 Environmental Protection Law. The former aims to further develop and modernise China's agriculture, focusing on better managing irrigation systems and investing in water conservation initiatives. The latter will include formal environmental performance evaluations for officials and tougher punishments for violations, including a removal of caps on fines and the introduction of a daily penalties system for ongoing violations. It may also include a plan worth two trillion yuan ($320 billion) to reduce water pollution (Reuters, 2014). These national commitments and high-level policies are improving China's environmental reputation, with the country in fifth place of 27 ranked nations in the 'top green reputation – perception' category of the 2012 Global Green Economy Index (Dual Citizen Inc., 2012).

2.2 Achieving 'more crop per drop'

Within this broader context and enabling environment, China is making significant progress on its agricultural water management – achieving agricultural production gains alongside improvements to water use efficiency. We discuss each of these outcomes in turn. We focus on the outcomes for the 17 provinces and regions of northern China,[4] examining three important provinces more closely: Hebei, Heilongjiang and Gansu. These three provinces produce much of China's grain and are critical hotspots for agro-environmental debate, particularly on water resource management. Both Hebei and Gansu – historic centres of grain production – have suffered from serious water stress, while Heilongjiang represents the spatial reallocation of Chinese agriculture in response to this stress. The province contained vast wetlands in the 1950s that were drained (with serious ecological impacts) in the 1960s and 1970s, leading to the area becoming a major source of agricultural production from the 1990s. To assist in this discussion, we first review some of the issues surrounding the idea of water 'saving' in irrigated agriculture in Box 3.

2.2.1 Agricultural production

China's growth in agricultural production in the 1990s drove much of its economic growth and poverty reduction. Ravallion and Chen (2007), for example, estimate that agricultural growth from 1981 to 2004 had about four times the impact on national poverty as did growth in the industrial or service sectors. Between 1990 and 2012, China's agricultural productivity[5] more than doubled, increasing by over 130%. Its total irrigated area increased by over 30% and its per capita grain yield increased by over 10%, resulting in a rise in total yearly grain production from 446 to 590 million tonnes (World Bank, 2014; NBS, 2014). Figure 2 overleaf illustrates these trends. China achieved this while growing its population by over 200 million. Among the BRICS, only Brazil's agricultural productivity growth was higher (increasing by 176%), though Brazil's population only grew by 50 million in the same period. India's agricultural productivity grew by only 46%, Russia's by 63% and South Africa's by 88%. Table 1 compares the agricultural productivity growth of the BRICS countries.

China's annual growth rate for agricultural value added[6] averaged 4.2%, even while the importance of agriculture to China's economy declined in favour of industry and services. As China steadily advanced its economy from 1990 to 2012, agriculture's share of total GDP fell from 27% to 10% and its share of total employment nearly halved from 60% to 35% (World Bank, 2014). Nevertheless, China's output of cereals, cotton and sesame per hectare of production all increased significantly: by around 35% for cereals, over

3 The policy defines 'irrigation efficiency' as the reduction of conveyance losses (e.g. from leaky canals), though, as we discuss in Box 3, this does not necessarily represent 'real' resource savings.

4 These are: Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Jiangsu, Anhui, Shandong, Henan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang.

5 Agricultural productivity measures the ratio of agricultural value added (defined below) per worker employed in agriculture. The data are in constant 2005 US Dollars.

6 Agricultural value added measures the output of the agricultural sector minus the value of intermediate inputs, without making any deductions for asset depreciation or natural resource degradation. The data are in constant 2005 US Dollars.

Box 3: Saving water in irrigation

Irrigated agriculture is often associated with inefficient, wasteful water use. This is true, up to a point, but the possible efficiency gains are often over-estimated since some of the water 'saved' with new systems and technologies was never lost in the first place. From a water balance perspective, water not taken up and transpired by a crop, even if withdrawn from its natural course, is not necessarily wasted. This is because unused water (e.g. leaks from irrigation canals) may be used further downstream in the irrigation system, may flow back to the river, or may recharge wetlands or aquifers. For the purposes of this report, we define water withdrawals that result in this unused water as 'non-consumptive uses'. Renewable freshwater is only 'lost' when it is transpired by a crop, evaporates from the soil, is fatally polluted, or when it joins a saltwater body. We define water withdrawals that result in these freshwater losses as 'consumptive uses'. A typical water withdrawal for agriculture will result in a certain amount of both non-consumptive and consumptive use – this is unavoidable. That said, 'savings' from reducing non-consumptive use that would have generated useful aquifer recharge (for example) are often termed paper savings, rather than real resource savings. Unfortunately, much of the literature on 'water efficiency' and 'water saving' fails to make the distinction between real resource savings (reducing non-beneficial consumptive use) and paper savings (reducing non-consumptive use). Figure 3 (overleaf) displays these flows.

What are the implications? First, only those modifications to irrigation and cropping practices that reduce non-beneficial consumptive use (e.g. reducing water losses from soil evaporation or fatal pollution) represent real water savings, rather than merely reducing conveyance losses (e.g. leaky pipes). Second, there will be no real resource benefit if savings are used to expand the irrigated area or to grow more water-intensive crops (unless a less-productive expansion was going to happen anyway). Therefore, the success of agricultural water saving measures aimed at stabilising groundwater levels, or in sustaining river flows, depends on savings being translated into permanent reductions in abstraction.

How can real savings be achieved? There are three main types of action:

- Engineering measures: such as water distribution through low-pressure pipes, and in-field application through drip and micro-sprinkler technology.
- Agronomic measures: such as deep ploughing, straw and plastic mulching, the use of poly-tunnels, and the use of improved strains/seeds and drought-resistant varieties.
- Management measures: to improve irrigation forecasting, water scheduling and soil moisture management.

The debate about 'real' water saving and 'efficiency' gained high-level attention in the 1990s and 2000s. The World Bank funded a number of pilot projects in the North China Plain to reduce consumptive water use, specifically non-beneficial evapotranspiration (see Box 12, page 35). However, most official data and policy targets – in China and elsewhere – still do not distinguish between consumptive and non-consumptive uses and use the terms water use, withdrawal, demand and consumption interchangeably, despite their different meanings. This reflects both continuing confusion about water savings and the scale/perspective that should be used (e.g. field vs river basin), and the difficulties associated with actually measuring and monitoring the movement of water through the hydrological cycle.

Sources: Foster and Garduno, 2004; Perry, 2007

80% for cotton and nearly 110% for sesame. As a result of all this, China's prevalence of undernourishment has halved, its food supply (measured as kilocalories per person per day) has increased by 22% and its Global Hunger Index score has decreased from 13 ('serious' hunger issues) to 5.5 ('moderate' hunger issues) (FAOSTAT, 2014; IFPRI, 2013). Table 1 compares China's progress on its Hunger Index over time, alongside the other BRICS countries.

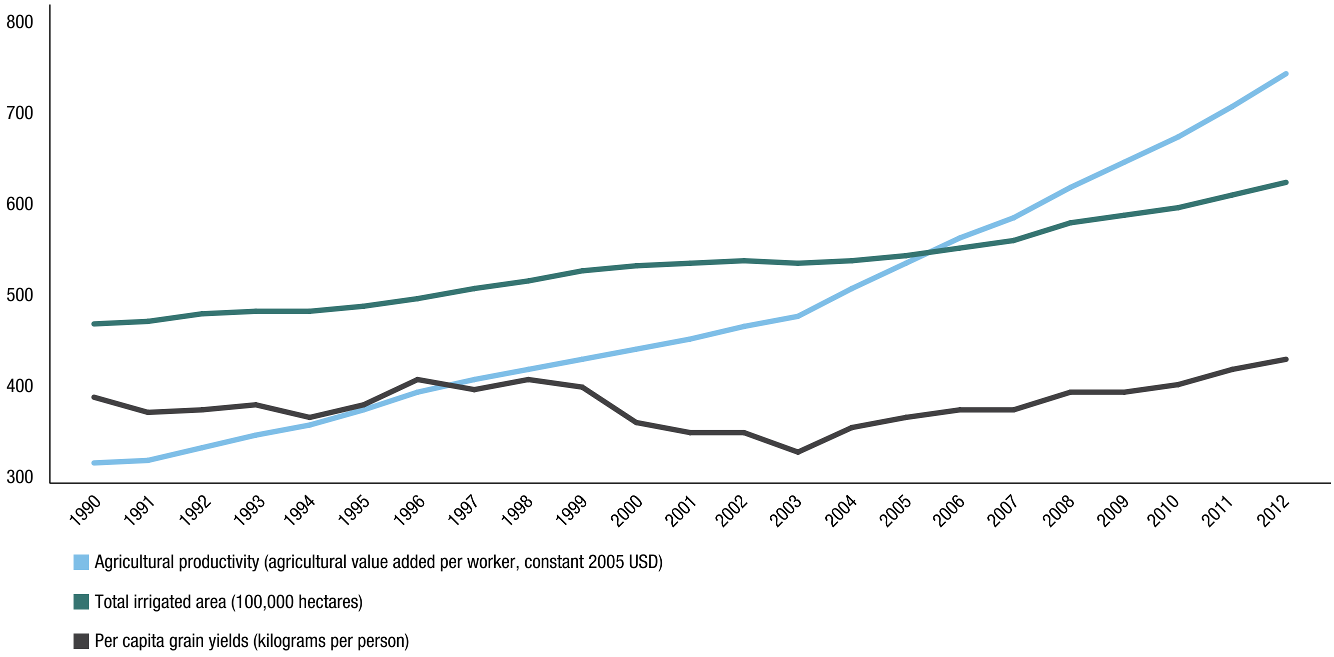
It is important to note that these results were achieved through intensification of production or reallocation within existing production areas, rather than through an expansion of agricultural land. The country's total percentage of land area devoted to agriculture has remained stable at around 55%,[7] growing by less than 3% since 1990, while allowing total forest area and terrestrial protected areas to increase by a few percentage points (World Bank, 2014). For example, much of its 30% growth in total irrigated area came in areas that previously relied on less productive rainfed agriculture.[8]

The data from northern China yield even more impressive results, though there are fewer official data available (NBS, 2014). Northern China's 17 provinces

7 This figure includes land that is arable, under permanent crops or under permanent pastures.

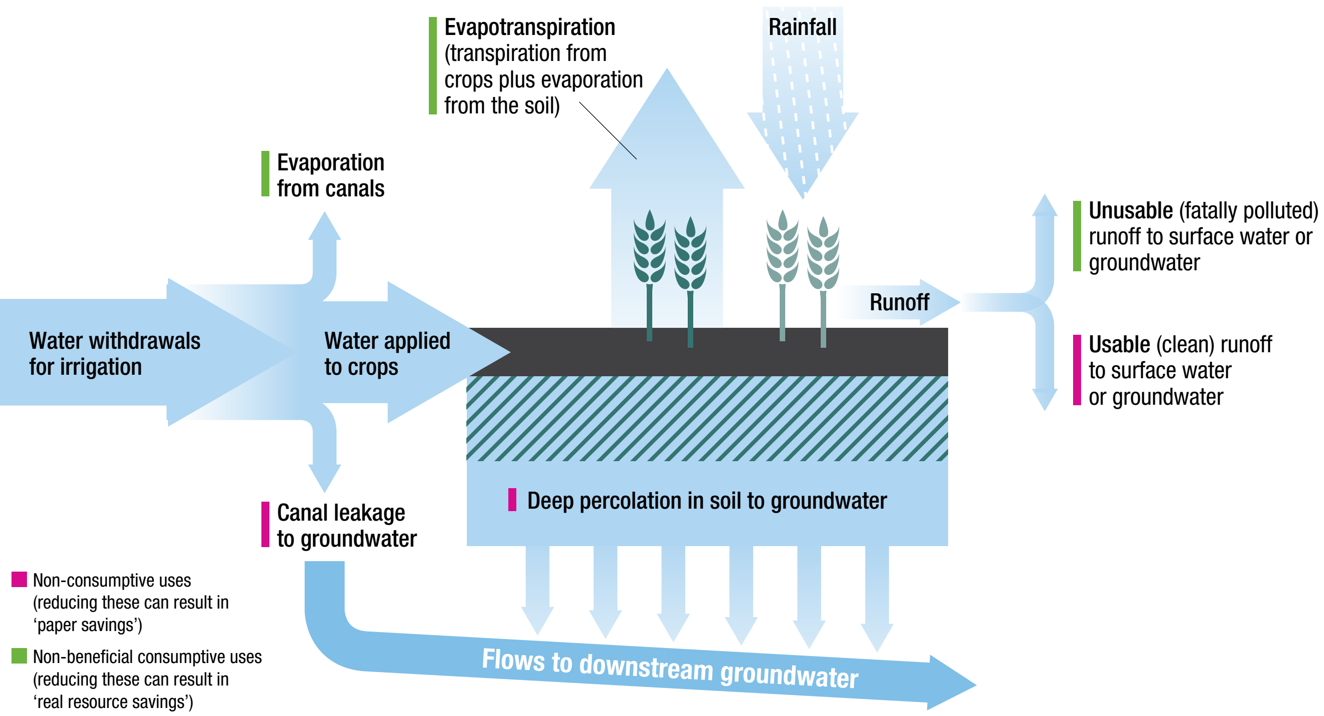
8 As a result, the percentage of irrigated land within China's total agricultural land area rose by about 3%, from 10% of the total in 1990 to 13% in 2012.

