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Agricultural and Agri-Environment Policy and Sustainable Agricultural Development in China

Wusheng Yu*

February 29, 2016

Abstract

This background paper provides a review on China's current agricultural and agri-environmental policy in relation to sustainable agricultural development. An assessment of China's natural resource constraints and selected agri-environment indicators reveals a host of concerns on sustainable agricultural development, ranging from fast growing nutrient inputs and pesticide use, rising energy consumption, inefficient water use especially in irrigation, contaminations and pollutions to soil and water resources, to increasing ammonia and GHG emissions. If these trends continue, sustainable growth of China's agriculture would be highly uncertain, especially against the backdrop of climate change.

Further review in this paper suggests that China does have a series of laws and regulations in place aiming at protecting the environment and key natural resources but their implementations in agriculture largely rely on specific government policy and have until recently not been prioritized as compared to the drive to achieve agricultural output growth and food security targets. In fact, while recent government policies aiming at boosting outputs and ensuring food security have largely been successful, they may very well be among the reasons behind the aforementioned concerns on agri-environment and sustainable development.

More recently, however, it appears that the Chinese government is crafting a new approach for supporting agricultural production while addressing its environmental and sustainability performance. This paper therefore provides a detailed account of new government policies and initiatives on reducing chemical inputs and on protecting and rehabilitating land and water resources. In connection to these new programs, the government is also changing the way to support agricultural production, seemingly shifting from the long-held position on using mainly domestic natural resources to achieve food security targets to a new approach of utilizing both domestic and international resources. Based on this, the paper concludes with a discussion on the specific changes contained in this new approach and on their likely environmental and sustainability implications.

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List of abbreviations:

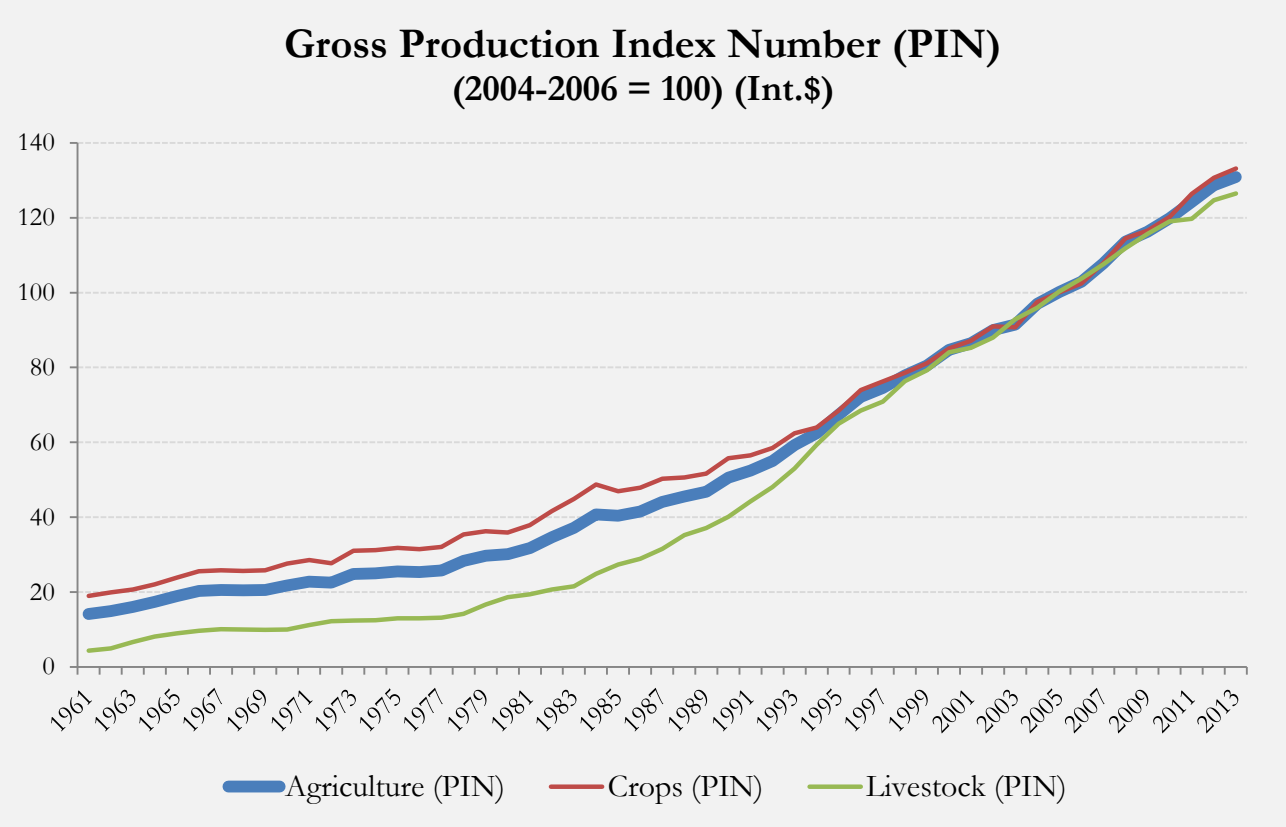
EU:	European Union
CCCPC:	Central Committee of the Communist Party of China
MEP:	Ministry of Environmental Protection of China
MIIT:	Ministry of Industry and Information Technology of China
MOA:	Ministry of Agriculture of China
MOF:	Ministry of Finance of China
MLR:	Ministry of Land and Resources of China
MST:	Ministry of Science and Technology of China
MWR:	Ministry of Water Resources of China
NDRC:	National Development and Reform Commission of China
OECD:	Organization of Economic Cooperation and Development
PRC:	People's Republic of China
WTO:	World Trade Organization

1. Resource constraints and environmental challenges in assuring long-term sustainability of Chinese agriculture

China's agricultural has experienced sustained output growth in the new millennium, as reflected particularly in the growth of outputs of food grains (MOA, 2015d). By the end of 2014, grain outputs have achieved annual growth for 11 consecutive years and national food security targets have been attained for rice, wheat and other important agricultural commodities. For instance, total grain outputs have been stabilized at levels above 500 million tons for 8 consecutive years; for the recent biennial period of 2013-14, annual grain outputs exceeded 600 million tons. Outputs for other important commodities such as cotton, oilseeds, sugar, meats, eggs, meats have also experienced similar growth. Overall, China's agriculture has experienced continuous growth in the past half century, as can be seen from the gross Production Index Number (PIN) presented in Figure 1.

However, sustainable growth of China's agricultural sectors still face serious challenges in relation to natural resource constraints, in terms of the availability of vital natural resources such as land, water and other resources, their sustainable utilization, and degradations of these resources which may limit long term sustainability. In addition, climate change may also impose extra constraints on the long term viability of China's agriculture.

Figure 1. Gross Agriculture PIN, Gross Crops, and Gross Livestock over time



Source: FAOSTAT.

1.1 Availability and quality of cultivated land resource

In terms of land availability, it is widely acknowledged that on a per capita basis China's endowment of agricultural land is generally well below that of the worldwide average. China's per capita cultivated land is roughly 1.4 mu (less than 1/10 ha), which is less than 2/5 of the worldwide average. According to the *2014 National Land and Resource Bulletin* of the MLR (2015), towards the end of 2013, China has 646.17 million hectare agricultural land, including 135.16 (or 2.027 billion *mu*; one *mu* equals 1/15 hectare) million hectare cultivated land, 253.25 million hectare forestry land, and 219.51 million hectare grazing grassland. In terms of China's total land area, its cultivated land area only has a share of 14.3%. Even this relatively lower number of cultivated land is under threat from reductions due to increasing construction land demand, destructions from natural disasters, ecological restoration projects such as the Grain for Green and similar programs, and structural adjustments within agriculture. For instance, in 2013, reductions in cultivated land due to the above reasons amounted to 354.7 thousand hectare as compared to an increase of cultivated land of 359.6 thousand hectare from land reclamation and consolidation, and structural adjustments, for a net increase of 49 thousand hectare. However, in the preceding years, China's cultivated land area has been on a decline; for example from 2009 to 2013, total cultivated land decreased from 135.38 million hectare (2.031 billion *mu*) to 135.16 million hectare (2.027 billion *mu*), thus threatening the "read line" of maintaining at least 120 million hectare (1.8 billion *mu*) cultivated land, a goal that has been emphasized time and again by the Chinese authorities.

Among the available cultivated land, only 1/3 is considered high-quality. According to the 2nd *National Land Survey* (as cited in MLR, 2015), the average quality grade of China's cultivated land is below 10 on a 15 point scale (with 1 being the best quality and 15 being the poorest quality; Grade ranges 1-4, 5-8, 9-12, and 13-15 give respectively the designations of excellent quality, good quality, medium quality, and low quality). In that survey, only 2.9% and 26.5% of China's cultivated land receive the designations of "excellent" and "good", respectively, whereas 52.9% receive the "medium" grade and 17.7% are designated with the "poor" grade. Typical reasons for these lower quality grading is the thinning of soils such as the black oil, soil acidification, and shallow tillage layer. In addition, converted arable land used as construction land also causes enormous waste of soil resources, as these soils are not relocated to cultivated land elsewhere. This problem is further compounded by the generally poorer quality of the compensated land through land consolidation and reclamation, as per the requirements of the land use regulation of China (as will be discussed later in this paper).

1.2 Availability and utilization of water resources in agriculture

According to the *2014 China Water Resource Bulletin* (MWR, 2015), China's total water resource in 2014 is 2,726.69 billion m^3, of which 2,626.39 billion m^3 being surface water and 774.5 billion m^3 being underground water (the volume of non-overlapping volume is 100.3 billion m^3). This total volume places China as the sixth ranked country in the world in terms of

total fresh water volume. However, on a per capita basis, China only has 25% of the world average, thereby being generally considered a water scarce country. Total water supply and water use in 2014 is 609.5 billion m^3. Agricultural remains the biggest user of water in China, having consumed 63.5% or 386.9 billion m^3 of China's water supply. Within agricultural water use, irrigation is the predominant force with 55% of total water use in 2013; however, this is a reduction of 6.4 percentage points from the level of 2002. In fact, China has managed to maintain zero growth of its irrigation water use in the last fourteen years. At the same time, the effective utilization ratio has also improved from 0.44 in 2002 to 0.52 in 2013, through water conservancy projects and adoptions of water-saving irrigation technologies.

