China’s success in increasing per capita food production

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Abstract

China has to feed 20% of the global population with only about 5% of the planet’s water resources and 7% of its arable land. With such limited natural conditions, however, China’s grain production has increased from about 200 kg per capita in 1949 to about 400 kg in the early 1990s. Hunger as a social problem has largely disappeared after being prevalent in China for several thousand years with the rise and decline of dynasties. This achievement has been accompanied by a 2.5-fold increase in the population and a 4.5-fold increase in total grain production. Although total cropped land has increased slightly in some areas, land used for cropping has decreased from 0.18 hectare per capita in the 1950s to less than 0.1 hectare per capita today. Apparently, yield increase or improved land productivity is the major contributor to the increase of food production per capita. What are the major reasons for the unprecedented achievement in China’s food production? Political decisions, good or bad, on land distribution and ownership changes, have caused unusual fluctuation in grain production. Technical progress, however, has maintained a long-term increasing trend. The semi-dwarf cultivars of rice and wheat, the use of heterosis in rice and maize, and the alleviation of salinized soil stress in the major grain-producing areas have all played significant roles in increasing China’s food production capability.

Key words: China, China’s agriculture, China’s food production, crop production, food security.

China’s agricultural resources

Who will feed China? When Lester Brown asked this provocative question in his book (Brown, 1995), the whole world was listening and China was certainly shocked. Indeed, China’s agricultural resources are very limited although the country’s land size is the third largest in the planet. China’s food security is certainly vulnerable if the best use cannot be made of the limited arable land and water resources.

Firstly, China’s available land for cropping is relatively small when compared with the United States which has a similar total size, and it has been pushed to its limit. The whole Tibetan Plateau is too high and therefore too cool for any warm season crops. Only patches of highland barley can be grown there as supplementary food for the traditional animal-raising Tibetan people. Inner Mongolia and North-West China suffer from a very limited rainfall (less than 400 mm per year). In these regions desert and grassland are the major landscape features and only patches of oasis agriculture exist. The vast area of South and South-West China are very mountainous and agriculture is only good in their valleys. Most of the arable land in China is concentrated in the North China Plain, the North-East China Plain, and some river deltas. In total, China’s arable land is about 120 million hectares, less than 0.1 hectare per capita and far below the world average (National Bureau of Statistics of China, 2009).

Secondly, China’s water resources are very unevenly distributed in location and in time of year. The areas near the south-east coastlines receive the most rain, more than 1500 mm per year, while inner areas like Xingjiang have less than 200 mm per year. A 380 mm (15 inches) isohyet starting from the north-east to the south-west divides the map of China into two almost equal halves. The western half, including Inner Mongolia and North-West China, are not able to support crops without irrigation. The eastern half of the isohyet can have one or two crops per year but most of the rains come in the summer (June to August). Periodic droughts in spring and autumn are common in those areas. In terms of total water resources, the Chinese water resources per capita is only about one-quarter of the world average and China should be classified as a high-water-shortage country. In fact, in the Northern Plain of China where nearly half of the wheat and maize are produced, water resources per capita are less than severe water-shortage countries such as Israel (Wang et al., 2004).

China has to feed 20% of the global population with only about 5% of the planet’s water resources and 7% of its arable land. Food security will always be an issue with such limited conditions. If the uncertain climate changes are
taken into consideration, the uneven distribution of water resources and of arable land in this country may even intensify (Wang et al., 2010). More rain may fall in areas where summer floods are already a problem. High temperature stress and drought may be aggravated in northern China (Piao et al., 2010). Such changes may bring an unpredicted shift in the crop belts along the different climate zones.

Achievements in China’s food production

China’s total grain production was a little over 100 million tons in 1949 and has reached to 500 million tons in 1998 (Fig. 1). The grain production per capita has increased from about 200 kg per capita in 1949 to about 400 kg in the early 1990s (Fig. 2). Hunger as a social problem has largely disappeared after being prevalent in China for several thousands of years with the rise and fall of dynasties. This achievement has been accompanied by a 2.5-fold increase in the population and a 4.5-fold increase in total grain production (Fig. 1).

Although total grain production has largely levelled off since 1998, other food production, such as meat and dairy products, has rapidly increased since the 1990s (Fig. 3). This indicates the increased living standards in China (Feng, 2007).

Although the total cropped land has increased by 20% in some areas, such as in North-East China, the land use per capita for cropping has decreased from 0.18 ha per capita in the 1950s to less than 0.1 ha per capita today (Fig. 2). Apparently, yield increases and/or improved land productivity is the major contributor to the increase in food production per capita. China’s land productivity for major agricultural crops doubled during the period from 1978 to 2007, and wheat had the largest growth in this period with its production 2.49 times more than the 1978 level (Li, 2009).