Figure 2: China's growth in agricultural production, 1990-2012



Source: World Bank, 2014; NBS, 2014

Figure 3: The agricultural water cycle



Source: Based on FAO, 1997

Table 1: Comparing growth trends across the BRICS countries

	Brazil	Russia	India	China	South Africa
Population, 1990	149,600,000	148,300,000	868,900,000	1,135,200,000	35,200,000
Population, 2012	198,700,000	143,200,000	1,236,700,000	1,350,700,000	52,300,000
Life expectancy at birth (years), 1990	66.5	68.9	58.5	69.5	62.1
Life expectancy at birth (years), 2012	73.6	70.5	66.2	75.2	56.1
Per capita GDP growth, 1990-2012 (constant 2005 USD)	1.3%	0.9%	4.7%	8.9%	0.8%
Number of people lifted out of $2 a day poverty, 1990-2012 (2005 prices, PPP) (Negative values indicate a growth in poverty)*	24,000,000	12,200,000	(-62,000,000)	598,600,000	(-300,000)
Growth in agricultural productivity, 1990-2012 (agricultural value added per worker, constant 2005 USD)	176%	63%	46%	130%	88%
IFPRI Global Hunger Index - 1990	8.7	<5	32.6	13	7.2
IFPRI Global Hunger Index - 2013	<5	<5	21.3	5.5	5.4

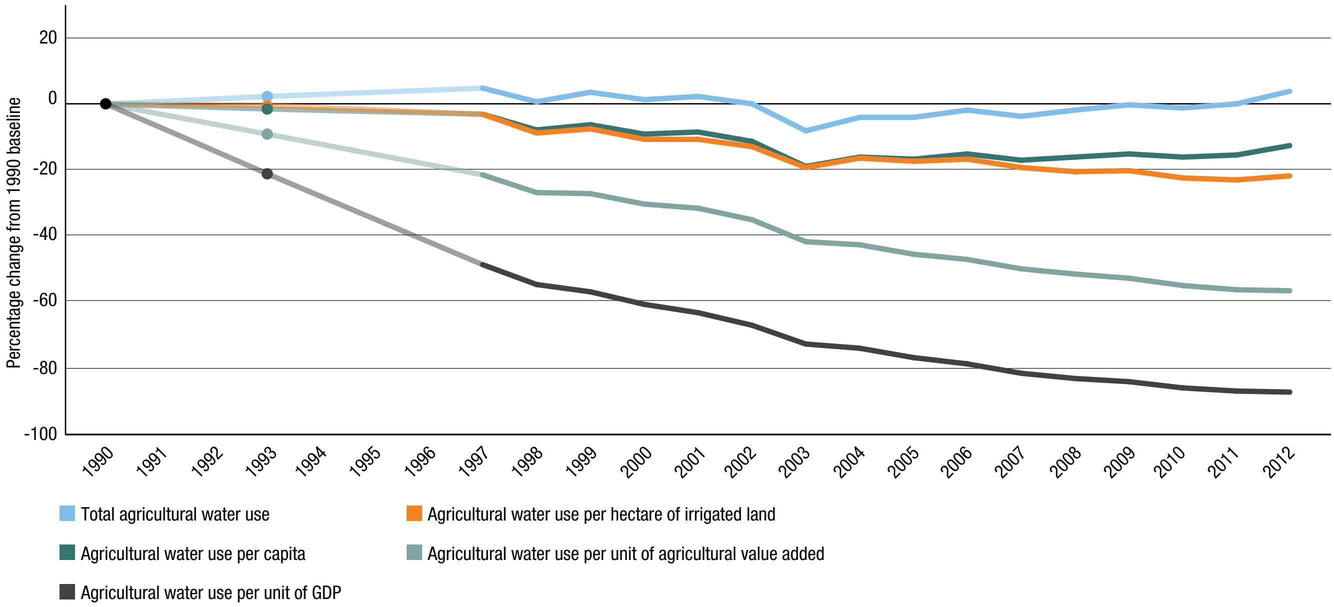
**Based on World Bank population data and available data on poverty headcount ratios for each country, which vary by country - these estimates are likely to be an underestimate, as some data are missing for each country*
Source: World Bank, 2014; IFPRI, 2013

Table 2: Agricultural production data for three provinces in water-scarce northern China

	Hebei	Gansu	Heilongjiang
Total irrigated area, 1995	4 million hectares	890 thousand hectares	1.1 million hectares
Total irrigated area, 2012	4.6 million hectares	1.3 million hectares	4.8 million hectares
Growth in total irrigated area	14%	45%	336%
Grain yields per capita, 1995	0.43 tonnes per person	0.26 tonnes per person	0.69 tonnes per person
Grain yields per capita, 2012	0.45 tonnes per person	0.43 tonnes per person	1.5 tonnes per person
Growth in per capita grain yields	5%	63%	118%

Source: NBS, 2014

Figure 4: Agricultural water withdrawals in China, 1990-2012



Source: World Bank, 2014; NBS, 2014; Cheng and Hu, 2011

and regions saw their total irrigated area grow by 35% from 1995 to 2012 and their per capita grain yields grow by 30%, although these values varied widely between individual provinces. Table 2 (page 19) summarises the differing growth trends for Hebei, Gansu and Heilongjiang. Heilongjiang displays the most impressive growth, though it came at the expense of the province's wetland ecosystems, as mentioned above.

Lastly, we caution the reader that the national data on agricultural productivity and value added include not only the value added from farming activities but also from forestry, fishing and animal husbandry. These other sectors contributed to the growth of these indicators in China and in the other BRICS countries. They are not generally disaggregated in national datasets. In China, animal husbandry will have made a significant contribution, as this sector has grown rapidly since 1990. For example, China's total meat production has more than doubled since 1990, increasing by around 130% (FAOSTAT, 2014). These data therefore represent a broader agricultural growth on China's part, not solely representative of farming activities.

2.2.2 Agricultural water withdrawals

China's agricultural water use data illustrate a strong and convincing story of progress. Even with the country's significant growth in agricultural production since 1990, its agricultural water use intensity has declined significantly, and its total agricultural water use[9] has been relatively stable (NBS, 2014). Between 1990 and 2012, China's total agricultural water use increased by only 4%, from 374 to 388 billion cubic metres per year. Its agricultural water use per hectare of irrigated land thus declined by 22% over the same period. We summarise this and other intensity metrics in Figure 4 and Table 3.

The data from northern China show generally similar trends, with a few exceptions (NBS, 2014). Between 1995 and 2012, northern China's total agricultural water use increased by about 9%, from 216 to 237 billion cubic metres per year. Nonetheless, its agricultural water use per hectare of irrigated land declined by 19% over the same period. Individual provinces varied significantly: while Hebei's total use decreased by about 10%, Gansu's remained stable and Heilongjiang's nearly doubled – increasing by 92%. We summarise these and other provincial intensity metrics in Table 3. Note Heilongjiang's impressive decrease in water use per hectare of irrigated land. This illustrates that, even though Heilongjiang rapidly expanded its agricultural production, it managed its agricultural water in an increasingly efficient manner.

However, we caution the reader on four important issues here. First, official data from the Chinese government probably under-estimate groundwater use, especially for agriculture. The official water use data do include estimates of total groundwater use, but do not disaggregate them by sector. They probably measure groundwater withdrawals only from 'official' sources, rather than from privately owned tube wells. This is important because official

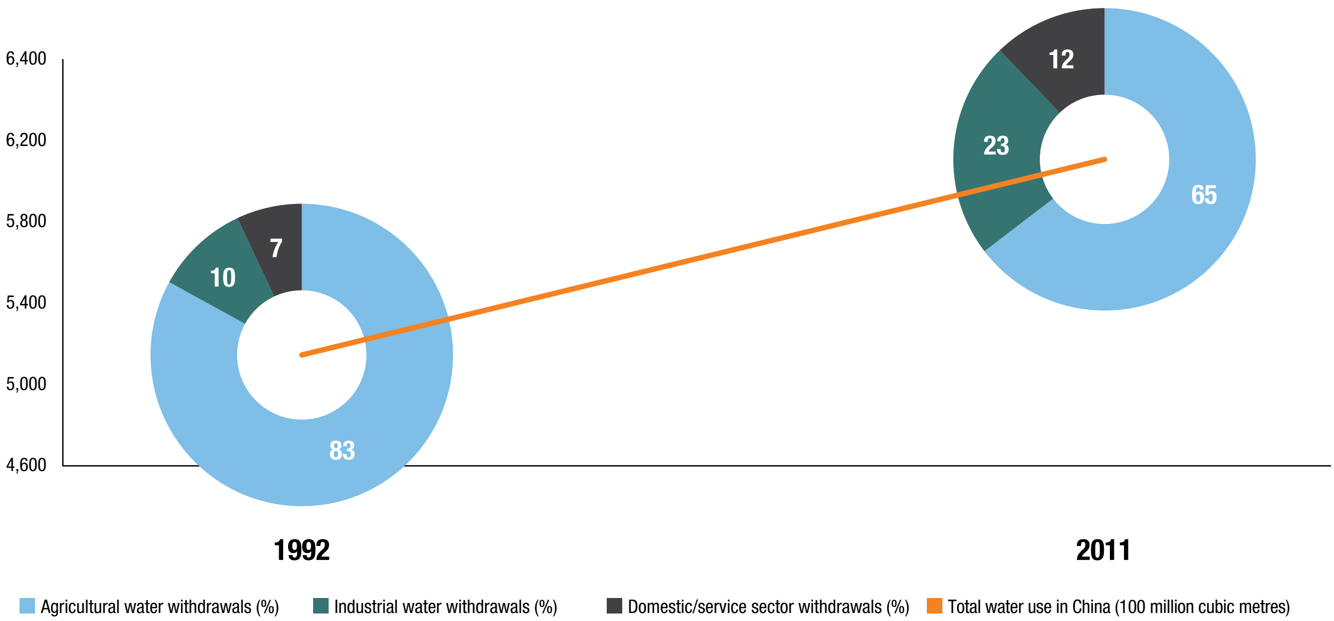
9 Agricultural water 'use' measures total withdrawals by the agricultural sector (i.e. consumptive plus non-consumptive uses).