Despite these positive developments, availability of water resources and its efficient utilization continue to be a challenge for achieving sustainable agricultural development in China. First, there remains a serious mismatch between the spatial distributions of water resources and irrigation land across China. For instance, according to the official classification of the MWR, the six level-1 water resource areas in Northern China (Songhua River area, Liao River Area, Hai River Area, the Yellow River area, Huai River area, and the Northwest Rivers area) has about 17.1% of China's total water resources (including only 14.5% of China's surface water resources and 29.7% of its underground water resources) but uses 45.6% of total water supply including 55% of total agricultural water use. In the Northern China Plain provinces Hebei, Shandong, and Henan where about 21% of China's cultivated land is concentrated, agricultural irrigation is heavily depending on underground aquifer resources, leading to their over-draft and rapid decline. Second, effective utilization ratio of water remains low in Chinese agriculture, especially with respect to the utilization of irrigation water which at 52% is about 20 percentage points lower than that of developed countries. China's open channel irrigation system is particularly susceptible to leakages and other losses. Another reason is that only a fraction of irrigation land is equipped with modern water-saving irrigation technologies. The current water pricing system also contributes to the inefficiencies in water allocation and utilization. A third issue with agricultural water resources in China is water pollution. According to the MWR (2015), in 2014, the overall water quality in China's rivers is of medium-quality, with 11.7% of water in total river length is judged to be unsafe for any use (including agricultural irrigation). In particular, river waters in Songhua River, Yellow River, Liao River, and Huai River are judged to be of medium quality, whereas water in the Hai River is rated as "bad". Of the 121 major lakes, 25 lakes (or 20.7%) are rated as "worse than Type V", the designation signaling the water to be unsafe for any use. In addition, 76.9% of the lakes are considered to be in eutrophication. Underground water is also suffering from pollution. In a survey conducted in 17 provinces in Northern China, overall underground water quality is judged to be poor, with 48.9% of the wells being given the designation of "fairly poor" and 35.9% the designation of "very poor".

1.3 Degradation of ecological system and pollutions to agri-environment

In addition to the constrains imposed by the limited availability and declining quality of China's land and water resources, the potential for maintaining and expanding China's agricultural resource base is severely limited by ongoing degradation to its ecological system. China's land area suffering from water and wind erosion reached 2.95 million square kilometers (1.29 million square kilometers from water erosion and 1.66 million square kilometers from wind erosion), exceeding 30% of China's total land area (MEP, 2015). Annualized soil erosion amounts to 4.5 billion ton. Land area suffering from desertification reaches 1.73 million square kilometers, whereas 120 thousand square kilometers' land area suffers from rocky desertification. These developments not only damage the existing land resource available for agriculture, they also damage long term land fertility and productivity and limit the extent to which cultivated land can expand in the future. Degradation of land resource is also reflected in the quality of cultivated land. Towards the end of 2014, 27.9% of China's cultivated land is considered to be of poor fertility and requires sustained improvement in farm infrastructure and quality upgrading.

In 2014, China has nearly 400 million hectare grassland or about 41.7% of its total land area, mostly located in Northern and Western China, particularly in Inner Mongolia, Xinjiang, Tibet, Qinghai, Gansu, and Sichuan. Total grass supply in dry grass equivalent is around 315.02 million ton, enough to support 247.61 million heads of sheep, a reduction of 3.2% from the previous year. China's grassland continues to suffer from over-grazing and cannot support the level of current livestock production. The deterioration to the ecological system in China's vast grassland has not been halted or reversed (MEP, 2015). Other challenges facing China's ecological system include the reductions in areas of land and wetlands, threats to biodiversity and increasing number of endangered species. Overall, with the degradation to the ecological system, simultaneously achieving the goal of further agricultural development and ecological conservation will continue to be a challenging task.

Pollution to the environment is another big challenge for maintaining a sustainable resource base for China's agriculture, especially regarding soil and water. According to the first *National Soil Pollution Situation Survey* for the April 2005 – February 2013 period (MEP, 2015), 16.1% of the surveyed sites have soil pollution; for cultivated land, this ratio is even higher at 19.4%. For forest land, grassland, and unutilized land, polluted soil sites are respectively 10, 10.4 and 11.4 percent. Pollutants are mainly inorganic and are present in 82.8% of the polluted locations in the survey, particularly heavy metals such as cadmium, mercury, arsenic, copper, lead, cadmium, zinc, and nickel. Organic pollutants are mainly BHC, DDT, and polycyclic aromatic hydrocarbons. China's soil suffers from pollutions from industry, domestic and agricultural sources. Heavy metal pollutions are mainly caused by wasted water, wasted gas and solid waste residues from industries. Within agriculture, the main pollution sources are chemical fertilizers and pesticides as their utilization ratios are less than one-third, plastic mulch whose recycling ratio is less than two-third, animal manure and wastes, and crop

residues including the burning of these residues. Similarly, water pollution is also quite serious in China, not only in terms of drinking water safety but also as measured by the suitability for agricultural irrigation. In addition, untreated rural garbage and waste water also contribute to the deterioration of rural environment. The worsening of agricultural and rural environment threatens sustainable production of safe agricultural products.

1.4 Impacts of climate change

Agriculture is a major contributor to China's total greenhouse gas (GHG) emission, mainly in terms of nitrous oxide and methane, the former of which is primarily due to the use of synthetic fertilizers and to a less extent from animal manure and crop residues and the latter of which is mainly due to enteric fermentation of livestock and rice cultivation.

Global warming and climate changes influence China's agricultural in several ways. Rising temperature has been recorded in the past century in the range of 0.5 to 0.8 degrees (Ding et al, 2007; PRC, 2007). Changes in precipitation patterns across China are also observed for the past century, with Northern China receiving less rainfall since 1950s and Southern and Southwestern China receiving significantly more rainfalls. In addition, there seems to be more frequent and severe extreme climate events such as droughts and flooding in the last half century. Depending on the projected changes in climate changes, rising temperature, changing rainfall patterns, and intensifying extreme weather events are likely to influence China's agricultural sectors, although consensus from current literature has not emerged regarding the signs and sizes of the impacts due to climate change.

2. China's sustainability performance in agriculture: selected agri-environmental indicators

2.1 China's sustainable performance in agriculture: an overview

Facing the needs to feed a growing population with rising income (hence increasing demand for agricultural and food products), sustainable use of its relatively limited natural resource base is increasingly becoming a challenge facing the current and future performance of Chinese agriculture. As highlighted in the previous section, China's agricultural production volume has steadily increased over the last decades – rising by 21% from 1993 to 2013 (13% for crops and 39% for livestock). This growth has been aided by productivity growth, intensive use of natural resources and increased use of agricultural inputs. Yet, the sustainability of needed agricultural productivity growth in China is exposed to a number of environmental pressures which have the potential to slow down future expansions of Chinese agriculture.

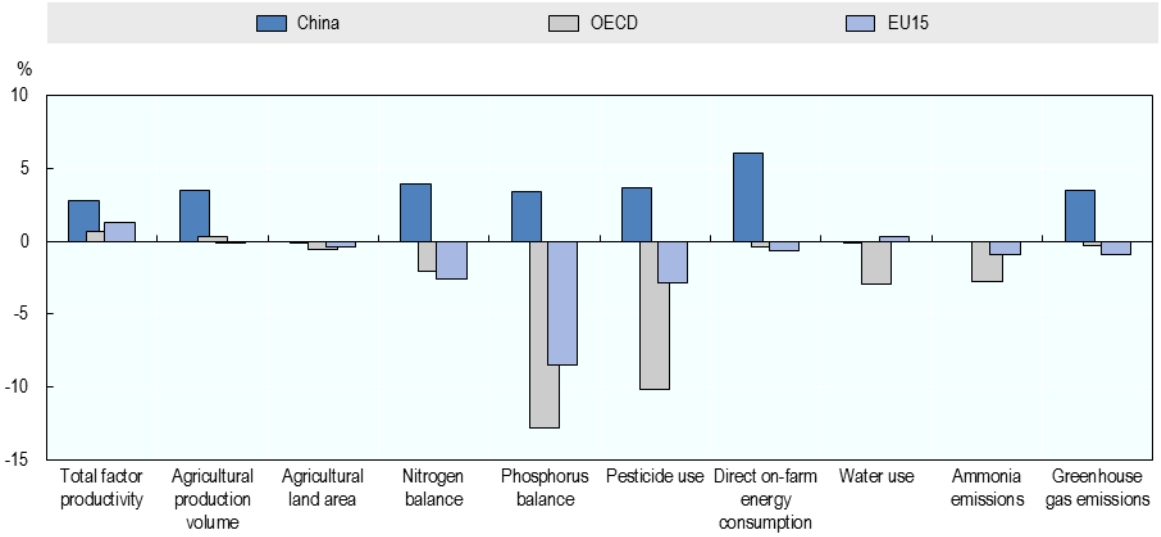
For instance, as can be seen from Figure 2, nutrient inputs used in agriculture have dramatically increased over the last two decades, which may have contributed to productivity growth, but has also weakened soil and water quality. Increases in pesticide use may also have supported the upward trend in production, while putting water systems and human and

ecosystem health at risk. Increases in water usage and pollution have raised red flags for the sustainability of current agricultural production levels. Lastly, increasing agricultural ammonia emissions and Greenhouse Gas emissions (GHG) have also contributed to climate change which itself brings further uncertainty to sustainable agricultural development. Indeed, these trends generally contrast with average declines in these key agri-environmental indicators in the group of EU15 (i.e. the 15 member states of the European Union prior to its enlargement in 2004) as well as in the OECD countries.

A positive trend for sustainable productivity can be seen in the expansion of organic farming over the last decade, which is associated with lower chemical fertilizer and pesticide use. As China's agriculture sector faces the challenges of climate change – from rising temperatures to increasingly severe and frequent disasters – further investment in sustainability of the sector is critical. Rising GHG emissions levels – coupled with mounting soil, water and air pollution – indicate that preparing for and adapting to climate change does not currently seem to be a strong priority for the sector. In what follows in this section, a more detailed description on individual agri-environmental indicators are offered.

Figure 2. Selected agriculture and environmental indicators

Average annual percent change 2000-02 to 2010-12, or nearest available period



Source: FAOSTAT, Chinese Statistical Yearbook, and OECDSTAT.