What are the major reasons for such impressive achievement in China’s food production? An analysis of China’s grain production over the years shows that there was a trend of increasing yields over time, although some significant fluctuations occurred periodically (Fig. 4). It is concluded that this increasing trend has largely been maintained by technical progress in China’s agriculture. Several major breakthroughs can be counted. For example, the First Green Revolution and the adoption of the semi-dwarf trait in rice and wheat breeding greatly increased their yield potential starting from the late 1960s (Gaud, 1968; Wang et al., 2010). China’s progress in this synchronized with the significant achievements at the International Maize and Wheat Improvement Centre (CIMMYT) and the International Rice Research Institute (IRRI), respectively, on wheat and rice.

Another major technical progress has been the use of heterosis in maize and rice. The use of heterosis in maize started in the USA as early as the 1940s but China’s maize yield only started showing a significant yield increase in the 1970s with the development of useful inbred lines. In recent years, maize production in China has again shown a significant increase. This is largely due to the increased market
demand for animal feed. Growing maize has become more profitable now than ever.

It is for the use of heterosis in rice that China deserves major credit and applause. Rice is a self-pollinated plant and, so far, it has been impossible to use mechanical methods in order to obtain hybrid seeds on a large scale such as with maize. Chinese rice breeder, Yuan Longping (Yuan, 1992), first found a male sterile trait in a wild rice and successfully transferred the trait into cultivated rice in the early 1970s. The male sterility is caused by an interaction between two male sterile genes separately located in the cytoplasm (the mitochondria) and nucleus. Starting in the mid-1970s, Yuan succeeded in the development of a three-line hybrid rice with the *indica* subspecies. The male sterile line produces seeds that remain male sterile when it receives pollen from a maintainer line which carries a male sterile gene in its nucleus. The maintainer line is male fertile because its cytoplasm does not have the male sterile gene. However, the male sterile line will produce seeds that restore male fertility when it receives pollen from a restoring line which does not carry the male sterile gene in its nucleus. Yuan found that a remotely related cultivar bred at IRRI could bring the strongest heterosis with his male sterile line. Such hybrids can have yield potentials of 25% more than the conventional cultivars. Extensive adoption of hybrid rice in China successfully pushed China’s rice production to a new level starting in the 1980s (Yuan, 1992; Katsura et al., 2007).

Another major reason for the significant increase in wheat production starting in the late 1980s was solving the soil salinity problem in the North China Plain. This area covers several northern provinces/cities and the region today produces almost half of the country’s wheat, maize, and cotton. This could not have been achieved without overcoming the extensive salinity problem present before the 1980s. Wheat yield in this area almost tripled from the 1970s to the 1990s. Ironically, solving this salinity problem was mainly due to the large-scale exploitation of underground water for irrigation and the rapid decline in the underground water table started in the 1980s. Adoption of affordable electrical pumps by farmers in this area led to extensive irrigation and the wheat crop was irrigated four to five times in the 1980s for high yields. Now, due to the depletion of water resources, irrigation has been reduced to two times in most cases (Zhang et al., 1998).

Problems for food security in China

China’s population is over 1.3 billion at the moment and is expected to reach a peak in 2033 at 1.5 billion. If it is assumed that grain food per capita will increase from today’s 400 kg to 470 kg in 2033 (Wang et al., 2010), it will be necessary to increase grain production by at least 35% during the next 20 years.

Can China achieve this target, with its limited land and water resources?

As shown in Fig. 4, a major problem of China’s food production has been the abnormal fluctuations over the years. Such fluctuations can be more than a 30% deviation from the projected yield and is not explained by fluctuations in natural conditions. While weather can account for some year-to-year variation over a 3–5 year scale at most, it does not account for trends that last decades. In fact, the main reason for such abnormally large fluctuations is due to agricultural policy changes during specific periods. In the early 1950s, ‘Land Reforming’ redistributed arable land almost equally to the peasants in the country. A sense of land ownership greatly promoted the farmers’ enthusiasm to produce more grain. Yield rapidly increased in the early 1950s. Starting in 1956, however, rapid collectivization over the whole country quickly led to a mismanagement of farming. In 1958, with the campaign called ‘Great Leap Forward’, peasants from several villages were working and eating together in what they called People’s Communes. ‘Close cropping’ (10 times more seeds sown), ‘deep plough’ (as deep as 1 metre), and many other absurd field practices were used to promote productivity. Very soon the yields plummeted. A great famine occurred in the next two years. Malnutrition and early death were rampant. The exact number of people who died from starvation has never been officially released (Dikotter, 2010), but can be seen as a dip in the population after 1958 in Fig. 1.