Table 3: Highlights of national, regional and provincial data on agricultural water withdrawals in China, northern China and the three provinces of Hebei, Gansu and Heilongjiang

	China	Northern China	Hebei	Gansu	Heilongjiang
Total agricultural water use, 1990 (China) / 1995 (northern China & provinces) (100 million cubic metres)	3,737	2,156	159	95.4	154
Total agricultural water use, 2012 (100 million cubic metres)	3,880	2,365	142.9	95.1	294.9
Percent change in total agricultural water use (negative indicates decline in use, positive indicates rise in use)	3.8%	9.7%	(-10.1%)	(-0.3%)	91.5%
Agricultural water use per hectare of irrigated land (cubic metres per hectare), 1990 (China) / 1995 (northern China & provinces)	7,884	6,770	3,936	10,689	14,068
Agricultural water use per hectare of irrigated land (cubic metres per hectare), 2012	6,156	5,494	3,105	7,329	6,174
Percent change in agricultural water use per hectare of irrigated land (negative indicates decline in use, positive indicates rise in use)	(-21.9%)	(-18.9%)	(-21.1%)	(- 31.4%)	(-56.1%)
Agricultural water use per capita (cubic metres per person), 1990 (China) / 1995 (northern China & provinces)	329	338	247	391	416
Agricultural water use per capita (cubic metres per person), 2012	287	335	196	369	769
Percent change in agricultural water use per capita (negative indicates decline in use, positive indicates rise in use)	(-12.7%)	(-0.8%)	(-20.6%)	(-5.7%)	84.8%

Source: World Bank, 2014; NBS, 2014; Cheng and Hu, 2011

Figure 5: China's shifting water allocations between its three main sectors



Source: World Bank, 2014; NBS, 2014; Cheng and Hu, 2011

estimates of total groundwater use increased by only 6% from 2000 to 2012, but this contrasts with findings from field studies that indicate significant declines in groundwater levels and significant increases in the number of tube wells in some parts of the north. For example, Wang et al. (2009a) cite some sample communities in northern China where the number of tube wells increased by more than 12% annually between 1995 and 2004.

Second, note that the official data on 'agricultural water use' include water use not only for irrigation, but also for the replenishment of fish farms, for forestry and for animal husbandry (NBS, 2014). We can expect these sectors to require significantly less water than irrigation. Even for animal husbandry, the biggest water uses are the irrigation-based withdrawals needed to grow water-intensive feed crops like soybeans and corn. The efficiency gains we see in agricultural water use data thus reflect efficiency gains in these other sectors as well, though irrigation is the main user.

Third, note that official data on agricultural water use report a figure only for total withdrawals – they do not disaggregate these withdrawals into consumptive and non-consumptive uses. Beyond a few case studies (e.g. Box 12), the Government has not yet attempted to collect national data on these different uses, due to the challenges involved in doing so. It is therefore difficult to determine China's progress on reducing non-beneficial consumptive use.

Fourth, this progress story applies only to China's agricultural sector. The country's total water use across all sectors of the economy increased by about 27% from 1990 to 2012, from 480 to 614 billion cubic metres (Cheng and Hu, 2011; NBS, 2014). China's growing industrial and service sectors drove most of this increase, since total agricultural water withdrawals remained stable over this period. Agriculture's share of total freshwater withdrawals declined from 83% to 65%between 1992 and 2011, while industry's share rose from 10% to 23% and the domestic/service sector's rose from 7% to 12% (World Bank, 2014). Figure 5 depicts these changes.

There are two ways to consider these data. A realist perspective would propose that these agricultural water savings were simply consumed by growing industrial and domestic uses and did not result in an overall environmental benefit. However, if we consider a counterfactual scenario where China had not made any effort to improve agricultural water use efficiency, there

Box 4: What if China hadn't improved its agricultural water use efficiency?

We can attempt to calculate a simple counterfactual scenario to illustrate the potential magnitude of the averted impacts from China's improved agricultural water use efficiency. We first assume that China's 1990 value for its agricultural water use per hectare of irrigated land remained the same until 2012, instead of decreasing by 22% as it did in reality. We assume everything else in China's history remained the same. We then multiply this 1990 value by the 2012 value for total irrigated area to calculate the counterfactual value for total agricultural water use in 2012 and compare it to reality. Although it is a crude assumption, the results from this calculation suggest that total water use in China from 1990 to 2012 could have increased by 50% instead of 27%.

is some cause for optimism. The savings allowed China's industry and service sectors to develop further within natural water resource limits than they would otherwise have been able to, lifting more people out of poverty as a result. Likewise, the environmental problems introduced by a 27% increase in total water withdrawals are arguably less significant than those that would have occurred if this increase in total withdrawals had been larger. Box 4 calculates a simple counterfactual scenario in this context.

Despite these issues, another noteworthy indicator of progress is that China has avoided a large-scale 'water crisis' to date. A variety of mainstream media and professional writings have labelled China's challenges with water quality and availability as a 'crisis' (Moore, 2013b; *Economist*, 2013; Cho, 2011; Yu, 2011; Xie et al., 2009), but have not supported this label with systematically presented evidence. Lohmar et al. (2003) argued that a national 'water crisis' in China could only be evidenced if data show: i) a large-scale disruption of water deliveries (i.e. water shortages), ii) substantial declines in relative areas under irrigation, and/or iii) substantial declines in relative industrial production that threaten economic activity. By these criteria, Lohmar et al. concluded in 2003 that China was not suffering a national water crisis. They acknowledged that disruptions of water deliveries (both surface water and groundwater) to various users were occurring in some areas, but were not yet severe enough to affect the country's aggregate production metrics. Our data indicate a similar result. We do not have official data with which to assess the extent of water delivery disruptions at a small scale, but the aggregate data on irrigated area and industrial production both continue to illustrate strong relative growth.

3. What are the factors driving change?

Growing rapeseed in Anhui. Photo: © Frank Tsang

摸着石头过河

Crossing the river by feeling for stones (Chen Yun)

This section looks at four factors that have worked in combination to drive China's progress toward more sustainable agricultural water management:

- balancing water for food versus water for growth
- institutional and policy reform
- sustained financial investment
- technical, economic and regulatory incentives.

We discuss these four drivers in more detail below.

3.1 Balancing water for food versus water for growth

As agriculture's share of the economy has decreased, China has increasingly grappled with the question of how to release water to rapidly growing urban areas and industries while continuing to increase farm production and rural incomes. With the famines of the Great Leap Forward still in living memory, this balancing act in the face of increasing water demands has been the country's overarching driver of change on agricultural water management. Until very recently, one of the country's 'most sacred tenets' was its policy of being self-sufficient in grain (Hornby, 2014). The wellbeing and incomes of rural farmers continues to be one of the most important and sensitive political issues, evidenced by the focus on rural agricultural development of every No. 1 Document since 2004. As a result, releasing water to industry and services has not been an easy task for the Government, as this needs to be done without hurting rural farmers. Demand

Box 5: Preserving the CCP's political legitimacy

As the single governing party of China, the CCP is concerned about preserving its political legitimacy with its citizens. Social unrest from environmental pollution can pose a threat to this legitimacy if citizens perceive the Government as being no longer able to address their concerns on these issues. To avoid this, d'Alançon argues that the CCP is adapting its rhetoric to reflect this growing environmental consciousness. In Mao Zedong's era, the CCP's sources of legitimacy centred on ideology and nationalism, while in Deng Xiaoping's era, they centred on economic growth. Now, with rhetoric like 'beautiful China', 'harmonious society' and 'war on pollution', it seems that the CCP is attempting to establish a new source of legitimacy on sustainable development and green growth. Its success with this remains to be seen.

Source: d'Alançon, 2014

management incentives – like water pricing at farmer level – have not worked well in China due to these sensitivities.

Instead, these tensions have pushed the Government to adopt an ethos of 'learning by doing'. Chen Yun (a top government official in the 1980s and 1990s) famously called this 'crossing the river by feeling for stones' – a development philosophy favouring problem-focused solutions that has persisted to the present. This approach of experimenting to find out what works and what doesn't is reflected in the other three drivers of change that we discuss below. These have encouraged innovative solutions that have helped to release agricultural water for higher-value use by industry and services without hurting farmers.

Alongside this ethos, China's growing energy insecurity, resource degradation and pollution have increased the environmental consciousness of the country's citizens and policy-makers and prompted them to respond. Concern about China's so-called 'cancer villages' and Beijing's 'airpocalypse' are particularly high-profile examples. Pollution is now the main cause of social unrest in the country (Van Rooij, 2010). This is probably driven by the sheer unpleasantness of pollution for China's public, but may also be driven in part by a recent resurgence of Confucianism in the country (Palmer, 2013; Boyd, 2012). Chinese policy-makers increasingly understand the negative effects of environmental degradation on economic growth and social stability. They are taking them seriously – evidenced, for example, by the nine binding targets in the 12th Five-Year Plan and the ambitious new 'war on pollution'. Their response is pragmatic, motivated mainly by efforts to avoid economic and social costs. Box 5 discusses this further.

China's balancing act between competing water demands may become more significant with the recent emergence of a stronger civil society in China. The Government increasingly allows citizens to voice complaints about their local contexts, such as local enterprises or development projects (d'Alançon, 2014). Public protests and campaigns at this level have influenced policy decisions on water management. Mertha (2008) gives examples of successful anti-dam campaigns in Sichuan and Yunnan provinces that succeeded because of the ideas the protesters promoted, the way they framed the problems and, at times, their close connections to high-level officials. NGOs are also increasingly able to monitor independently things like water quality, which can promote citizen awareness and guide local officials toward better responses (Carino and Xie, 2013).

3.2 Institutional and policy reform

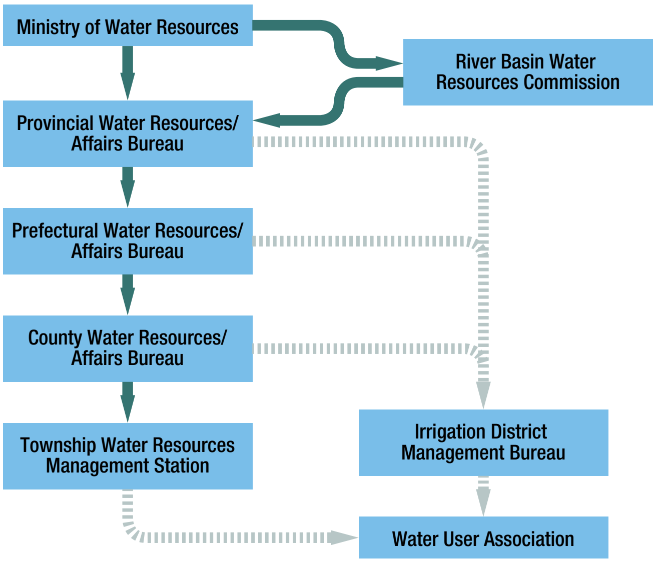
In the context of water allocation tensions and environmental concern, the Government's recent institutional and policy reforms are a driver of progress. These have incentivised local action toward the goal of 'more crop per drop'.

An early contributor to this progress was the original 1988 Water Law. It aimed to address the shortfalls of the existing, piecemeal system and to reprioritise investment in agricultural water infrastructure (Lohmar et al., 2003). This helped to spur new growth in investment (with investment in water conservation infrastructure rising from 4.9 billion yuan in 1990 to 12 billion yuan in 1995)[10] and irrigated areas (rising from a steady 45 million hectares in the period from 1978 to 1985 up to 48 million by 1992) (Lohmar et al., 2003; NBS, 2014). However, it did not adequately address a variety of growing issues related to agricultural water management, such as pricing inefficiencies and perverse incentives against water conservation at both the household and administrative level. This became more visible as water demands increased during the 1990s. For example, a common village practice was to incorporate all rural taxes and fees into a single, lump-sum charge for farmers to pay on an annual basis (Lohmar et al., 2003). As a result, farmers did not actually see a disaggregated cost figure for their water payments, and had little awareness or incentive to conserve.[11] Conflicts over water use and allocations between different users and regions also grew in intensity as demands increased. For example, a drastic reallocation of agricultural water for growing industrial use in Hubei province from 1993 to 2001 led to a 31% decline in irrigated rice area and a similarly large decline in rice production (Hong et al., 2001).