2.2 Selected agri-environmental indicators

Nutrients

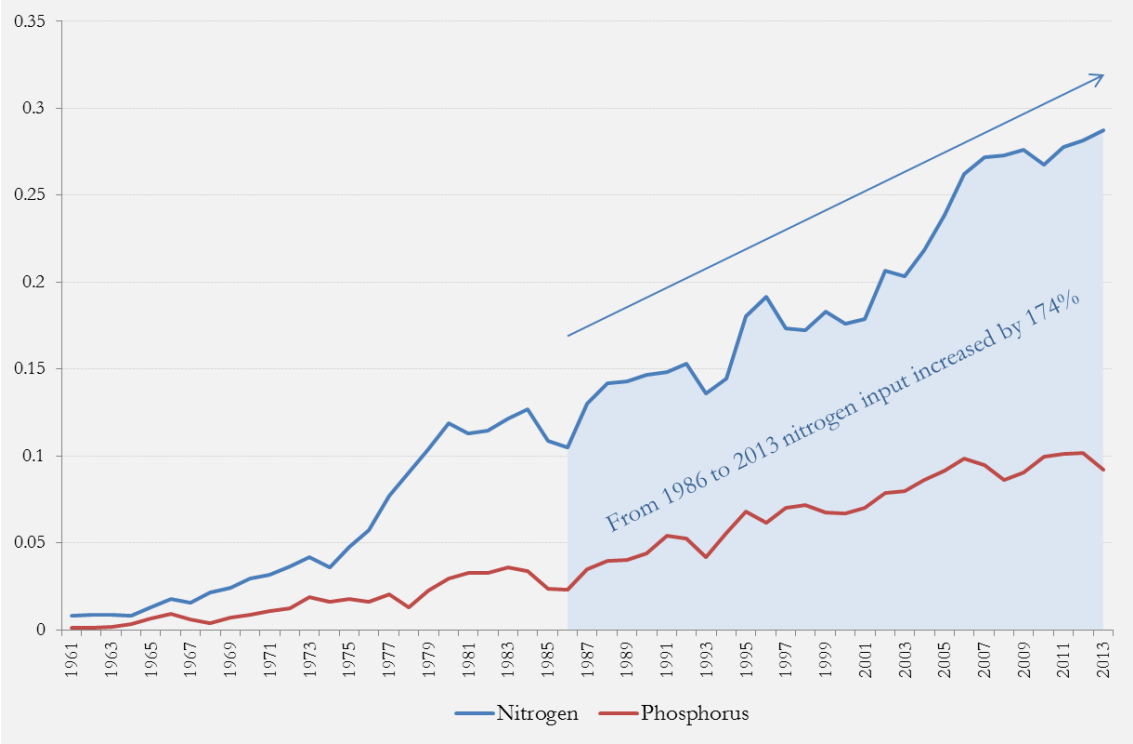
Nutrient inputs for example through applications of chemical fertilizers have steadily increased over the last decades in China, helping to promote production levels but also raising concerns about sustainability due to the risk of soil pollution and water eutrophication. Over the last

three decades, nitrogen use has dramatically increased (from 105 kg per hectare to 287.6 kg per hectare or by 174% from 1986 to 2013). Phosphate inputs have increased from 23.3 to 92 kg per hectare for an increase of 294% over the same period (Figure 3). These increased uses of nutrient inputs have in fact exceeded yield growth, possibly suggesting the former's diminishing marginal contributions to the latter. It is also an indication of low utilization of the nutrients. This trend greatly contrasts the situations elsewhere, such as in the OECD and EU countries where nitrogen and particularly phosphorus uses have declined sharply in the most recent decades (Figure 1). In fact, the nationwide average use of fertilizers in China at around 400 kg per hectare (in Eastern China, this number is about 600 kg per hectare) is nearly twice of the generally acceptable use in developed countries.

Despite this overall rising trend, in the more recent years, particularly from 2007 and onwards, increases in the use of both nitrogen and phosphorus inputs have levelled off to some extent. With new initiatives to further curb the growth of fertilizer use (to be discussed later in this paper), it is hoped that the overuse of nutrient inputs may be reserved in the near future.

Figure 3. Nitrogen and phosphorus inputs, 1961-2013

Tonnes per hectare of arable land and permanent crops



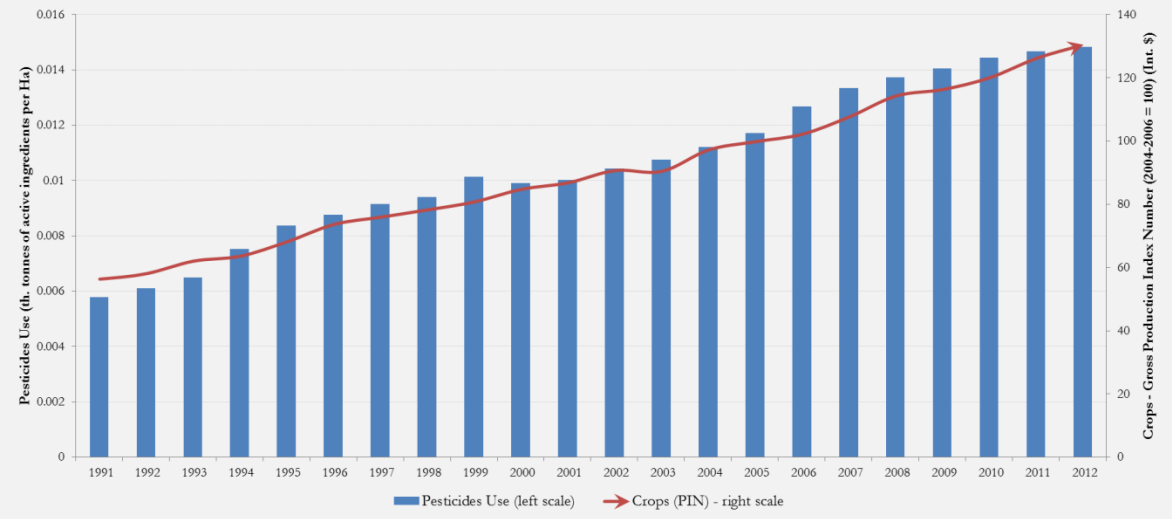
Source: IFA.

Pesticides

Pesticides can boost agriculture productivity by reducing pest damage, but it can also threaten sustainability by polluting water systems and jeopardizing human and ecosystem health.

China's use of chemical pesticides has steadily increased since the early 1990s, paralleling the upward trend in crop production (Figure 4). Pesticide use (as measured in its active ingredients) per hectare was about 5.78 kg in 1991 but was more than doubled to 14.6 kg in 2012. While the structure of pesticides have changed with high-toxicity and high-residue ones being gradually eliminated and/banned, per hectare use of pesticides in China is still about 2.5 times of world average (China Pesticide Information Network, 2015). This trend is particularly worrying as compared to that of other countries, for example the trends in EU15 and the OECD countries where large annualized percentage reductions have been observed in recent years (Figure 2).

Figure 4. Pesticide use and crop production volume (PIN), 1991-2012



Source: FAOSTAT.

Agricultural ammonia emissions

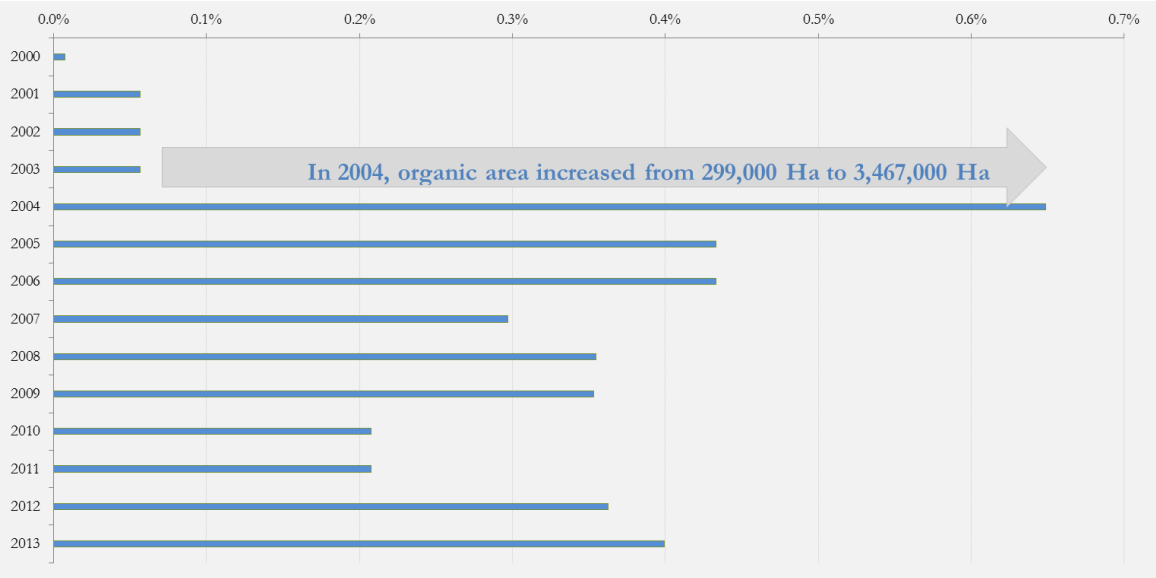
Ammonia emissions due to the use of fertilizers and livestock production have increased significantly in China in the past decades. These emissions have been recognized as a major contributing factor to China's atmospheric pollutions. While official statistics of agricultural ammonia emissions are not available to our knowledge, there have been a number of studies providing such estimates which suggest that China has been the largest emitter of ammonia emissions globally (according to an interview appeared in Guangzhou Daily, 2014). Huang et al. (2012) suggest that China's ammonia emission was about 20% of the global total. In a recent study, Xu et al. (2015) suggests that total agricultural ammonia emissions in China reached 8.4 million tons in 2008, while other studies surveyed by them put the estimate between 4.3 million tons to 13.7 million tons; for example, Liu et al. (2013) suggest that total ammonia emissions in China more than doubled during the 1980-2010 period, rising from about 6 million tons to around 14 million tons. In all studies surveyed by Xu et al. (2015), synthetic fertilizer application and livestock manure spreading are estimated to be the main

sources of these emissions. In particular, rising livestock production and consumption have led to increased share of livestock manure spreading in total ammonia emissions, from 37% to 45.5% during the period of 1978-2008, whereas the contribution from synthetic fertilizers decreased from the high level of 42.7% during that period to around 38.9% in 2008, according to Xu et al. (2015). Total ammonia emissions have also been on the rise during the 1978-2008 period at an annual average pace of 3 percent, increasing from 3.2 million tons to 8.4 million tons. Without proper treatment and management of animal manure, ammonia emission from livestock production would likely to go up further against the projected further increase in the demand for livestock based products.

Organic production

Organic farming can reduce environmental pressure and strengthen sustainability by improving soil condition and water quality (OECD, 2013). Organic farming in China has increased

Figure 5. Organic Area in China, 2000-2013
% on Agricultural Area



Source: Research Institute of Organic Agriculture (FiBL).

dramatically in recent years, from 0.01% in 2000 to 0.40% of agricultural area in 2013 (Figure 5). Key crops for organic production include maize, rice, wheat, soybeans, and nuts.[1]The most significant increase occurred in 2004 when organic area rose from 299,000 hectare to 3,467,000 hectare. However, after this one-year dramatic rise, China's organic farming area has contracted. Overall, organic farming area in China remains negligible in its total agricultural areas and has yet to generate noticeable environmental impacts at national scale.