The collectivized land ownership of the People’s Commune system did not serve China’s food production well and farming became notoriously inefficient from the 1960s to the 1970s. In the early 1980s, a new way to divide the land into individual households was implemented, the so-called ‘Household Responsibility System’. Under this new arrangement, each household was allocated a plot of land for farming (but not owning it as their disposable property). This gave the farmers incentives to produce more and earn more. This system quickly led to an instant success. China’s grain production enjoyed another golden age starting in the

![Fig. 4. Fluctuation of China’s grain production. A regression curve is fitted with the total grain production from 1949 to 2005. The difference between the real grain production value (filled squares) and the regression-suggested value ($y = 7.2155x - 13955$; solid line) is divided by the real production value in that year as the fluctuation index (%), in bars. (Data from the National Bureau of Statistics of China, 2009.)](https://academic.oup.com/jxb/article-abstract/62/11/3707/508742/fig4d1a97d4e8405f9e736381970b4a943f)
early 1980s and reached a record in 1998. It is believed this record has not been overtaken since then (National Bureau of Statistics of China, 2009).

In this century, grain production in China has stagnated, but other foods, such as meat and fish, have increased rapidly. People’s living standards have increased with the more diversified food supplies (Feng, 2007).

There are still many fundamental policy issues with China’s agriculture today. The lack of land ownership and limited utilization rights, low productivity due to small size and low input, and the low profitability of farming are just a few of the problems that cannot be tackled easily. All that can be hoped is that the Chinese Government will take all the necessary measures to maintain farmers’ initiatives and help them to stay in business with a decent livelihood. This will avoid unnecessary fluctuation in our food production.

Another major problem in China’s food production is that China’s agriculture is limited by the available resources, particularly water resources. China has a total renewable water resource of 2825.5 × 106 m³ (Ministry of Water Resources, 2002). This perhaps ranks as number 6 in the world following Brazil, Russia, United States, Canada, and Indonesia. However, due to its large population, the per capita water resource is only 2130 m³ person⁻¹ year⁻¹, which is about one-quarter of the world average and China ranks 118 among the 154 countries where data are available (Water Resources Institute, 2003), not mentioning that China’s rainfall is very unevenly distributed by location and by time of year.

Water shortage is a major problem in many parts of the world. The World Economic Forum (2009) at Davos published a ‘Water initiative’ report and warned that ‘the bubble is close to bursting’. If the business-as-usual way of water usage continues, it is estimated that global crop production would lose 30% of the current yield by 2025 due to water shortage and 55% of the population would rely on food imports. A gradual and well-planned reduction of water use in crop production is essential if such a disastrous consequence is to be avoided.

The planet has had a finite amount of water since its beginning. The root of the problem is that, over the past century, world population has increased by 4-fold but our water use has increased by 9-fold (World Economic Forum, 2009). Agriculture uses more than 70% of the water that humans consume. An unprecedented expansion of irrigated land and over-irrigation for high yield is the major reason and this has caused an unprecedented water shortage problem worldwide.

The same problem is worse in China. In North-west China, where annual precipitation is less than 200 mm, agriculture traditionally relies on rivers from the high mountain glaciers, so-called oasis agriculture or inland river system. Expansion of cropped land during the last five decades has led to serious ecological problems, such as the shrinking of oases and the desertification of grasslands (Kang et al., 2008). A tough choice has to be made that requires using less water for cropping and returning more water for the ecological needs of the oases. Otherwise the disappearance of many ancient oases, such as the famous Lop Lake that changed from a lake with many thousand square kilometres of water surface area into a complete desert in less than 100 years, will be the fate of many current oases.

In the North China Plain, annual precipitation is around 600 mm, but the two crops, winter wheat plus summer maize, require more than 1000 mm water. The use of underground water on a large scale to supplement the deficit has solved the salinity problem and pushed up wheat production significantly since the 1980s. However, it should be recognized that such water use is not sustainable. The underground water table has dropped from 20 m to over 100 m and the water resource will soon be depleted (Zhang et al., 1998; Zhan, 2006). Again, the tough yet inevitable choice is to use water within our means and to preserve the underground water for the future.

We need a ‘Water Initiative, the China version’. In such strategic planning, the unique problems of water scarcity at different locations in China will need to be highlighted, the possible consequences need to be analysed if it is business-as-usual in social and economic developments and in food security, strategic plans need to be designed to cope with the challenges, and the specific targets in water-saving and water usage need to be set for different locations. In most cases, it is believed that a 50% reduction in the use of irrigated water in North and North-west China is inevitable. Technically, this is an achievable target (Kang and Zhang, 2004), but whether agricultural investment is enough to implement the water-saving methods is another issue.

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