10 These figures are expressed in constant 1990 prices for the yuan.

11 This is still the case in some Chinese villages.

Figure 6: China's institutional framework for water management under the Ministry of Water Resources



Source: Shen, 2014

This period saw a rapid growth in the use of groundwater for water supply as well. The country's earlier decollectivisation of agriculture and fiscal reforms incentivised local actors to engage in entrepreneurship on this issue (Oi, 1995). Village-managed private entrepreneurs and individual farmers increasingly tapped groundwater, as a response to poorly managed and unreliable irrigation systems, cheaper tube well components and an absence of effective groundwater regulation within the 1988 Law (Shah et al., 2004; Lohmar et al., 2003). As a result, groundwater-based irrigation, which was essentially non-existent in China in the 1950s, had risen to perhaps 40% of total water use in irrigation by the mid-1990s (Calow et al., 2009). India, by comparison, experienced the same trend in its agricultural sector to an even greater extent, with over 60% of its total water use in irrigation now supplied by groundwater (GWP, 2013).

In this context, China's ambitious revisions to the Water Law in 2002 began to shift the country toward more sustainable water resources management. As discussed in Section 2, the Law explicitly addressed the need to reduce inefficient water use and poor water management (Lohmar et al., 2003). Its policies and subsequent regulations supported a variety of institutional reforms, at both national and sub-national scales. Most notably, it reformed the Ministry of Water Resources. Among other things, this helped lead to three, relatively independent, institutional reforms: the strengthening of river basin commissions, the consolidation of some local water-related bureaus into water affairs bureaus and the growth of water user associations for agricultural water management. These three sets of reforms helped to drive significant progress toward more sustainable agricultural water management at different scales of influence. We will discuss each one below. They did so by reducing water use conflicts between regions and users, and by promoting irrigation system improvements at the village level. China's recent 'three red lines' policy also continues to support these reforms. Figure 6 displays their positions within China's broader institutional framework for water management under the Ministry of Water Resources.

3.2.1 River basin commissions

Within China's ten major river basins, river basin management commissions have a long history, with early versions dating back to Imperial China. Since then, these commissions have undergone a variety of centralisation and decentralisation reforms. Immediately prior to 1988, they had been strong, centralised agencies, accountable directly to the State Council (Shen, 2004). The 1988 Law weakened their authority though, giving them an ambiguous definition as 'residential missions' of the Ministry of Water Resources. This gave them an unclear legal status and did not clarify their regulatory instruments, coordination mechanisms or internal structures (ibid.). The 2002 Law reversed this, recentralising their authority and defining 'river basin management' as a concept for the first time. It focuses on four key elements of the concept: river basin planning, water resource protection, water resource allocation and conservation, and water dispute resolution and law enforcement. In this regard, the Law was a 'milestone' in the country's history of water management (ibid.), providing river basin commissions with legal authority to implement laws and administer penalties within their jurisdiction. This includes managing complex water rights claims and making allocations across provinces, with the goal of reducing interregional water conflicts.

Tensions remain however in terms of jurisdiction and authority (Song et al., 2010). The Law did not clarify the relationship between the potentially overlapping jurisdictions of river basin commissions and of other administrative units, like provincial governments. This can cause tensions in the application of national law by these different organisations. For example, the national target for total water use defined under the 'three red lines' policy is sub-divided to provincial and then county levels – in other words to administrative units rather than hydrological ones managed via basin commissions. Box 6 gives another example of these ongoing tensions for the Yellow River Conservancy Commission.

3.2.2 Water affairs bureaus

In addition to interregional conflicts, the country has also experienced allocation conflicts between different users – agriculture, industry and domestic. China's rapid industrialisation and urbanisation have put pressure on the different allocations to these users. Agriculture is often the loser in these debates for all new water source developments, as industrial and domestic uses carry higher

Box 6: Allocating the waters of the Yellow River

The Yellow River is the sixth-longest river in the world, estimated at over 5,464km, flowing through nine Chinese provinces/regions – Qinghai, Gansu, Ningxia, Inner Mongolia, Sichuan, Shaanxi, Shanxi, Henan and Shandong. Throughout the 1970s, 1980s and early 1990s, the Yellow River frequently ran dry before reaching the sea, due to extensive overuse by agriculture. In 1987, the State Council approved a water resources allocation plan for the Yellow River to coordinate the water demands of major users and regions within the river basin. This strengthened the Yellow River Conservancy Commission, which is charged with setting minimum flow requirements for the river at provincial and regional boundaries, and allocating shares of available water to the nine provinces/regions of the river basin. Beginning in the 1990s, the Commission began regulating river flows, boosting storage capacity and controlling sediment levels by operating reservoirs along 3,000km of the river in an integrated manner. It also began outlining water shares within any given year in an Annual Regulation Plan, based on an Annual Allocation Plan, incorporating an annual water forecast and reservoir storage and release plans. In addition, the Regulation Plan provides for monthly water allocation scheduling by the Commission, based on monthly water use and reservoir operation plans prepared by individual provinces and regions.

These new management measures have had success. The Yellow River has experienced continuous flow to the sea since 1999 and sediment control measures have improved the river's flow capacity and decreased flood risk. The Commission has also worked hard to consult and to secure the support of the nine provincial/regional governments for its decisions, to promote more equitable water allocations. As a result of its work, the Commission was awarded the prestigious Lee Kuan Yew Water Prize in 2010. The award committee cited its work on '*rejuvenating the Yellow River and managing floods, which brought about social, economic and environmental benefits to over 100 million people*'.

Challenges remain, however, particularly regarding issues of interprovincial equity in water allocations. Prior to 1987, the upstream and lower-income provinces and regions of the river basin (Qinghai, Gansu, Ningxia and Inner Mongolia) enjoyed free access to water resources and had more than three times the per capita water availability of the downstream provinces. Since then, the Commission has reallocated much of this water to downstream provinces without significant compensation to those upstream. These new quotas and restrictions were generally introduced in advance of any measures to improve the local efficiency of water use in the upstream provinces and regions. This caused tensions by forcing the lower-income farmers in these upstream provinces and regions to reduce their levels of water use and crop production to support growth in the higher-income downstream provinces. The situation is gradually being rectified through investment in upstream infrastructure and institutional reforms, but illustrates the risks of regulation in the absence of adequate social protection.

Sources: Calow et al., 2009; SIWW, 2010; Wang and Zhang, 2010

economic value (Lohmar et al., 2003). Prior to 2002 however, the ambiguous legal framework often allowed upstream agriculture to hoard water at the expense of downstream industry. Lohmar et al. (2003) describe cases of industries shutting down during water-scarce periods because of this. Much of the problem arose from the adversarial nature of local water resource management institutions in the 1980s and 1990s (Shen and Liu, 2008; Shah et al., 2004; Lohmar et al., 2003). Urban Construction Commissions generally managed the water resource needs of urban areas and industry, while Water Resource Bureaus and Agriculture Bureaus managed agricultural needs. Local Environmental Protection Bureaus also existed in a similarly separate and adversarial position.

A water crisis from overuse, pollution and floods in Shenzhen in 1991 first prompted a radical rethink of these institutional structures. Uncoordinated infrastructure and policy development by these different bodies in response to growing demands were exacerbating floods and levels of pollution and overuse. For example, the city suffered a series of floods due to the hasty construction of some canals and wastewater treatment plants that were not coordinated with other parts of its water system (Lohmar et al., 2003). In response, the city merged the functions of these three adversarial organisations into a single water affairs bureau (WAB) to allow one entity to manage all local water deliveries to agriculture, industry and urban areas (ibid.). This holistic model succeeded in more efficiently managing the city's water resources between different users and in reducing pollution through better oversight and treatment of wastewater releases. The model then began to spread to other areas. At least 160 counties had reorganised their institutions into WABs by 1999 (Shah et al., 2004). The 2002 Water Law and its associated regulations further incentivised the rapid growth and nationwide scaling up of this model in the last decade. As of 2012, nearly 80% of China's counties and cities now use a WAB model – at least 1,923 functioning WABs (MWR, 2012).

The challenge now is for the Government to clarify legally and harmonise the various types of WAB model, as no standard model yet exists (Shen and Liu, 2008; Chen, 2006). The decentralised nature of WAB development to date means that some WABs are probably more effective than others. The transition to a WAB model has not always been easy. For some, competition has simply moved from being inter-institutional to intra-institutional, particularly

Box 7: Principles for effective WUAs

In the mid-1990s, World Bank project managers in China described five necessary principles for effective WUAs. These were:

- WUAs should only be used where an adequate and reliable water supply is available and where on-farm delivery infrastructure is in good condition and can be properly maintained by WUA members.
- A WUA should be the farmers' own organisation, a legal entity and have a leadership elected by its members.
- The jurisdiction of a WUA should be the hydraulic boundaries of the delivery system.
- A WUA should be able to receive its water under contract from its water suppliers and there should be the capacity to measure water volumetrically.
- A WUA should equitably assess and collect water charges from its members and make payment for the cost of water.

Source: Wang et al., 2010

if the new WAB assimilates staff members from the old bureaus without careful balancing of power dynamics. Some reforms have taken many years to implement (Lohmar et al., 2003).

3.2.3 Water user associations

At the village level, China has focused on better managing its agricultural water through decentralisation. Working closely with the World Bank, the country has promoted the water user association (WUA) model since the mid-1990s, based on the Bank's experiences with the model in other countries (Shen, 2014). By definition, WUAs are farmer-run, participatory institutions that manage the lower-level channels of irrigation systems. They distribute water, maintain canals, collect fees and disseminate new agricultural water management technologies or techniques to their users (Shen, 2014; Zhang et al., 2012; Wang et al., 2010). WUAs are accountable to their members and have a contractual relationship with local irrigation districts.

As with WABs, the decentralised nature of the WUA model means that WUAs can vary in structure and effectiveness. Based on its experience in China and elsewhere, the World Bank recommends that WUA structure and activity follow five principles to help ensure effectiveness in achieving more efficient agricultural water use (World Bank, 2010; Wang et al., 2010). Box 7 gives further detail. In China, studies by the World Bank (2010), Zhang et al. (2012) and Wang et al. (2010) suggest that WUAs can improve agricultural water use efficiency when managed according to these principles.

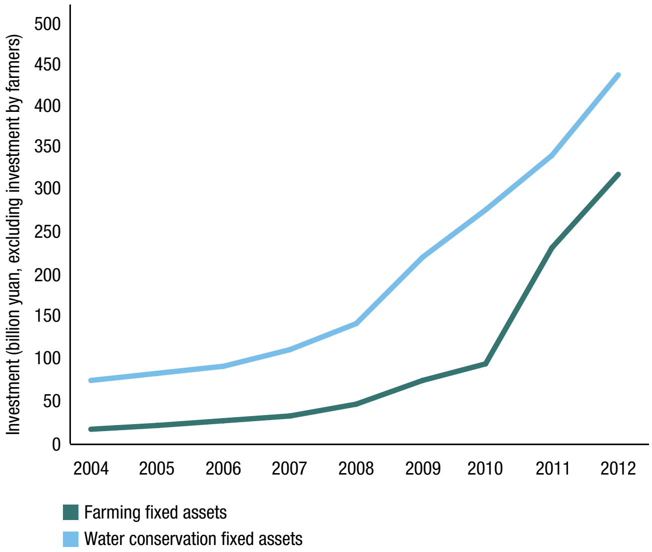
However, other authors commenting on international experience strike a more cautious note. They argue that while WUAs may provide benefits in terms of water delivery at lower levels, these do not necessarily translate into gains in water 'efficiency' in terms of water saving, and certainly not above field level (e.g. Vermillion, 1997; Cornish et al., 2004; Perry, 2013). WUAs face a variety of challenges with their financial sustainability and human resource capacity that contribute to this result. For example, the World Bank (2011) points out that most WUAs lack the legal authority and capacity to set their own water fees and, as a result, WUA income is often insufficient to cover the operation and maintenance costs for the canals that they manage. WUAs are also often managed by local village committees, rather than existing as their own, independently managed organisations. This can interfere with their ability to handle water fees, ensure good operation and maintenance and promote farmer participation, depending on the leadership dynamics of the existing village committee.