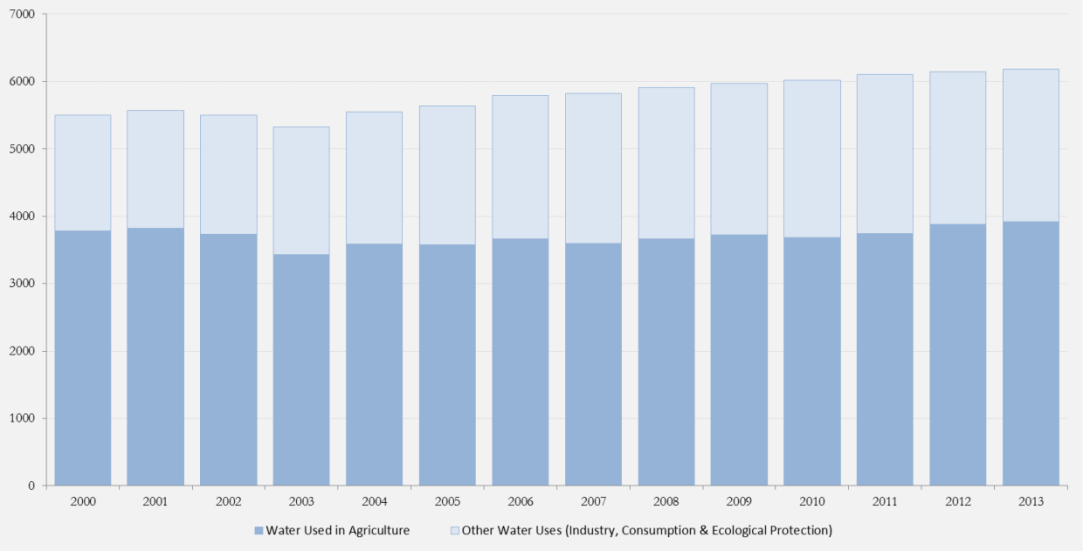
[11] Source: Organic World, available from http://www.organic-world.net/index.html.

Water

Sufficient water quantity and quality are critical for a sustainable agriculture sector. In the case of China as a water-scare country on a per-capita basis and where serious spatial mismatches between water resources and water uses exist, more effective and efficient use of water is particularly crucial for the sustainable development of its agricultural sector, especially in the presence of clime change which likely will lead to more extreme weather patterns and natural disasters, thus compounding China's water challenges. Since 2000, water use in agricultural initially decreased and reached the lowest level in 2003 at 343.3 billion m^3; however since then agricultural water use has gradually increased and eventually reached 392.2 billion m^3. As total water use in China gradually increased during the 2000-2013 period, the share of agriculture water use shrank from 68.8% in 2000 to 61.3% in 2011, before rebounding to 63.4% in 2013. It is quite clear that agriculture remains the biggest user of China's water resources (Figure 6).

Figure 6. Agriculture and total water use in China, 2000-2013

(100 million cu.m.)

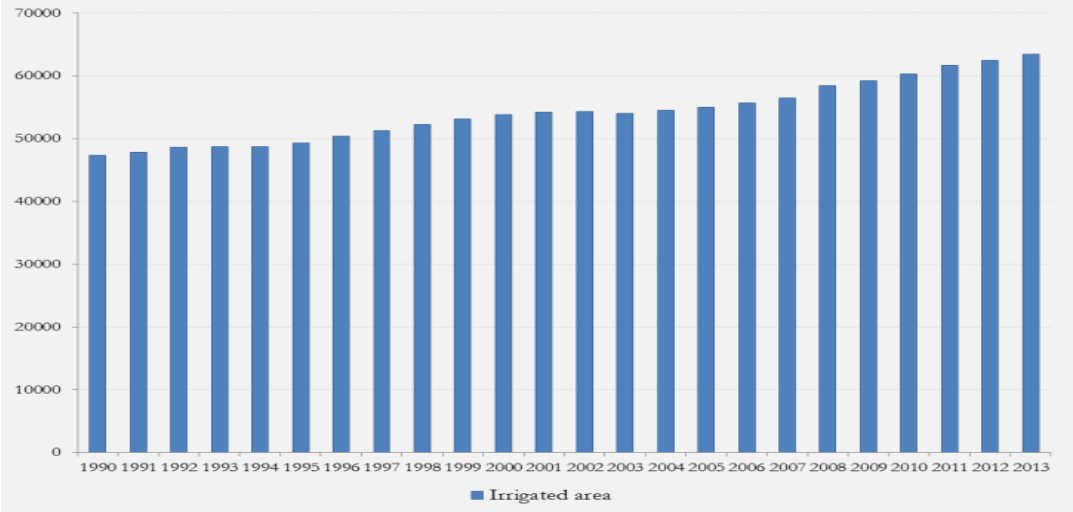


Source: Chinese Statistical Yearbook, 2014.

One key reason for the dominant share of agriculture water use in total water use is due to China's vast irrigation areas as well as low effective utilization ratio of irrigation water. China's irrigated land area increased 34% from 1990 to 2013 (Figure 7). While total agricultural area has also expanded, the proportion of irrigated land has increased 3% over the same period (from 9% in 1990 to 12% in 2013) (Figure 8). In 2013, irrigation consumed 55% of China's total water use, even though China has managed to maintain zero growth of its irrigation water use during the 2000-2013 period. However, only slightly over half of this irrigation water was effectively utilized. Therefore, without further improvement of irrigation water utilization, agricultural irrigation will continue to constrain the sustainability of Chinese agriculture.

Figure 7. Irrigated area in China, 1990-2013

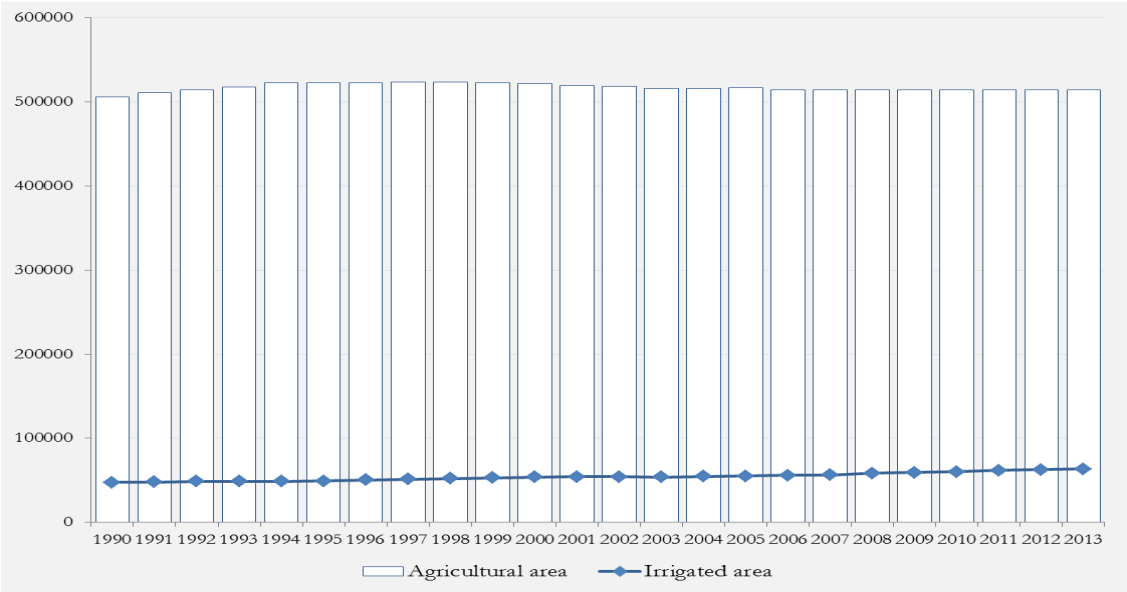
(10,000 hectare)



Source: Chinese Statistical Yearbook, 2014.

Figure 8. Irrigated area as a share of total agricultural area, 1990-2013

1000 Ha



Source: Chinese Statistical Yearbook, 2014.

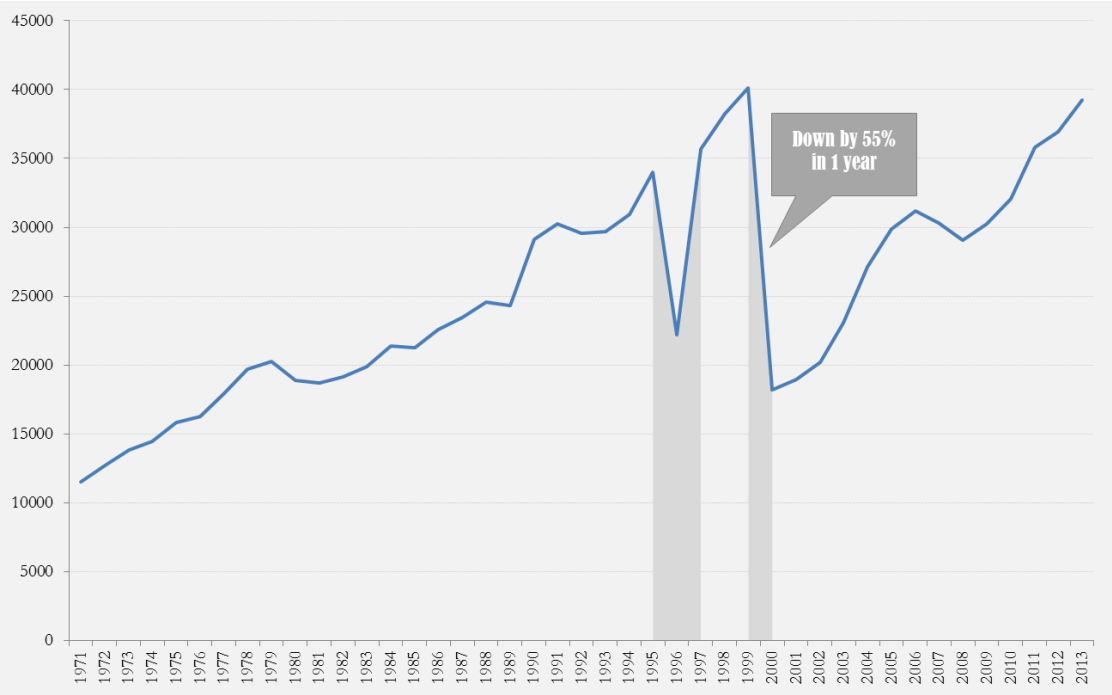
Direct on-farm energy consumption

On-farm energy consumption has followed an upward trend since the 1970s, interrupted by two sharp declines in 1996 and 2000 (Figure 9). These sharp declines are due to adjustments made to the energy statistics by the Chinese government in its national economic surveys conducted in 2009 and 2015. However, these adjustments have not been extended to all previous years in the statistics, thereby resulting in the inconsistencies listed above. Despite this upward trend, the agriculture sector's share of total energy consumption in China has

remained low, actually declining from 3% in 1971 to 2% in 2013. This is however consistent with the shrinking share of the agricultural sector in China's total economic activities and does not necessarily suggest improved efficiency in direct on-farm energy consumption. On the contrary, as rural labor forces continue to shrink and mechanization continue to rise, it is quite possible that total on-farm energy consumption as well as energy consumption per hectare would rise further in the future.

Figure 9. Energy consumption in agriculture, 1971-2013

Ktoe



Source: OECDSTAT.

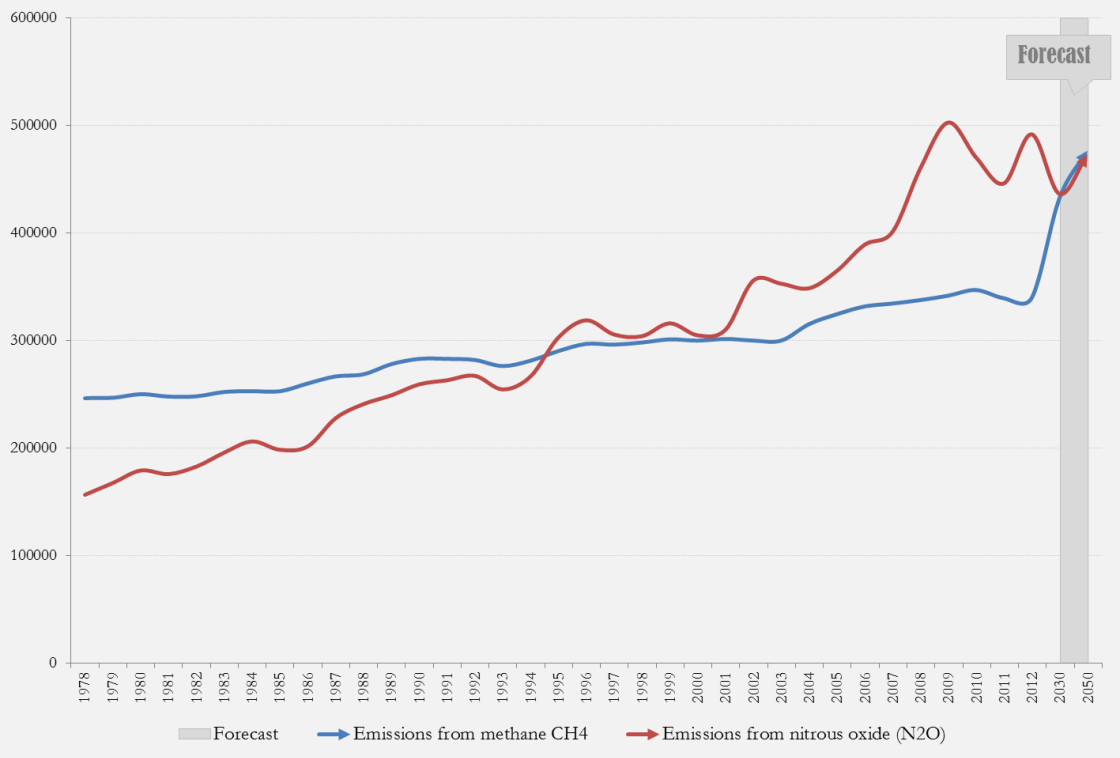
GHG emissions and Climate change

Sustainable agricultural productivity growth in China and elsewhere is exposed to a number of new challenges in a changing climate – from rising temperatures to increasingly severe and frequent shocks. Climate change heightens the urgency of strengthening sustainable practices. In China, an awakening to this urgency has not yet come to pass. As shown in Figure 19, total annual GHG emissions from agriculture have more than doubled from 404.2 thousand tons in 1978 to 831.6 thousand tons (CO2 equivalent) in 2012, for an annualized increase of 2.1%. Methane was initially the more important agricultural sourced GHG, representing about 60% of total agricultural GHG emissions in 1978; and it grew at about 0.94% per year during the 1978-2012 period. Nitrous oxide emissions on the other hand increased at a faster pace of 3.4% per year, and exceeded methane emissions in 1995. By 2012, share of nitrous oxide emissions in total agricultural emissions approached 60%. Since 2000, however, agricultural emissions have increased at a faster pace, at about 2.6% annually, with methane and nitrous oxide emissions rising at 1% and 3.9% per year respectively (Figure 10).

These increased GHG emissions from agriculture (which are projected to still rise further, for example due to increased livestock production) add to the total GHG emission of China, now among the leading GHG emitters of the world.

Figure 10. GHG emissions: methane and nitrous oxide, 1978-2050

CO2 eqivalent (Gigagrams)



Source: FAOSTAT.

Soil contamination impacts on food quality and safety

China faces serious soil contaminations due to both industrial and agriculture pollutants, especially in areas bordering highly polluting factories and mines as well as in areas where intensive farming are practiced. According to the first *National Soil Pollution Situation Survey* for the April 2005 – February 2013 period (MEP, 2015), 16.1% of the surveyed sites have soil pollution; for cultivated land, this ratio is even higher at 19.4%. For forest land, grassland, and unutilized land, polluted soil sites are respectively 10, 10.4 and 11.4 percent. Pollutants are mainly inorganic and are present in 82.8% of the polluted locations in the survey, particularly heavy metals such as cadmium, mercury, arsenic, copper, lead, cadmium, zinc, and nickel. Organic pollutants are mainly BHC, DDT, and polycyclic aromatic hydrocarbons. China's soil suffers from pollutions from industry, domestic and agricultural sources. Heavy metal pollutions are mainly caused by wasted water, wasted gas and solid wasted residues from industries. Within agriculture, the main pollution sources are chemical fertilizers and pesticides

as their utilization ratios are less than one-third, plastic mulch whose recycling ratio is less than two-third, animal manure and wastes, and crop residues including the burning of these residues.

Although no official statistics exist to show the impacts of soil contamination on food quality and safety, it is widely believe that soil contaminations are harmful to the safety and quality of agricultural products. A few studies have demonstrated such linkages. For instance, according to Lei et al. (2010), significant heavy metal pollutions are founded in rice produced from many main rice production provinces according to surveys conducted during the period of 1999-2009. Li et al. (2008) also reported impacts of soil pollutions on food quality and safety, especially the impacts of pollutions from heavy metals, fertilizers, and pesticides on vegetables and grains.

Eutrophication

Eutrophication is a serious challenge to Chinese agriculture due to pollutions to China's water resources. A number of "key" lakes and reservoirs are put under national level monitoring and testing. According to China Environmental Bulletins (see Table 1 below), during the period of 2006-2011, between 11 to 15 of the 26 to 28 key lakes and reservoirs are judged to be in some state of eutrophication, or about half of these lakes are affected. Since 2012, these monitoring and testing was expanded to cover 61 key lakes and reservoirs, a similar number of which (between 15 and 17) was again tested with various degrees of eutrophication; however, in this period none of the lakes were judged to be in severe eutrophication. Due to the larger number of lakes under national monitoring, the share of eutrophication was lower for this recent period.

Table 1. Eutrophication in Key Lakes and Reservoirs in China: 2006-2014

	Number of key lakes and reservoirs with eutrophication				**% of total under national monitoring**	**total number under national monitoring**
Year	Severe	Medium	Mild	sum		
2006	2	4	9	15	55.6%	27
2007	2	3	9	14	50.0%	28
2008	1	5	6	12	42.9%	28
2009	1	2	8	11	42.3%	26
2010	1	2	11	14	53.8%	26
2011	0	2	12	14	53.8%	26
2012	0	4	11	15	25.0%	60
2013	0	1	16	17	27.9%	61
2014	0	2	13	15	24.6%	61

Source: China Environmental Bulletin, various volumes.

Eutrophication is not limited to China's fresh water resources. In fact, this phenomenon is also spread to China's sea areas. According the 2014 China Oceanic Environment Quality Bulletin, in the autumn season China has 104,130 km^2 of sea areas affected by eutrophication. The East China Sea has the largest eutrophication sea area of 55,220 km^2 in the autumn, followed by 27,900 km^2 in the Yellow Sea, and 14,530 km^2 in the Bohai Sea.

Transgenic crops

According to data obtained from International Service for the Acquisition of Agri-Biotech (ISAAA), China ranked the sixth the world in terms of sown areas of transgenic crops during the 2008-2014 period. This sown area ranged between 3.5 million hectares in 2010 to 4.21 million hectares in 2013. The main transgenic crops are cotton (4.2 million hectares in 2013), papaya (6,000 hectares), and smaller sown areas for poplar, sweet pepper, and tomato.

China maintains considerable capacities in the research and development of transgenic crops beyond those which have received official approvals for actual production. However, the adoption of transgenic crops in commercial production and human consumption remains a very sensitive issue. The very fact that the officially approved transgenic crops do not include major food grains reflects a careful and prudent approach by the Chinese government.

2.3 Challenges for the future

The above descriptions of major agri-environmental indicators demonstrate several important environment constraints on the sustainable growth of Chinese agriculture, including fast growing nutrient inputs, pesticides, and energy consumption, inefficient water use especially in irrigation, contaminations and pollutions to soil and water resources, and increased ammonia and GHG emissions from agriculture. If the trends as illustrated by these indicators continue in the future, sustainable growth of China's agriculture would be highly uncertain, especially against the backdrop of climate change. Therefore, a national strategy and policy framework should be developed to curb and eventually reverse the current practice in chemical inputs use and in the manner where natural resources are currently exploited to mitigate these environmental constraints. Additionally, agricultural emissions should also be taken more serious in China's environment policy agenda to minimize the damages caused by agriculture itself so as to mitigate the uncertainties related to climate change.

3. Regulations on natural resource use: land use and air pollution

3.1 land use regulations

China's main legal regulation on land use is set out in the *Land Administration Law of the People's Republic of China* (*Land Law* for short hereafter; PRC, 2005), which entered into force on January 1, 1999 and was revised in 2004. This law includes seven chapters, with chapter one stating the overall principles, chapter two on land ownership and use rights, chapter three on land use planning, chapter four on the protection on cultivated land, chapter five on construction land, chapter six on land supervision and inspection, and chapter seven on legal responsibility.

In chapter one of the *land law*, article 1 clearly states that one of the purposes of the law is to "effectively **protect cultivated land**". Article 3 further states that "it is the country's basic strategy to treasure and properly utilize land and to effectively protect cultivated land". In

article 4, it is declared that conversion from agricultural land (defined as land directly used for agricultural production including cultivated land, woodland, grassland, land for water conservancy, and water aquaculture) to construction land is to be "strictly limited" and cultivated land is to be especially protected.

Land tenure and use rights are defined in chapter 2. Article 10 states that land collectively owned by farmers belongs to village farmers collectively. The ownership of collectively owned land is to be registered by county governments who issue certificate to certify the ownership. Ownerships and use rights of other agricultural land such as grassland and woodland are specified in other laws such *Forest Law, Grassland Law, and Fisheries Law*. In article 14, land owned by farmers' collective economic organizations (villages) are to be leased to members of the organizations for purposes of farming, forestry, animal husbandry, fishery activities and leasing period is for 30 years.

Chapter three is on the overall **land planning**. Land planning at the provincial level is conducted so as to ensure the aggregated cultivated land volume to be maintained. In article 19, it is required that *basic agricultural land* has to be strictly protected and nonagricultural use of cultivated land is to be controlled. It is also stated that the ecological environment is to be protected to ensure the sustainability of land. When cultivated land is used for other purposes, reclamation of cultivated land has to be conducted as compensation for the loss.

The entire chapter four is devoted to detailed regulations on the **protection of cultivated land**, including the compensation system to ensure the overall cultivated land area is not reduced by nonagricultural uses. This is to be realized mainly through strict control on land conversions and by reclamation when conversion happens. "**Basic agricultural land**" is to be particularly protected according to article 34, including cultivated land within the production base of grains, cotton and oil seeds, cultivated land with good water conservancy and water and soil conservation facilities, vegetable production base, and agricultural experimental and education land. The share of "basic agricultural land" in total cultivated land has to be over 80% at provincial level.