The other potential benefits of WUAs are less controversial. Huang et al. (2009) highlight that forming a WUA can leverage additional government investment in irrigation infrastructure. Once it arrives, WUAs can also have a valuable role in planning and implementing these infrastructure improvements compared to areas without WUAs. In their study villages, Huang et al. find that village leaders are more likely to turn an irrigation system over to a WUA when the canal system is more complex or of poorer quality, in the hopes of leveraging this new investment.

The 2002 Water Law provided a more favourable institutional and policy environment for the scale-up of WUAs. In particular, the Ministry of Water Resources issued a follow-on reform in 2005 whose purpose was to support the scaling up of WUAs (Shen, 2014). As with WABs, China has exponentially scaled up WUAs within the last decade. From the first WUA in 1995, the model grew to about 2,000 established WUAs in 2002 (Lin, 2003). In the next six years, this grew rapidly to more than 50,000 established WUAs in 2008, covering 34% of the country's total irrigated area (World Bank, 2011). By 2012, this number had reached over 78,000 (Chen, 2012). The World Bank predicts that WUAs will manage the local canals for 80% of the country's irrigated area by 2020 (World Bank, 2011).[12]

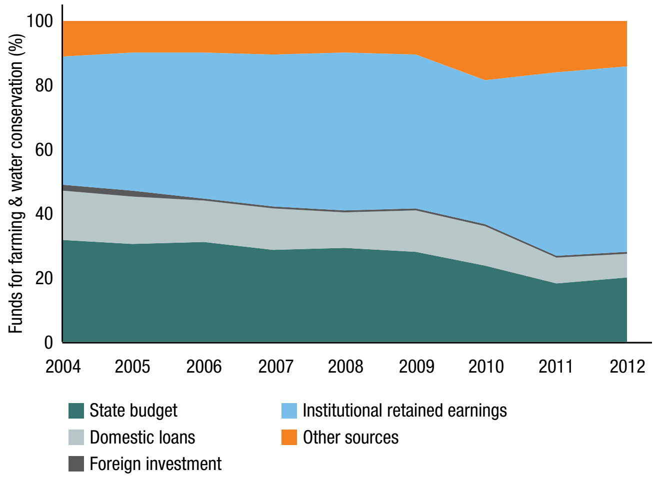
12 Though this does not imply that WUAs will be the sole managers. Irrigation districts and other water resource bureaus or WABs will still manage these areas and larger canals beyond village level.

Figure 7: China's growing agricultural investment since 2004



Source: NBS, 2014

Figure 8: China's shifting flows of agricultural investment since 2004



Source: NBS, 2014

3.3 Sustained financial investment

High levels of sustained investment in China's agriculture and water sectors are another driver of progress. This is partly the result of China's increasingly ambitious policy agenda on the environment, though a significant portion of investment has come from non-governmental sources too. Investment has come from the Government, farmers, businesses, and, to a lesser extent, international development agencies and NGOs. One statistical analysis by Fan et al. (2004) found that public investment spending drove the majority of China's agricultural growth in the 1990s, rather than institutional reform.[13] Likewise, an influential study at global level by Grey and Sadoff (2007) proposed that sufficient investment in water infrastructure can produce a 'tipping point' beyond which water makes an increasingly positive contribution to a country's growth and development.

The relative level of investment by the Government in agricultural water management has increased in the last two decades, compared to the level of investment by farmers (Shen, 2014). In the 1990s, the Government mainly invested in large-scale water management infrastructure. It left the responsibility for field-level irrigation investment to villages and individual farmers. Farmers' contributions – generally in-kind labour – were organised through the state's 'labour accumulation system', which had organised these contributions at village level and had been in place since 1949 (ibid.).

In 2000, however, the Government cancelled this system as part of a rural taxation reform in order to reduce the growing labour burden on farmers (ibid.). As a result, the Government no longer had free access to farmers' labour inputs for constructing new irrigation systems and maintaining existing ones. This created an unanticipated gap in field-level irrigation investment in the early 2000s, where the Government was unable to generate investment quickly enough to avoid drops in crop production and water use efficiency that arose from farmers no longer providing their labour to operate and maintain existing systems. By 2005, this gap had been filled, as the Government massively increased its field-level investment in new and existing irrigation systems and worked to re-engage farmers via labour subsidies. The Government's No. 1 Documents since 2005 also reflect this new ambition – they have committed to increasing the Government's rural agricultural investment every year, evidenced by the investment data below. Other examples include subsidy programmes in 2008 and 2011 that channelled finance to farmers for developing and enhancing more small-scale irrigation schemes.

National investment data reflect these events, with investment levels in agriculture and water conservation increasing rapidly since 2004. The main indicator with available data is the level of fixed asset investment (NBS, 2014).[14] Data on this indicator show that investment in

13 The study used a strong simplification for what 'institutional reform' meant. Nonetheless, the result broadly indicates the importance of investment to growth during this period.

14 This refers to investment in construction projects of a minimum size by any state or private entity, except for rural households. Some of the growth was due to a broadening of the indicator by China's statistics agency in 2011 to include investment by rural enterprises and institutions, though its rate of growth has been strong throughout.

farming infrastructure from all sources except farmers increased by nearly 19 times, from 17.1 billion yuan in 2004 to 320 billion yuan in 2012.[15] Likewise, investment in water conservation infrastructure increased by nearly six times, from 75 billion yuan in 2004 to 439 billion yuan in 2012.[16] Figure 7 (page 29) displays these growth trends.

The sources of these investments have changed over time as well. In both cases, the proportion of investment coming from central government budget has declined over time – though has still increased rapidly in magnitude. Total government investment increased, from 2.3 billion yuan in 2004 to 20.4 billion yuan in 2012 for farming infrastructure and from 25.6 billion yuan in 2004 to 132 billion yuan in 2012 for water conservation infrastructure (NBS, 2014). That said, the proportion from the retained earnings of local enterprises (so-called 'self-raised funds') has increased more significantly. For farming projects, the proportion of government investment fell from nearly 14% of total investment in 2004 to only 6% in 2012, while the proportion of investment from retained earnings rose from 56% to 81%. For water conservation projects, the proportion of government investment fell from 36% to 31%, while the proportion of investment from retained earnings rose from 36% to 40%. The proportion of foreign investment in these sectors has been insignificant throughout,[17] falling from 4% in 2004 to less than 1% in 2012 for farming projects and from 2% to less than 1% for water conservation projects. Figure 8 displays these changing investment flows (page 29).

These data reflect only fixed asset investment by government and businesses though, and omit any detail on investment by individual farmers, for which official data are unavailable. For rural households, national data report only a broad indicator of expenditure for the purchase of productive fixed assets, though this probably refers only to personal household assets. The values for this indicator are tiny, rising from an annual value of 20 yuan per person in 1990 to 273 yuan in 2012 (NBS, 2014).

Official data also omit any detail on investment flows generated by the many types of 'softer' interventions we discuss throughout this report. These types of financial flows are more difficult to quantify and few national data are available. For example, business has in some cases invested in agriculture to secure additional water from savings programmes in irrigation districts, but these investments are not reflected in fixed asset investment totals or in public databases.

Data from OECD donors are somewhat better and include non-infrastructural investments. Donors still support China's agricultural water management, though the flows of funds are tiny compared to national investment. Data from OECD member states from 2002 to 2012 suggest that total aid flows to China have remained relatively stable at over $2 billion per year (OECD, 2014). However, less than 5% of this aid flows to agriculture projects – only $100 million in 2002 and $50 million in 2012.[18] Even less flows to water resource management projects, though it is a growing donor priority.[19] Here, flows have increased from about $3 million in 2002 to over $30 million in 2012. While these total flows may be small, they can often be strategic – piloting new approaches or investing in areas that the Government does not. The World Bank is probably the most active donor in this sector. For the last two decades, the Bank has had a major role in promoting WUAs and in rehabilitating degraded watersheds in northern China through technical assistance and loan projects (World Bank, 2011; World Bank, 2010; World Bank Institute, 2010; Xie et al., 2009).

3.4 Technical, economic and regulatory incentives

Within the context of policy reform and investment, changing incentives are another driver of progress. These include internal programming incentives (such as the specific mechanisms of a water use policy) and external incentives (such as energy pricing). We highlight a few of these here and classify them as technical, economic or regulatory.

3.4.1 Technical incentives

The development of new agricultural water management technologies and practices helped to drive China's progress to date. In terms of staffing, China has the world's largest agricultural research and development system, involving over 43,000 full-time equivalent staff across 1,100 research institutes in 2007 (Chen and Zhang, 2011; ASTI, 2014). Brazil's system, by contrast, employed only around 5,400 people in 2006, while India's employed around 11,000 in 2009 (ASTI, 2014). China spent about 12.3 billion yuan ($1.5 billion, constant 2005 dollars) on agricultural research and development in 2007, about 9% of which (over 1 billion yuan) focused on water conservation technology (Chen and Zhang, 2011). At local level, the country has established a variety of agricultural technology extension centres to disseminate new crop varieties,

15 These prices, and those in the following paragraph, are current prices, unadjusted for inflation.

16 It is unclear from the national dataset as to which of these investment sources – 'farming' or 'water conservancy' compose the majority of irrigation investment, so we cite both here.

17 This includes foreign direct investment and loans from foreign banks or governments.

18 These data link to OECD's Creditor Reporting System code 311: III.1.a – Agriculture, Total.

19 These data link to OECD's Creditor Reporting System codes 14010, 14015, 14031, and 14040.

fertilisers and technologies – including agricultural water management technologies – to WUAs and farmers. It also passed an Agricultural Technology Extension Law in 2013 to further formalise and scale up these extension centres across the country.[20]

This research and investment aims to improve traditional, household- and community-based water management technologies, among others. Traditional, ‘good practice' techniques that Chinese farmers have used include border irrigation, furrow irrigation and land levelling. These were still used heavily in northern China in 2004 – for example, 61% of surveyed villages were then using border irrigation (Wang et al., 2007). Farmers are rapidly adopting newer household- and community-based technologies, however. These include the use of polythene soil covers, conservation tillage, lined canals, the use of drought-resistant crop varieties and, to a lesser extent, drip irrigation and sprinkler systems. Adoption rates of these technologies have increased sharply since the 1990s. For example, only 22% of surveyed villages were using polythene linings in 1990, but this rose to 58% in 2004 (ibid.). The trend is similar for the other technologies.

Chemical fertilisers and pesticides have been among the most influential technologies in Chinese agriculture. The total amount of chemical fertilisers used per hectare of irrigated land has increased by 70% from 1990 to 2012, while the amount of pesticides used on arable land and permanent crops doubled from 2000 to 2010 (NBS, 2014; FAOSTAT, 2014). Their use allowed China to intensify its agricultural production with less labour and without expanding its agricultural land area, but have also contributed to water pollution. We will discuss this challenge further in Section 4.