Not only is the area of basic agricultural land is to be protected, the **productivity and environmental quality of land** is also to be maintained. In this regard, article 35 states that governments at all levels should apply measures to maintained irrigation and drainage facilities, improve soil quality and fertility, prevent desertification, salinization, soil erosion and land pollution. Article 38 further states that under the conditions of protecting and improving the ecological environment, unutilized land can be developed with priorities on being converted to agricultural land if appropriate. However, under the overall land use plan, reclamation of unutilized land has to go through scientific assessment and it is prohibited to convert forest, grassland, and lakes to cultivated land (article 39). On the contrary, land reclaimed through conversion of forest, grassland and lakes are to be returned to forest, grassland and lakes.

Indeed, this forms the legal basis for the large scaled "*returning land to fores*t" (also known as the Grain for Green project) and "*returning land to grassland*" projects.

The protection for cultivated land is also embodied in the regulations on construction land in chapter 5. For instance, article 47 sets out the **compensation principle** when conversion of agricultural land is approved. Such compensation includes compensation of the loss of land, subsidies for relocation, as well as compensations for properties and crops.

The spirit of the *Land Law* has been reflected in many important government documents such as the most important no. 1 documents regarding agricultural and rural affairs typically released jointly by the Central Committee of the Communist Party of China (CCCPC) and the State Council (i.e. China's central government). Some of these documents either reiterate the main regulations in the *Land Law* or propose concrete measures for its implementations. In areas where the *Land Law* does not clearly specific the regulations or in responding to new situations which were not foreseen by the *Land Law*, these policy documents also reveal new directions of land regulations.

First, land tenure and use rights have been further clarified and developed in the subsequent policy documents. For instance, in the no.1 document of 2013 (which was issued on December 31, 2012 and publicly released on January 31, 2013; CCCPC and State Council, 2012), the first No. 1 document released by the current decadal Chinese leadership, it is reiterated that the land contract arrangements in rural areas are to be maintained and stabilized; however, the specific forms of implementation need to be further decided, for example through *orderly transfers of the use rights of land contracts*, particularly to specialized large farms, family farms, and farmers' cooperatives. In essence, this is a signal for encouraging land consolidations for large scale operations without depriving individual farmers of their land contracts. In the next no.1 document released in 2014 (CCCPC and State Council, 2014), under the condition of the "strictest" protection of cultivated land, farmers are to be given more freedoms with their land contracts, including the possession, use, transfer, and income. Farmers with contracted land are also allowed to use the land contract as collateral and guarantee when seeking finance from financial institutions. The implementation of these expanded possession and use rights is to be based on the registration and certification of land contracts. In the same document, regulations on commercial development of rural construction land and acquisition of agricultural land are also specified. In the more recent 2015 no. 1 document (CCCPC and State Council, 2015a), appropriate land consolidation and rural land tenure reform are again highlighted, with emphasis on the implementation of the clarification, registration, and certification of land contracts. Without changing the "red line" of total cultivated land areas, land reforms regarding acquisition, commercial use of rural construction land, and housing plots are to be carried in a "prudent and safe" manner.

Second, national food security has been explicitly listed as the purposes for setting the so-called "red line" for the protection for cultivated land. This is for example reflected in the

CCCPC's most recent recommendations on the 13th Five-Year Plan (CCCPC, 2015), where the "most strict" protection regime for cultivated land has to be upheld, including the "red line" of cultivated land. In the *Outline of the National Overall Planning on Land Use (2006-2020)* (the *Outline* for short hereafter), compiled by the MLR and approved by the State Council on Oct 6, 2008, the overall planning targets, main implementation tasks, and specific regulations on protecting and utilizing agricultural land are specified[2]. It is stated that the red line of 1.8 billion *mu* (i.e. 120 million hectare) cultivated land is to be defended with specific targets of 1.818 billion mu in 2010 and 1.805 billion mu in 2020, with the 1.56 billion mu basic agricultural land to be maintained with increasing quality. To attain this target, conversion of cultivated land to construction land has to be limited to 45 million *mu* by 2020. To reduce the conversion of cultivated land due to ecological reasons, such conversions can only happen if they are covered in relevant national plans. Also, land consolidation, rehabilitation and development should be implemented in order to provide at least 55 million mu additional cultivated land. For the protections of basic cultivated land, only under exceptional circumstances allowed by relevant laws that conversions of basic cultivated land can be carried out; however, in such situations, equivalent amount of basic cultivated land should be found as compensation. Quality upgrading of existing and reclaimed cultivated land is also envisioned through various programs and measures.

Third, increasing attention on agricultural-environmental concerns is reflected in subsequent government documents, emphasizing the needs to protect the natural resource base for agriculture and to maintain its sustainability. For example, chapter 5 of the aforementioned *Outline* is devoted to the coordination of land use and ecological development. Alongside the protection of cultivated land, "*basic ecological land*" is also to be strictly protected to ensure that cultivated land, grazing and grassland, water areas, and certain unutilized land that have ecological functions have to exceed 75% of total national land areas. Land ecological environment improvement is to be strengthened under the *Outline*, including maintenance of the ecological retirement of certain cultivated land, the ecological rehabilitation and reclamation of waste land from industry and mining activities, and the prevention and treatment of degraded land. These improvements are to be conducted in a differential manner according to the local characteristics; for example, the country is divided into 9 land utilization zones, with each zone having its own emphasis on land management.

3.2 Regulations on air/atmospheric pollution

[2] In light of the release of the recommendations on the 13th Five-Year National Economic and Social Development Five-Year Plan by the CCCCP (2015), on December 8, 2015, MLR passed an amendment to the *Outline*, pending the approval by the State Council. See http://www.mlr.gov.cn/xwdt/jrxw/201512/t20151209_1391006.htm, accessed on December 19, 2015.

The basic legal regulations on controlling and preventing air/atmospheric pollution is the *Law on Atmospheric Pollution Prevention and Control of the People's Republic of China* (*Atmospheric Pollution Law* for short hereafter; PRC, 2015), which was first passed by the National People's Congress (NPC) on September 5, 1987 and amended twice in 2000 and 2015. The recently amended version enters into force on January 1, 2016.

The *Atmospheric Pollution Law* states that the improvement of atmospheric environment quality must start with the control of the sources of pollutants and be conducted with a comprehensive approach to all sorts of pollutant sources including those from agriculture. A coordinated control should be applied to particulate matters, sulfur dioxide, nitrogen oxides, volatile organic compounds, ammonia and other air pollutants, as well as greenhouse gases. Governments at or above county level should include atmospheric prevention and control in their economic and social development plans and the associated fiscal spending is to increase. Local governments are responsible for achieving the atmospheric environmental quality and pollutants emission targets within their administrative areas. At the national level, the environment protection agency under the State Council (i.e. the MEP), in cooperation with relevant State Council agencies, is responsible for the monitoring and assessment of the implementation of these targets and the assessments are to be released publicly. The MEP is tasked with developing atmospheric emission standards, based on atmospheric quality standards and national economic and technologic conditions.

Section 5 of Chapter four of the *Atmospheric Pollution Law* lays out atmospheric pollution prevention and control measures for pollutions sourced from agricultural and other activities. In article 73, it is stated that governments at various levels should promote the transformation of agricultural production model to allow for the development of an agricultural circular economy; should increase the support for the comprehensive processing and handling of pollutants and strengthen the control of atmospheric pollutants caused by agricultural production activities. Specifically, article 74 requires agricultural producers to improve the method of applying fertilizers, to reduce the use of pesticides, and to reduce emissions of ammonia, volatile organic compounds and other atmospheric pollutants. Article 75 further requires that livestock and poultry farms and communities with intensive livestock and poultry farming activities should promptly collect, store, removal and safely dispose sewage, animal manure and carcasses for preventing emission of odorous gases. Article 76 states that governments at all levels and their administrative departments of agriculture should encourage and support the use of advanced and applicable technologies to comprehensively utilize crop residues and leaves as organic fertilizer, feed, energy, or industrial raw materials; for these purposes, government subsidies on the use of agricultural machineries should be increased. In particular, county level governments should coordinate the establishment of service systems to collect, store, transport and comprehensively utilize crop residues, including using government subsidies to mobilize rural collective economic organizations, farmers' specialized cooperatives, and other enterprises to engage in these activities. Article 76 further prohibits

burning crop residues and leaves in open air areas to prevent the emission of smoke and dust pollution in areas designated by provincial level governments.

Although there are no explicit numerical targets on atmospheric emissions sourced from agriculture activities, the MOA does emphasize the importance of preventing and controlling agricultural nonpoint source pollutions. Measures mainly meant to tackle soil and water pollution through regulations on fertilizers, livestock and poultry waste, and crop residues may also help reduce emissions of nitrous oxide and methane. In MOA (2015b), targets on zero-growth of chemical fertilizer and pesticide uses are declared, which should help curb the emission of nitrous oxide into the atmosphere. The wide application of soil testing formula fertilization should also improve the efficiency of fertilizer use and reduce nitrous oxide emission. Measures taken on manure and waste from livestock and poultry production may also have effects on methane and nitrous oxide emissions. In addition, regulations on burning of crop residues will have effects on reducing particulate matters in the air. In the next section, selected agricultural environment measures are discussed in details.

4. Agricultural environment policy in China

The steady growth of the Chinese agriculture sectors, especially for products with high self-sufficiency targets, has been aided by institutional reforms, productivity growth, intensive use of chemical inputs such as chemical fertilizers and pesticides, and (over)exploitation of the land and water resources (Fan and Pardy, 1997; Huang and Rozelle, 1996; Huang et al., 2002; Jin et al., 2002; Lin, 1992). As shown in previous sections of this paper, intensive use of chemical inputs in the crop sectors have led to soil degradation and pollution, water pollution, and damaged bio-diversities. Water resources have also been heavily exploited by agriculture, especially for irrigation, at the national scale and in particular in areas where irrigations are intensive and/or water resources are scarce. The development of livestock sectors creates serious stresses on China's grassland areas. The release of animal manure and waste water from intensive livestock, poultry and aquaculture farms further pollutes the environment, especially water resources. These negative agricultural environment effects have already started to constrain further development of Chinese agriculture and seriously undermine the resource base for its sustainable development.

4.1 National strategy on improving agricultural environment and the policy architecture

Aside from several large scaled projects on land use management and irrigation and water conservancy projects addressing land and water resource issues, agricultural environmental concerns have only been incorporated into China's agricultural policy agenda in the last several years, especially with regards to non-point source agricultural pollution, uses of chemical fertilizers and pesticides, livestock waste treatment, and polluted land restoration. While legal regulations on protecting the environment and natural resource have been set out in the various laws reviewed in Section 3 of this paper, their implementations usually rely on

specific government initiated projects that are often directed by a coordinating government ministry, with other agencies playing supporting roles. In the areas of agriculture, in recent years the *No. 1 documents* issued by the CCCPC and the State Council have highlighted the need to improve agricultural environment and to protect the natural resource base and laid out the overall national strategy for achieving these goals. For instance, the 2015 *No. 1 document* (CCCPC and the State Council, 2015a) explicitly mentioned that agricultural ecological management and governance should be strengthened. Concrete policy measures to be implemented include: non-point source agricultural pollution control and treatment through implementation of soil testing and fertilization recommendations, promoting the adoption of biological organic fertilizers and low-toxicity pesticides, use of crop residues and manure as resources, and regional demonstration of agricultural film recycling, all of which are to be backed by relevant fiscal and tax policies; promoting the development of the agricultural circular economy with emphasis on the environmental impact assessment of large scale livestock and poultry operations; continuations of subsidy and compensation for grassland ecological protection; protections for aquaculture biological resources; establishing and improving water resource assessment of zoning and construction projects and creating the national water inspection system; promoting water-saving technology by implementing regional large scale high efficiency water-saving irrigation action; increasing the efforts on water pollution prevention and treatment and on aquatic ecological protection; implementing a new round of cropland to forest and grassland conversion project and other land restoration projects; and vigorously promoting the large scale forest ecological projects.

Some of these measures are also reiterated in other high level policy documents such as CCCPC (2015) regarding recommendations on the 13th Five-Year Development Plan, CCCPC and State Council (2015b) regarding the construction of ecological civilization. Details about these initiatives and projects are explained in more details by relevant government ministries, such as MOA (2015c and 2015d). In what follows, important policy measures are described and discussed.

4.2 Policy initiatives on reducing chemical inputs

To reduce the use of chemical fertilizer and pesticides, China initiated the **2020 Zero-Growth Action Plan for Chemical Fertilizers and Pesticides** (MOA, 2015b). In the Action Plan for chemical fertilizers, four issues related to current practices are highlighted: *excess application of fertilizer* per unit of land, currently at 21.9 kg/mu as compared the worldwide average of 8 kg/mu; *uneven fertilizer use* across regions and products, with excessive use observed in Eastern China, the lower Yangtze River area, as well as for cash and horticulture products; *low utilization rate of organic fertilizers* at around 40% of the estimated 70 million tons that are available; and the *unbalanced structure of fertilizer uses*. The goal of the action plan is therefore to restrict the annual growth of chemical fertilizer use to be below 1% for the 2015-2019 period and to achieve zero-growth by 2020 for major agricultural crops, as compared to actual annualized growth rates of nitrogen and phosphorus uses at 3.9% and 2.5% during the

2000-2013 period (source: IFA). Implementation details will vary across Chinese regions due to uneven regional application of fertilizers. For instance, in regions where fertilizers are currently used excessively, such as Northeastern China, the Northern China Plain, and the mid and lower Yangtze River area, nitrogen and phosphorus inputs are either to be controlled or reduced whereas the use of potassium is to be stabilized. In Southwestern China, nitrogen use is to be stabilized, use of phosphorus fertilizers is to be adjusted, and potassium use is to be increased; in Northwestern China, the focus is to match the use of fertilizers and water resources, with the use of both nitrogen and phosphorus to be stabilized (MOA, 2015b).

Similarly, it has been recognized in the Action Plan for pesticides that the use of pesticides has been on the rise, for instance by a total of 9.2% during the 2012-2014 period as compared to the 2009-2011 period. The excessive use of pesticides not only increases production costs but also influences food safety and damage the ecological system. The objective of the action plan is therefore to limit the use of pesticide so that the average use per unit of land falls below that of the last three years, thereby realizing the target of zero-growth by 2020. This action plan emphasizes the role of green pest prevention and control, professional pest control, and scientific application of pesticide.

The initial steps of the Zero-Growth Action Plans include several pilot projects (MOA, 2015a). In 2014, the central government started to support the **high efficiency slow-release fertilization demonstration pilot project** on maize production in five provinces. Another pilot project that started in 2011 provides subsidies to lower farmers' costs of applying **low-toxicity biological pesticides**. In 2014, this project was expanded to 42 major vegetable, fruits and tea production counties in 17 provinces. A third project, which is currently at a much larger scale, is the government support for **soil testing formula fertilization**. In 2015, the government committed CNY 700 million aiming at providing technical service on soil testing formula fertilization for 190 million farm households, covering 1.5 billion mu of agricultural land.

4.3 Policy initiatives on protection land resources

To protect and improve the quality of arable land, from 2014 the "soil organic matter enhancement project" was renamed to be the "**Farmland Protection and Quality Improvement Project**" (MOA, 2015a and 2015e). The central government committed CNY 800 million in 2015 to support and encourage large scale grain producing farm households and family farms to return crop residues to the fields, to better utilize green manure and organic fertilizer, and to improve soil and fostering soil fertility. The project particularly emphasizes three initiatives: promoting the comprehensive technology in returning crop residues to the fields particularly straws from rice cultivation in the South and maize straws in the Northern China Plain; intensifying the adoption of the technology of soil fertility through utilization of straw, organic fertilizers and organic fertilizer crops, and soil conditioner; and construction of green manure demonstration zones. These efforts were particularly planned in 2015 for

selected counties to improve the fertility of the black soil in Heilongjiang, Liaoning, Jilin, and Inner Mongolia.

To deal with pollutions to key agricultural resources such as land and water, the Chinese government also initiated the **Agricultural Resources Respite Pilot Policy** (MOA, 2015a). This policy includes three key components.[3] The first key component is to carry out comprehensive prevention and control of heavy metal pollution to soil through conducting national surveys, surveillance and dynamic early warning of soil heavy metal pollution.[4] In particular, concrete measures are to be taken in the rice cultivation areas in 6 provinces in Southern China to tackle heavy metal pollutions. For moderately polluted arable land in those regions, demonstrative restoration of heavy metal polluted land is to be conducted without interrupting production activities, whereas for the heavily polluted arable land, production is to be stopped while restoration is undertaken. In the latter case, farm households in the demonstration projects are to be properly compensated. The second component of the pilot policy is to implement agricultural non-point pollution control and management, including the construction of national agricultural non-point pollution monitoring and control network, with particular emphasis on building the prevention and control demonstration areas surrounding Tai Hu, E Hai, Chao Hu, and the Three Gorges Reservoir. In areas with particular serious pollutions from livestock and aquaculture operations, agricultural film residues, and straw burning, this pilot policy also emphasizes solutions such as pollution controls of large scale livestock and poultry farms as well as aquaculture farms, adoption of decomposable biological agricultural films, recycling of residues of agricultural films, and comprehensive utilization of crop residues. To complement that efforts to deal with nonpoint source pollution, the third component of the pilot policy is to explore and build the agricultural ecological compensation mechanism to provide subsidies to farm households for their reduced use of chemical fertilizers and pesticides and increased adoption of high efficiency, low toxicity and residue pesticides. These compensations are to be strengthened in important watersheds where agricultural non-point pollution is particularly serious.

To protect the ecological system in the grassland areas and for developing the livestock sector there, the central government has established the **Grassland Ecological Protection Subsidy Policy** since 2011 (MOA, 2015a). In 2011, the policy was initially implemented in 8 provinces and regions with grassland pasture areas in Northwestern and Western China (Inner Mongolia, Xinjiang, Tibet, Qinghai, Sichuan, Gansu, Ningxia, and Yunnan, as well as the Xinjiang Production and Construction Corps); later it was expanded to grassland in another 5 provinces (Shanxi, Hebei, Heilongjiang, Liaoning, Jilin, as well as the Heilongjiang Land Reclamation

[3] These measures also appeared in longer term policy plans such as the *National Agricultural Sustainable Development Plan: 2015-2030* (MOA, 2015d). Therefore, it is understood that they will be implemented in a longer time frame beyond 2015, even though the MOA (2015a) does not specify the time line of this pilot policy.

[4] The first *National Soil Pollution Situation Survey* for the April 2005 – February 2013 period provides some estimates on soil pollutions (see MEP, 2015).

Bureau) so that currently it covers13 provinces (regions) with a budget from the central government of CNY 15.769 billion in 2014 and 19 billion in 2015. The main components of the policy include: grazing moratorium in areas with serious ecological degradations (which render grazing detrimental to the ecological system) with compensations of CNY 6 per mu for an initial five-year period; subsidy for balanced livestock-grassland ratio that grants herders a CNY 1.5 per mu subsidy for not exceeding the established ratio on eligible grassland not subject to the grazing moratorium; and production subsidies which include new improved variety subsidy for both livestock and grass at CNY 10 mu per year and comprehensive input subsidy CNY 500 per household per year.

4.4 Policy initiatives on protection water resources

Protecting the water resources is the responsibility of the MWR and MEP. In collaboration with the NDRC, MIIT, and MOA, the MWR and MEP have developed a **Water Pollution Prevention and Control Action Plan,** which is issued by the State Council (2015). In this plan, various references and measures have been made to water pollution sourced from agricultural activities.

First, to reduce pollutions from intensive livestock and poultry farming, strict zoning regulations are declared so that certain areas are declared free from these activities and existing operations at scale level and by specialized farm households are to be closed or reallocated; in particular, by the end of 2017, this measure is to be first implemented in the Beijing-Hebei-Tianjin area, the Yangtze River Delta, and the Pearl River Delta. Permitted large scale operations must build complementary manure and waste water storage, processing, and reutilization facilities, whereas areas with intensive backyard livestock and poultry activities need to implement a system of individual manure and waste water collection and collective treatment and reutilization. From 2016 and onwards, newly built, expanded, and remodeled large scale livestock and poultry farms must implement separate treatments of rain and waste water and provide processing and utilization of manure and waste water. These requirements are to be coordinated by the MOA with participation from the MEP.

Second, concrete measures are initiated to control agricultural non-point pollution from the use of fertilizers and pesticides.[5] Aside from government programs for supporting the use of low-toxicity pesticides and the application of soil testing formula fertilization, environmental requirements are also imposed on the construction of high standards farm land and on land consolidation and exploitation. In particular, in sensitive areas and large and medium scaled irrigation areas, existing ditches and ponds are to be utilized for growing water biomes and for installing permeable dams and other installations, for purposes of purifying farmland drainage

[5] For example, the MOA (2015b) issued the Zero-growth action plans for both fertilizers and pesticides. See discussions in subsection 4.1 in this paper.

and surface runoff. These measures are to be implemented by the MOA, with participations from NDRC, MLR, MEP, MWR, and others.

Third, adjustments are to be made to the nationwide structure and spatial distribution of the crop sectors. In water-shortage regions, pilot projects are to be implemented on retirement of land for reduction of water uses. In areas where ground water is susceptible to pollution, priorities should be given to the cultivation of crops requiring less fertilizer and pesticide. In areas where surface water and underground water has already been over-drafted and where agricultural water withdrawal is high, such as Gansu, Xinjiang, Hebei, Shandong, and Henan, appropriate adjustments are to be made on reducing the cultivated areas of crops that are intensive in water uses.[6] By the end of 2018, it is planned that comprehensive adjustments are to be made on 33 million *mu* (2.2 million hectare) irrigated farmland to achieve water saving amounted to more than 3.7 billion cubic meters. These projects are to be led by the MOA and MWR, with participations from the NDRC and MLR.