That said, China has also encouraged farmers to make better use of existing technology and has developed new technology to make fertiliser use more efficient. China's farmers use more fertiliser per hectare than almost anywhere else in the world (nearly 1 tonne per hectare of irrigated land or around 500kg per hectare of total arable land, on average, in 2012), at least partly due to insufficient farmer knowledge about the effects of overuse (Kumar et al., 2014; NBS, 2014). The Ministry of Agriculture promotes a training-based model known as ‘farmer field schools' to build knowledge on this and other agricultural topics among farmers. A recent impact evaluation of these schools found mixed evidence of their effectiveness on reducing fertiliser use (Kumar et al., 2014). The schools promoted more efficient fertiliser use for some rice farmers, but were less effective for tomato farmers and were not very cost-effective overall. Since the early 2000s, the Government has also promoted the ‘water and fertiliser integrated technology', beginning to scale it up nationwide from 2013 (Shen, 2014). This system uses pipeline irrigation to dissolve fertilisers in water and deliver them more efficiently to crops. It can save 50% water and 30% fertiliser compared to traditional practices, and can increase yields by 20% and decrease irrigation costs (ibid.).

Box 8: Farmers' incentives in Hangjin Irrigation District, Inner Mongolia

Hangjin Irrigation District is located on the south bank of the Yellow River and covers an area of roughly 26,800 hectares. WUAs purchase water tickets from the District on behalf of their members in advance of each irrigation as part of what is both a pre-ordering and pre-payment system.

Field surveys conducted in 2007, summarised in Calow et al. (2009), and conversations with WUA managers and bureau officials held in July 2014, confirm that water charging has little influence on water use. For the Hangjin Irrigation District, ticket sales provide revenue to help cover bureau costs, though a programme of channel lining from 2003 to 2009 has significantly reduced revenue. Farmers are no longer paying for ‘leaked' water and the District cannot increase its ticket prices in response.

At the point of sale to WUAs, the District charges water tickets at RMB 0.054 per cubic metre (roughly $0.01 per cubic metre). The Government sets this price because of sensitivities about ‘the farmers' burden'; the Hangjin Irrigation District cannot change it. Farmers then pay for water in advance by purchasing area-based amounts through the WUA, which aims to recover the purchase price plus a bit extra for reinvestment. Over the last 10 years, farmers have shifted from food to cash crops despite a small government subsidy for grains, with the result that most now plant sunflowers. This is because sunflowers are easy to grow with little labour, and labour availability is now a key constraint as young people seek work in urban areas rather than in unprofitable farming. The main costs to farmers (beyond labour) are seeds and fertiliser; water charges are a small component of total input costs (typically around 5%). As one farmer put it: ‘*Water is not a problem. The main thing for us is labour. Our children want to work in the cities and leave the old people behind*'.

Sources: WET, 2007; Calow et al., 2009; personal communications with Hangjin Irrigation District and WUA staff in July 2014

20 China is also beginning to export this model of technology extension centres in its development assistance to Africa (SCIO, 2014).

Box 9: Experimenting with energy charging and water use

In provinces such as Hebei and Gansu, pilot projects are experimenting with energy charging for rural groundwater use. Officials have equipped collectively owned (village) boreholes with 'Intelligent Card' readers: farmers purchase cards that allow pumps to be turned on for a set amount of time, with payment linked to energy consumption (and therefore water discharge). A quota system, with incentives and penalties for below- and above-quota abstraction then encourages water conservation.

A pilot currently underway in Hebei goes one step further, with 'saved' water sold to other (industrial) users. The 'increase price and provide subsidy' reform involves ramping up the cost of water (energy) to farmers by around 50% over the irrigation season, with 'water managers' in villages banking the extra charge. Once irrigation has finished, money is returned to farmers on an area-irrigated basis, so that farmers are incentivised to use less water while irrigating more land. The Government makes up any shortfall in revenue. Meanwhile, saved water is 'transferred' to the quotas of water-hungry industry, mediated by government – a cap and trade system of sorts.

Source: Wang Jinxia, personal communication, July 2014 (Centre for Chinese Agricultural Policy, Beijing)

The Government aims to reach 10% of the country's effective irrigation area with this technology by 2015.

China's organic agriculture sector has also grown, with increasing outputs and levels of industry professionalism (Qiao, 2011). Recent, high-profile incidents of food contamination in the country may invigorate the sector, as affluent Chinese citizens seek 'safer' organic food (Yuan et al., 2013). That said, levels of production are still insignificant at the national scale. One estimate by Yuan et al. (2013) suggests that less than 1% of arable land is currently allocated to organic vegetable production.

3.4.2 Economic incentives

Economic incentives offer another point of influence, either directly (through water pricing) or indirectly (through energy pricing). Currently, China's fee system requires payment for all surface water and groundwater withdrawals, except for rural domestic and livestock use and for emergency purposes (Shen, 2014). In practice, agricultural water resource fees are not generally charged to farmers and direct volumetric water pricing of individual users/entities is restricted to urban areas where household and industrial use is metered and rising block tariffs can be levied. The Government has invested heavily in water metering systems for monitoring and pricing these urban withdrawals at both large and small scales.

In rural areas, water charging in surface water irrigation schemes is aimed at recovering costs rather than managing demand, as irrigation schemes have not been engineered to deliver flexible, metered flows to individual farmers. Hence, in those systems where WUAs have been established, water allocation may combine bulk volumetric charging to WUAs established on branch canals (through sale of water tickets) with area-based charging for individual farmers. Area-based charging provides some degree of volumetrically linked payment, though in practice water charges are not set high enough to affect cropping decisions and water use, and farmers typically pay for water before irrigating, providing little incentive to conserve water when irrigation actually begins (Calow et al., 2009). Box 8 (page 31) discusses this challenge in the Hangjin Irrigation District of Inner Mongolia.

Because of the large number of users, monitoring and charging for groundwater remains very difficult. The Government is experimenting with indirect energy-based charging schemes on collectively owned village wells in some water-stressed northern provinces. Box 9 provides an example. Irrigation pumps need energy to operate, so energy pricing can influence irrigation. A study by Shah (2007) on informal groundwater economies in India and (to a lesser extent) China suggested that the manipulation of energy pricing systems could be a more effective way of managing agricultural water demand than direct water pricing, as farmers are already paying for energy and fee collection systems are in place. Nonetheless, electricity prices paid by agriculture are only about 60-70% of those paid by industry and cities (Shen, 2014), and the Government also compensates farmers for their costs of diesel. In addition, some provinces implement special pricing schemes to further subsidise irrigation water use – for example, in mountainous areas along the Yellow River where pumping costs are high (ibid.). Politically, any charging scheme – direct or indirect – that affects farm incomes remains contentious. Nonetheless, charging matters and a 'learning by doing' approach is being used to test different reforms. The difficulties associated with charging are also driving innovation elsewhere, particularly in regulatory reform.

3.4.3 Regulatory incentives

Regulations that define and allocate volumetrically defined quotas or permits between different users and uses, beneath an overall 'cap', are the main instrument used for

'Water is not a problem. The main thing for us is labour. Our children want to work in the cities and leave the old people behind' - Farmer

Box 10: Administering water rights in Inner Mongolia

Inner Mongolia is an arid and water-stressed region of northern China. It has been one of the fastest-growing regions in China over the last decade, with an economic boom fuelled by coal production, power generation and heavy industry.

Faced with growing demands for water and limited supply, the Inner Mongolia Water Resource Department has embarked upon a water conservation and reallocation programme aimed at saving and transferring within and between sectors. For example, a water saving competition is run across schools, public offices and industries, with rewards and 'good publicity' for winners; water saving regulations and targets have been set for major users; groundwater permitting regulations have been implemented for major abstracters; and the Department is attempting to 'reclaim' any part-unused industrial permits for transfer to others. At the same time, an Inner Mongolia Water Affairs Investment Company has been established to manage major storage and delivery infrastructure.

In terms of agricultural water reallocation, the Department also initiated a novel water transfer programme aimed at alleviating water shortages experienced by downstream industrial users on the Yellow River. In 2004, it established a dedicated 'Office of Water Rights and Transfer' to oversee this programme. The programme transfers irrigation returns saved through channel lining in Hangjin Irrigation District to downstream industries, with the costs of channel lining paid directly by industrial beneficiaries. The programme aimed to save as much as 138 million cubic metres of water a year. By September 2006, six projects had been completed, each funded by a separate industrial enterprise. They attained a total water transfer of 78 million cubic metres per year to downstream users and a corresponding reduction in the irrigation district's (agricultural) water permit. By 2009, this figure increased to 153 million cubic metres per year of savings, with 130 million cubic metres per year being transferred. Phase 2 (2009-2014) is now focusing on in-field water management through the roll-out of drip irrigation and sprinkler systems, with industry meeting the capital costs and government subsiding electricity for pumping.

Although the transfer programme is a new one, its effects on different stakeholders – both positive and negative – are already becoming apparent. In particular:

- **Impact on industry.** Although details on the marginal cost of new supplies from alternative sources are not available, the willingness of industrial enterprises to invest in channel lining indicates that this is a least-cost supply option for them, at least in the short to medium term.
- **Impact on farmers.** The programme is popular with farmers. Firstly, farmers have benefited from the lining of higher-order (i.e. main) channels, as they no longer have to pay for unlined delivery (and therefore leakage) to the WUA point of purchase. Secondly, the extension of channel lining to lower-order (i.e. small, local) channels under the management of WUAs will increasingly benefit farmers through reduced water charges (which were paid on the leaked water) and lower labour demands. Finally, farmers are likely to benefit from reduced soil salinity, as waterlogging in some areas is a serious problem.
- **Impact on the irrigation agency.** The Hangjin Irrigation District, on the other hand, has seen its financial position undermined by the channel lining programme. This is because the District relies on fixed-price ticket sales (which have declined through leakage reduction) rather than core funding from government to fund its activities.
- **Impact on other uses/users.** One outcome of the savings-transfer programme appears to be the drying up of wetlands along the main (now lined) irrigation channels. Impacts on groundwater levels within the district are not being monitored, though many villages remain groundwater dependent for domestic use. They may face challenges accessing water if reduced leaks mean that groundwater recharge is reduced.

More recently, the Department has established a 'Water Right Collection, Storage and Transfer Centre', replacing the previous Office of Water Rights and Transfer. The Centre raises its own capital and invests in both water conservation and the purchase of unused or underused rights. Rights are then effectively 'banked', allowing the Centre (under guidance from the Department) to transfer those rights to the most hard-pressed areas and users. The Department is now seeking more clarity from the Government on how its programme can better synergise with national policy frameworks. As one senior Department official put it, '*We are experimenting here. The problem is there is no national, top to bottom guidance on how to proceed or on how such trades can be reconciled with the fixed system of quotas under the three red lines*.'

Sources: WET, 2007; Calow et al, 2009; personal communications with Inner Mongolia Water Resource Department staff, July 2014 balancing demand and supply internationally. China is no exception (Calow et al., 2009).

In China, government agencies are increasingly using these systems to mediate between agricultural, industrial and domestic users at the regional level, and between individual farmers or WUAs at the local level (ibid.). The 2002 Water Law included a formalised system of water rights that has since expanded. River basin commissions or water affairs departments and bureaus usually manage these rights, at least in the water-scarce north. In addition to long-term rights, some basins reserve some water for short-term, annual rights – depending on the amount available in any given year (ibid.). To date, water-scarce northern China has developed its rights systems more extensively than the water-abundant south. Domestic use usually gets first priority, followed by industry and then agriculture. This means that agricultural use is often the first one curtailed during droughts (ibid.). This can promote agricultural water use efficiency but can also have a negative impact on farmers' livelihoods if not carefully managed. To avoid negative impacts on farmers' livelihoods, some of these systems promote water efficiency investments and transfers between users. To date, China's Yellow River basin has developed the most sophisticated system of water rights in the country, with some success. We describe the system in more detail in Box 10 (page 33).

Other parts of China have also had success in implementing water rights systems, as well as with a new variation known as evapotranspiration-based (ET-based) water rights. We describe the experience of water rights in the Shiyang River basin in Box 11. We give more detail on ET-based water rights systems and their increasing use in China in Box 12.

China has also improved its use of target-based reporting systems to align its national and local interests. China's political and institutional apparatus is complex, with power, interests and incentives differing at every level of the country's governance. This complicates the national government's attempts to implement sustainable agricultural water management policy, as Beijing's objectives are not always mirrored at the local level (d'Alançon, 2014). To get around this, the national government relies on a cascading system of mandatory ('hard') and optional ('soft') performance targets for its provincial and local officials – the 'target responsibility system' (McElwee, 2011). The targets are usually negotiated between a higher and lower level of government and form official contracts that both parties commit to. The Government first used this system in its national environmental policy in the 1989 Environmental Protection Law. Since then, it has rapidly scaled up its use, incorporating it into the 11th and 12th Five-Year Plans and its 2008 Water Pollution Control Law (ibid.).

The system is pragmatic, performance-based and provides a high degree of flexibility on how targets are met. It is up to the lower level of government to determine how and to whom to allocate responsibilities for meeting the target(s) (Kostka, 2013). For example, a provincial government that agrees to a certain target with the national government will then have the freedom to decide how to allocate it among its counties and towns. Good performance provides the lower-level officials with bonuses and promotions, while poor performance brings the threat of punishment (Naughton, 2010). This sounds effective in theory, but the Government has struggled to make it work for environmental targets in practice. We discuss this further in Section 4.

Box 11: Water rights in Wuwei Prefecture, Gansu

In the Shiyang River basin in Gansu province, the Wuwei Prefecture has been implementing a system of water rights since 2007, alongside a variety of other water use restrictions. The greatest restrictions are in Minqin County, where almost 90% of agricultural water was taken from groundwater via small tube wells in 2006. Excess abstractions had led to groundwater levels dropping at a rate of 0.65m per year and downstream lakes drying up. Here, restrictions included the forced closure of over 30% of the existing wells and the reduction of irrigation area by nearly 40% and irrigation quotas by nearly 20%. Alongside these, the water rights system issued each rural household with a water certificate and incorporated rights to groundwater use by installing Intelligent Cards on individual wells. To compensate, the Prefecture allowed a 90% increase in surface water allocations from upstream reservoirs, though this reduced supplies to upstream irrigation districts. They also subsidised the introduction of more efficient greenhouses to increase 'crop per drop'.

Overall, the system has seen rapid success. In the five-year period from 2006 to 2011, the Prefecture's annual water use decreased by nearly half – from 2.3 to 1.6 billion cubic metres. Groundwater levels have begun increasing and some downstream wells even became springs. The lakebed at the tail end of the Prefecture – Qingtu Lake – became a lake again after 51 years of being dried up. Alongside this, a noteworthy correlation was that Wuwei's rural incomes increased by over 10% per year.

Source: Shen, 2014

Box 12: Evapotranspiration-based (ET-based) water rights in China

A new method of implementing water rights systems shifts the focus from water extraction to water consumption. The concept behind this approach is that the portion of water consumed through plant-based evapotranspiration (ET) is the 'real' amount of consumption that is lost and unavailable for downstream users, rather than the amount delivered to a particular field or farmer. Advances in remote sensing and geographic information system technology now allow scientists to measure ET from agricultural areas with increasing accuracy. These data can then feed regularly into a water rights system to determine and update allocations based on usage rates.

The strength of an ET-based approach is that it focuses on actual water consumption by farmers and encourages conservation. For example, farmers can reduce evaporation by reducing waterlogged areas in their fields, irrigating at night instead of during the day, replacing canals with pipes, and using moisture-retaining mulches. The weaknesses include higher monitoring costs, challenges with data reliability at small scales, and the fact that an ET-based approach relies on the assumption that water not consumed by ET can actually be used again. If farmers are overusing fertilisers and pesticides, outflow water may be too polluted for downstream use. This could deprive downstream users of their allocated rights.

Several counties in northern China are currently piloting this approach. In Hebei, Guantao County has piloted the approach since 2005. Since then, they have had good results in decreasing the rate of groundwater decline. Prior to 2000, the county's rate of groundwater decline was 0.73 metres per year. From 2005-2009, the rate fell to only 0.024 metres per year and the total volume of groundwater overuse fell by more than 50%.

More recently, the World Bank funded the development of an ET-based water rights system in the Turpan Prefecture in Xinjiang. It is still too early to assess results, but the project developed useful reports detailing the practicalities and institutional arrangements of implementing an ET-based system. For example, in Turpan, the Prefecture's water resource bureau is charged with monitoring the remote sensing data on ET flows, but the system was initially established with support from the Geographical Institute of the Chinese Academy of Sciences.

Sources: Shen, 2014; Gao et al., 2012; Xie et al., 2009; World Bank, 2013

An irrigation channel in China. Photo: © Erwyn van der Meer

4. What are the challenges?

冰冻三尺，非一日之寒

It takes more than one cold day for a river to freeze three feet deep (Proverb)

China still has many challenges to face on its path toward more sustainable agricultural water management, though it has made strong progress to date. To continue making progress, China needs to address at least five key challenges:

- political incentives
- groundwater management
- social equity and labour availability
- water pollution
- future threats.

We discuss each in turn.

4.1 Political incentives

China's policy and institutional reforms are progressive in theory, but, in practice, they continue to suffer from perverse incentives, unclear responsibilities, weak enforcement and a lack of transparency. The target responsibility system is a good example. It provides performance-based incentives and has worked reasonably well for economic targets. However, it has struggled to succeed in practice for environmental targets.

This is due in part to inconsistencies and differing levels of priority between environmental targets and economic targets for government officials. In practice, if a clash in activities results from attempting to meet both sets of targets, local officials will still give priority to economic targets at the expense of environmental ones. For example, environmental targets can bring real cost to local businesses. Officials often have close ties to local businesses and rarely want to risk damaging relations by imposing measures that hurt economic growth.

Institutional structures can further penalise good policy-making. In China's government agencies, a rotation system ensures a regular turnover of officials between posts (Eaton and Kostka, 2012). Officials are often not experts in their post and have only a short tenure to achieve their targets. This can push them to seek short-term gains at long-term cost or to exploit weak monitoring regimes by faking data. A well-known example came during the final year of the 11th Five-Year Plan. The desperation of officials to meet their energy efficiency targets led to them cut power to hospitals and other essential services, which then had to operate on (much dirtier) diesel generators (Hilton, 2011). Data faking is also common, as the benefits of doing so accumulate upwards for officials at each level of government (Wang, 2013; Kostka, 2013).

Individual reform models such as WABs and WUAs can bring their own challenges. For example, creating a WAB sometimes requires – or is perceived to require – staff reductions. If not managed appropriately, this can increase internal resistance to reforms and undermine the chances of success. The design of WUAs in China has met similar challenges in attempting to incentivise managers to reduce water use. A recent study by Wang et al. (2014) found that the practice of an irrigation district providing financial rewards to WUA managers to reduce water withdrawals was ineffective. The rewards (based on the value of the water saved) were not large enough to compensate farmers for the value of crop losses (particularly wheat) that would have occurred from reducing their withdrawals.

4.2 Regulating groundwater withdrawals

The use of groundwater by Chinese farmers has risen rapidly in the last two decades, and regulations have been unable to keep pace. Much of this growth began with China's agricultural reforms toward decollectivisation and decentralisation in the 1980s and 1990s that encouraged more entrepreneurship and private ownership of assets among farmers (Calow et al., 2009). The proportion of privately-owned wells increased from 42% of total wells to 70% between 1995 and 2004 (Shen, 2014). With these newfound freedoms, farmers drilled wells to protect their crops from unreliable surface water irrigation and droughts.

To date however, national policies and quotas on agricultural groundwater withdrawals have not been implemented effectively and have not provided appropriate

'Environmental and energy targets are binding targets but they are not our ultimate targets. No leader will be promoted because of their better achievements in environmental protection and energy savings. GDP growth is still the target we work hardest to achieve' - Official in China's Environmental Protection Bureau (Kostka, 2013)

local incentives to conserve water (Wang et al., 2009a). In most villages, farmers can still drill new wells whenever and wherever they want without seeking approval (Wang et al., 2007). On the plus side, this has increased rural incomes. On-demand groundwater allows farmers to shift production toward more water-sensitive and high-value crops (Wang et al., 2009b). On the down side, it has led to a classic tragedy of the commons (Ostrom, 1990) in which the individual actions of millions of farmers lead collectively to over-exploitation. In the absence of effective regulation, groundwater levels in some northern Chinese communities have declined significantly, particularly in the North China Plain (Wang et al., 2009a).

The Government increasingly recognises this challenge and is working to address it. It is rapidly scaling up the use of electronic groundwater metering as part of its water pricing and water rights systems. Individual provinces and regions are taking action as well, though there is still a long way to go. Hebei recently launched a new campaign to reduce groundwater overuse, aiming to balance recharge and demand by 2020 (Xinhua, 2014b). The campaign will involve improving surface water irrigation, scaling up water pricing systems and reducing the cultivation of water-intensive crops like grains. The latter implies that the Government is also scaling back its ambitions for national food self-sufficiency, which we discuss again in Section 4.5.

4.3 Social equity and labour availability

China has a growing problem of social inequality, and its water management policies risk hurting the poorest the most. China's success in decreasing absolute poverty has come with a steep rise in inequality. The country's Gini index has risen from a value of 32.4 in 1990 to over 42 in 2009 (World Bank, 2014).[21] There is a growing rural–urban income gap and farmers still suffer the highest rates of absolute poverty in the country. Even among farmers, incomes vary widely, particularly between farmers in the wealthier eastern portion of the country – which has received more of the Government's investment and attention – versus the western portion (Schiavenza, 2013).

China therefore faces a complex and sensitive challenge in its efforts to manage water in this context. Water pricing and rights schemes can hit the poorest farmers hardest if not thought through properly, or unless the Government implements appropriate social protection and compensation schemes (Dercon, 2012). As we discussed in Section 3, Chinese policy-makers are acutely aware of the need to alleviate the farmer's burden. It is simply too contentious (and logistically difficult) to charge farmers for the full economic costs of water, so the Government has experimented with regulatory reform instead, and with energy pricing. There is a still a long way to go to in achieving results at the scale required to mitigate China's water management challenges.

Income level is not the only potential discriminator. To date, Chinese water policy has largely overlooked gender equity. Women and men have different water needs and varying household responsibilities, in both practical terms (water access and use) and strategic terms (taking part in water management decision-making). Women in poor farming households are increasingly responsible for the burden of water management at both the household and field level, as men migrate to cities for work to supplement farm incomes (Lu, 2009). For a woman-headed household, balancing these demands can be onerous, yet women have far less voice in the decision-making process. A review by Lu (2009) found that both local and national water policies and management institutions in the country had not yet incorporated social and gender perspectives that could help to address these wider issues of rural poverty and additional burdens on women.

Village-level water management systems in the country can also marginalise women's strategic needs. For example, WUA constitutions generally use the household and household head – usually male – as the unit of management. This can make women invisible, since only the household heads are elected to participate in WUA decision-making. Even when the household head is a woman, embedded cultural norms can continue to marginalise them. Similarly for water rights systems, Lu (2009) argues that vesting rights in households essentially means formalising control by men, who may have very different priorities, for example in favouring water use for commercial irrigation over small-scale household needs.

Lastly, age and labour availability for agriculture are another growing social challenge. As we highlight in Box 8, the average age of a Chinese farmer is increasing as more young people shun an agricultural life in pursuit of more financially attractive industrial or service sector work.

'We are experimenting here. The problem is there is no national, top to bottom guidance on how to proceed or on how such trades can be reconciled with the fixed system of quotas under the three red lines' - Inner Mongolia Water Resource Department official

21 The Gini index measures income inequality in a society on a scale from zero (perfect equality) to 100 (perfect inequality) – higher values indicate greater inequality.

Bing (2007) reports that, in some areas, the average age of farmers is now above 40 or even 50. This leaves the author to wonder, '*in ten years, who will farm the land?*'.

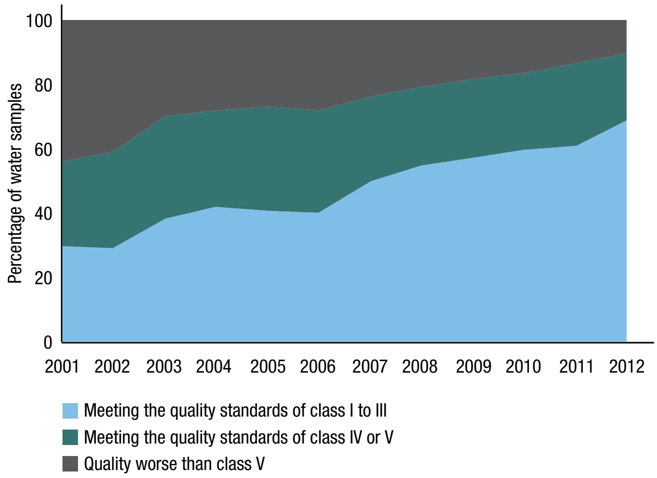
The issue also relates to income poverty. The incomes of many smallholder farmers are still too marginal to allow them to rely on farming alone – many also engage in off-farm income-generating activities to support themselves. The Government has not made this easy though. Its household registration system (the *hukou* system) classifies citizens by their area of descent and uses it to restrict their access to public services within these areas. This means that farmers who migrate to urban areas in search of off-farm income generally do not receive any public services (e.g. health care) and live precariously as a result. The recent announcement of planned reforms to the *hukou* system may begin to lessen this livelihood insecurity for migrant workers (Buckley, 2014).

A decreasing agricultural labour force therefore has potentially major implications for agriculture and its styles of production in China, and on the 'who' and 'how' of water conservation in the country. It will place increasing strain on the Government to rely on food imports and on those remaining farmers to grow more with less – using strategies that could include land consolidation, increasing commercialisation via big agri-businesses and increasing fertiliser use. These strategies can be more efficient from the perspectives of economic growth and food security, but can also risk exacerbating social equity issues unless the Government implements social protection measures alongside. China's response to this challenge remains unclear, though some experts predict a trend of increasing commercialisation mixed with social protection measures to protect poor farmers (Simon Howarth, 2014, personal communication).

4.4 Water pollution

China's problems with water pollution are well known and, although it has made progress, huge challenges remain. Water pollution is water scarcity in another form, as polluted water is unavailable for other human and environmental purposes without expensive treatment. China's rapid industrialisation and urbanisation has driven much of this pollution, particularly heavy-metal pollution. Industries and urban areas have grown without effective wastewater treatment infrastructure and the regulations to enforce water quality standards. Agriculture has also contributed to pollution, through its increasing use of chemical fertilisers and pesticides. Most agricultural pollution comes from animal husbandry, especially with the recent growth of China's livestock and poultry rearing sector. The amount of organic pollutants (chemical oxygen demand) and ammonia emissions from China's livestock and poultry rearing sector accounted for 95% and 79% of total agricultural emissions in 2010, respectively (PDO, 2013). They contributed to 45% and 25% of their

Figure 9: China's changing levels of water pollution since 2001



Source: NBS, 2014

respective total emissions of these compounds across all sectors in China in 2010.

This is polluting both surface water and groundwater. China ranks freshwater quality in six classes – I through V and 'worse than V' – where I is the cleanest and 'worse than V' is the most polluted. Surface water quality seems to have improved since 2003 (MEP, 2003). In 2003, nearly 30% of surface water samples from seven major river basins were worse than class V and unfit for use in any form. In 2012, this fell to about 10% for samples from ten major river basins (MEP, 2012). However, a further 20% is still rated as class IV or class V and is heavily polluted and unfit for most use without treatment. Figure 9 displays China's changing levels of water pollution since 2001.

China's groundwater quality is steadily worsening. A recent government report found that nearly 60% of the urban groundwater wells it tested were polluted (Kaiman, 2014). This closely correlates with China's general level of soil pollution, for which official data were a state secret until this year. Finally released, these data suggest that 16% of the country's soil is contaminated, particularly from heavy metals, with 1% heavily contaminated (MEP, 2014).

China is working hard to address this challenge, but still has a long way to go. To reduce agricultural pollution, the Government is focusing on reducing unnecessary fertiliser and pesticide use in farming and on reducing waste outflows from its livestock and poultry rearing sector. As discussed in Section 3, the Government uses training activities like farmer field schools and new technology to promote more efficient fertiliser and pesticide use, though the former has had mixed results. The Government also recently set short-term pollution targets for its livestock and poultry rearing sector, aiming to reduce the 2010 emission levels of chemical oxygen demand and ammonia by 8% and 10% by 2015, respectively (PDO, 2013).

4.5 Future threats

A variety of other threats may affect China's progress. Risky development policies in other sectors of China's economy will increasingly contribute to water stress. For example, more than half of the country's proposed coal-fired power stations may be built in areas with high water stress (Luo et al., 2013). The country is also rapidly developing its shale gas reserves – another thirsty industry that could threaten water insecurity for other users.

Shifting government priorities may threaten future investment in agricultural water management, much as it did in the 1980s. As we discussed in Section 3, the Government's commitment to continuously increasing its levels of agricultural investment in the last two decades drove much of the country's progress toward achieving more crop per drop, but will come under pressure as agriculture's contribution to GDP continues to decline. This creates a risk that agricultural investment may level off or decline, with detrimental effects on the Government's water efficiency and management targets.

China's growing middle class and its shifting dietary preferences toward greater meat consumption will pose additional risks. China's per capita meat consumption rose from 4kg to 61kg from 1961 to 2010 and will surpass that of the EU for pork consumption by 2022 (Levitt, 2014). The country already uses 70% of its water-intensive maize crops for animal feed and growing demand may create an additional maize deficit of 19-32 million tonnes by 2022. This could have a global impact on the world grain market and on the water resources of China's growing network of trade partners in Asia, Latin America and Africa (Sharma, 2014).

Until very recently, China has (more or less) achieved self-sufficiency in grain. Indeed this has been a key government policy (Hornby, 2014). Grains are water-intensive crops, but meeting the needs of a growing population took precedence over local water scarcity issues (Kendy et al., 2003). As of early 2014 though, the country's increasing resource pressures have forced the Government into a more flexible position, acknowledging the importance of imports and the need to shift local production in part toward higher-value and less land-intensive products (Hornby, 2014). While this could ease water resource pressures within China, it could pose strategic threats to national food security if the country becomes too dependent on imports.

Lastly, climate change will pose a major risk to Chinese agriculture. The latest report by the Intergovernmental Panel on Climate Change (IPCC, 2014) suggests that rising temperatures, melting glaciers and changing precipitation patterns could worsen China's north–south water distribution by increasing aridity in the north. This could put additional pressure on northern China's agricultural production and water scarcity.

5. What lessons can we learn?


Wolfberry farmer. Photo: © Bert van Dijk

惩前毖后

Learn from past mistakes to avoid future ones (Proverb)

China is fundamentally a different country now, compared with two decades ago. It has experienced development progress at an unprecedented rate, transforming from a low-income, agrarian economy to an upper-middle-income, industrial one faster than any other modern nation. It managed this despite, or perhaps because of, its huge and complex population and geography. That said, this growth was not always equitable or sustainable. The country has experienced major environmental problems, well rehearsed in both the international and Chinese media, that have demanded government attention. Nevertheless, it is important to recognise the rapid progress that China is making toward greener growth – especially through its management of agricultural water resources to achieve ‘more crop per drop’.

The overarching lesson from China’s story is that agricultural water use efficiency can encourage economic growth and is a good investment. China’s success in releasing water from its agricultural sector allowed its industry and services to use the water saved to grow. This economic transition has helped to lift millions of its citizens out of poverty. However, the development can only be called ‘sustainable’ if it ensures that farmers and ecosystem services also benefit from these efficiency measures. Balancing the needs of these multiple users is possible, and China’s pragmatic and incremental approach to reform demonstrates how this can be done.

We summarise four additional lessons from China’s story below. The recurring theme from China’s story relates to the complex politics of incentivising, encouraging or compelling – but not penalising – action among the country's many different stakeholders to 'grow more with less'. Whether technical, financial or regulatory, China succeeded when it was able to incentivise appropriately and invest in reform, and failed when it wasn't able to.

Strong national leadership can adopt ambitious policies at speed, but implementation is strengthened by engaging with citizens and local officials

China's government and motivated leaders drove the rapid adoption of new policies, technologies and practices related to agricultural water management, partly influenced by the country's growing environmental consciousness. The country's single-party political system allows it to avoid many of the messy debates that accompany sustainable development policies in a democracy. This does not guarantee the success of these policies, however. China's top-down environmental targets and policy reforms have not always produced the intended results due to their failure to account for complex local contexts and power dynamics. The Government has had more success when it has engaged citizens and local officials to gain a better understanding of who and what it is trying to incentivise and to adapt policies accordingly.

Reforms can be more effective when they focus on the problems and experiment with a variety of models for different contexts

One reform path does not fit all. For example, rather than mandating certain institutional blueprints, leaders have allowed a variety of institutional and policy reforms to be piloted to see what works best in different contexts. The 'target responsibility system' is another example, providing significant flexibility for lower levels of government to define their own path to success. In sum, China has worried less about how something is achieved, to focus instead on the end goal. Rather than enforce idealised procedures, the emphasis has been on the 'nuts and bolts' issues of rewards and incentives, and the clarification of roles, responsibilities and accountabilities among different users.

Engaging with the power and politics is messy and difficult, but ultimately cheaper and more efficient than technocratic fixes

As much as China illustrates the benefits of a problem-focused approach, it also illustrates the drawbacks of a technocratic one. China's 'hydraulic mission' and focus on big infrastructure for agricultural water management has not returned equitable and sustainable results in isolation. China increasingly realises that its attempts to engineer itself out of its growing environmental problems are more expensive and less sustainable than a 'softer' and more comprehensive approach. The latter can ensure that technical solutions are appropriate, sustainable and well governed. Without tackling the behaviour and incentives that drive scarcity, technocratic fixes in isolation will only ever offer temporary relief.

Transformative change at scale requires sustained ambition and investment across all levels of society

Since Deng Xiaoping's era, China's sustained and countrywide commitment to economic growth has had truly transformative effects, with few parallels in modern history other than the Marshall Plan. It urged and incentivised its citizens and leaders at all levels to believe in the country's growth model and to do their part toward achieving it. In the last decade, China has begun applying this same cohesive energy and high-level political commitment to the principles of sustainable development and green growth and is beginning to see the positive effects. In less than a decade, it has achieved huge scale-up on a variety of more sustainable agricultural water management interventions, often from a near-zero baseline. Its citizens and leaders increasingly understand the importance of an 'ecological civilisation' and a 'beautiful China', as a pragmatic response to the damage caused by rising pollution and resource overuse. If Deng Xiaoping's focus on a 'material civilisation' was China's first Marshall Plan, its shift toward an 'ecological civilisation' may well be its second. China's single-party government and communist ideals undoubtedly support its ability to launch Marshall-Plan-style initiatives like these, yet they are just as feasible in a capitalist democracy. Democracies have shown a strong ability to coalesce the same degree of ambition and investment support for military interventions. It is time for them to focus on doing the same for sustainability interventions.

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