Other measures relevant for the agriculture sectors in the **Water Pollution Prevention and Control Action Plan** are: the development of water saving technology and constructing of water conservancy infrastructure, to meet the targets of having 700 million *mu* of farm land covered by water-saving irrigation technology; the implementation of comprehensive reforms of the agricultural water pricing schemes; and the inclusion of agriculture pollutants in the national survey and monitoring system of pollutants, especially via the inclusion of nitrogen and phosphorus in the binding targets of total pollutant discharges.

In connection with the new zoning regulations discussed above on livestock and poultry production, to support large-scale livestock and poultry production and to combat the associated manure and waste problems, the **Rural Biogas Support Policy** is also established (MOA, 2015a). Under this policy, the government is to promote and prioritize the construction of large scale biogas facilities with daily capacity exceeding 10,000 cubic meters per facility. These biogas facilities are to be matched with large scale livestock and poultry farming facilities and mainly use the latter's manure and wastes as raw materials. Small and median sized biogas facilities, on the other hand, are to be built in areas with population mass and plentiful supply of raw materials. Biogas produced from these facilities will serve community gas supply in the rural areas.

6 Although it is not stated in this document how such adjustments will be conducted, it is understood that government incentives will be provided to facilitate these adjustments. In section 15 of the Action Plan, it is stated that government funding will be increased for supporting water environmental projects, with preferential treatment for projects in less developed and key areas and particular attentions to projects in preventing and controlling livestock and poultry pollution and rehabilitation of water ecology.

5. Agricultural domestic support and agricultural trade policies and their impacts on sustainable resource use and environmental performance of agriculture

The importance of agriculture in the overall economy has been generally placed at the highest end of the Chinese government's policy agenda. This is exemplified in the successive *Number 1 documents* issued by the CCCPC and the State Council of China, which generally emphasize the "basic" role of agriculture in national economy and policy goals in supporting agriculture and increasing farm income, despite the fact that the share of agriculture in its national economy has been declining continuously in the past decade.

These documents also typically address important issues and challenges facing the agricultural sectors and provide the policy orientations in tackling these challenges. For instance, in the *Number 1 Documents* of 2014 and particularly of 2015 (CCCPC and State Council, 2014 and 2015a), the transition from a quantity-driven, high resource-dependence extensive development model to a modernized, competitive, innovative and sustainable agriculture development model is envisioned. This new growth model emphasizes both quantity and quality, with the aim to develop a highly efficient, safe, resource and environmentally friendly development path. This represents a major shift in the overall objective of China's agriculture policy. Consequently, the role of domestic and border policies that influence the agriculture sectors on its sustainable resource use and environmental performance has been elevated considerably. For instance, agricultural ecological management is now listed as one of the six goals in creating a modernized agriculture, with concrete initiatives targeting various agri-environmental challenges, which are discussed and described in details in the previous section.

However, it must be pointed out that as existing domestic agricultural support and trade policy instruments are mainly used to maintain domestic self-sufficiency through intensive use of chemical inputs and agricultural natural resources through subsidizations of these inputs, these very policies may have generated the stresses on the environment and natural resource base which the new agri-environment initiatives are trying to mitigate. Therefore, it is important to develop a good understanding of this potential conflict between existing agricultural policy and the newly initiated agri-environmental policy. On the flip side, China's more recent agricultural policy also contains elements that may improve the agricultural sector's environmental performance and its sustainability. These include policy measures aiming at increasing scales of farm operations (e.g. through land consolidation, agricultural cooperatives, agricultural extensions and training of professional farmers) and agricultural service provisions, and initiatives to improve safety and quality of agricultural and food products.

In the rest of this section, an overview of China's agricultural domestic support and trade policy is offered, followed by a discussion on how these policy instruments influence the sustainable use of resources and the environmental performance of agriculture.

5.1 Domestic subsidies and market price support on grains and other crops

China's current domestic support and market price support system has been heavily favoring food grain production and to a less extent some cash crops such as cotton, oil seeds and sugar as well. It mainly includes direct payments attached to either contract/registered/actually planted land, subsidies to specific inputs, and market price support in the form of minimum purchase prices, and more recently, pilot projects of the target price system. Additional support has also been given to measures directly aiming at increasing operation scales and productivity and extension services.

The first direct payment introduced by the Chinese government since the abolishment of agricultural taxation is the **direct payment for grain production** which was first introduced in 2004 and has since been distributed according to either contracted/registered or actual planting areas of land, typically in the range of CNY 10-15 per *mu*. The total national spending on this subsidy has been kept quite stable in recent years and the budget for 2015 was set at 14.05 billion yuan.

The other main direct payment related to grain production is the so-called "**comprehensive subsidy on agricultural inputs**", intended for reducing farmers' costs of purchasing agricultural inputs such as fertilizers, fuels, pesticides, and plastic films. Spending on this central government funded subsidy program had increased quite rapidly in its first several years of existence since its inception in 2006, especially when grain prices and energy prices (hence agricultural input prices) were at very high levels, reflecting the government's intention to use this subsidy to offset the rising input costs for farmers. In fact, in those years the central government followed a "dynamic adjustment system" that ties projected levels of fertilizer, diesel and other agricultural input prices to the size of the subsidy for adjusting the overall spending on this subsidy program. Therefore, on average at the national level this subsidy had indeed been tied up to the input prices (see Yu and Jensen, 2010). However, in practice, the subsidy has been dispensed as a payment per unit of land, thereby seemingly making it an income transfer to individual farm households. In the more recent years, with receding input prices, the total spending on this subsidy has stabilized and by the end of 2014, the central government allocated around 10.71 billion yuan on this subsidy, roughly the same amount as in immediate preceding years.

Improved seed variety subsidy is another major input-based support policy that is implemented either as a direct payment per unit of land (for rice, maize, and rapeseeds) or through direct payments or reduced seed prices that are decided by provincial governments (for wheat, soybean and cotton). The purpose of this subsidy is to encourage the adoption of improved seed varieties that would lead to increased yields and quality. In 2014 the spending on this subsidy amounted to 21.4 billion yuan and the budgeted spending in 2015 was 20.35 billion.

Subsidies on the purchase of agricultural machinery are available to both individual farmers and agricultural operation entities such as specialized mechanization providers when they purchase agriculture machineries. In 2015, buyers of 11 categories (including 43 sub-categories) of agricultural machineries can effectively receive a 30% subsidy of the selling prices. In addition, provinces included in the *National Agricultural Mechanization Implementation Plan for Subsoiling and Cultivating Operation* can provide subsidies to these operations. In total, this program cost the government CNY 21.8 billion in 2013. In 2015, subsidies were also planned for **renewing and replacing existing agricultural machineries**, although the budgetary outlays are not known. The introduction of this subsidy can be understood as a response to rising labor costs and shrinking rural labor force as it facilitates substitution of machine services for labor. It also facilitates land consolidations and large scale farm operations (Van den Berg et al. 2007). Zhang et al. (2015) further argue that the emergence of a national labor-cum-machine service market – aided by the machinery subsidies – help farmers to outsource some of the power-intensive steps of farm operations to professional service provides. This substitution can help to explain the rising land productivities of smallholder farmers in China, despite rising wages and high degree of land fragmentation.

In addition to the above direct payments and input based subsidies aiming at encouraging mainly grain productions, it has also been reported that the central government's "**tilting policy**" towards main grain producing regions have now expanded to support new types of agricultural operation entities such as specialized producers, family farms, and farmers' cooperatives. The latter support is meant to promote larger scale agricultural operations. In total, it is reported that this "tilting policy" has a budget outlay of CNY 23.4 billion. Although it is not clearly stated, it appears that these funds are within the above stated national financial figures on the direct payments and related input subsidies but the distributions of these funds have now been more concentrated on grains and other important agricultural products in the main producing regions with specific targeting of the larger scale producers.

In 2015, a new policy support for promoting the **development of modern seed industry in main grain, cotton and oilseeds producing counties** was introduced, aiming at providing new variety demonstration, learning and technical training, and other extension services for farmers. In the same year, the central government also earmarked CNY 2 billion on supporting **high yield production of grains, cotton and sugar and "green" grain yield enhancement projects**. The former covers 50 counties whereas the latter covers 60 counties nationwide.

On the procurement and marketing side, the Chinese government has mainly relied upon the **minimum purchase prices** to regulate the market prices and to maintain producer incentives. The minimum prices are set annually. When market price falls below the minimum prices, China's state grain reserve corporation makes intervention purchases; when market price rises above, the same entity release grains to the market through auctions. Similar policy instruments exist for other agricultural products such as maize, soybeans, rapeseed, cotton, and

sugar cane, albeit on a more *ad hoc* basis. In connection to these intervention prices, China also maintains **public stockholding** of various agricultural products, thereby also incurring storage costs. With falling world market prices for grains and rising domestic costs and appreciating Chinese currency in recent years, China's grain prices have been increasingly above the corresponding world market prices, which has resulted in higher minimum purchase prices and increases in intervention purchases, and large cost of public stockholding, not only for grains but also for other crops such as cotton.

Due to the buildup of public storage of various agricultural products purchased at prices higher than the world market prices, the Chinese government has started some pilot programs on decoupling price formation mechanisms for several products from government support for purposes of controlling the cost of these policies. In 2014, the Chinese government started two pilot projects on establishing the **targeted price system** for soybean and cotton, with the government providing subsidies to cover the difference between the (higher) target prices and the actual market prices. These targeted price systems have since been expanded to cover pilot projects on grains and pigs.

Another support provided by the government to support agricultural production is agricultural insurance subsidy. This subsidy was first offered in 2007, aiming at reducing the risk associated with agricultural operations. It has since been expanded in terms of product coverage and subsidization rates. At the moment, the central government provides **agricultural insurance premium subsidies** for 15 products, including major crops, livestock such as sows, pigs and dairy cows, forestry, and products originated from Tibet, which subsidize 40% of the premium in central and west regions and 35% in the east regions. Provincial and county governments provide additional subsidies, although that from the latter is to be gradually reduced to lessen the burden on county governments. In 2016, the subsidization rates from the central government will rise to 47.5% for the central and western regions and to 42.5% for the eastern regions (MOF, 2016).

5.2 Trade policy instruments on grains and other crops

The aforementioned domestic market price support instruments are used in conjunctions with border measures such as import tariff and tariff rate quotas to help maintain desirable domestic market prices and targeted domestic self-sufficiency ratios for important agricultural products such as rice and wheat. As compared to industry products, average tariff protection is higher for agricultural products at 14.8% in 2013, with sugars and confectionary (30.9%), cereals and preparations (23.4%), cotton (22.0%), and beverages, spirits and tobacco (21.8%) having higher than average protection. On the other hand, oil seeds, fats, and oils, China's major import products, have the lowest tariff protection at 10.5%. (WTO, 2014).

In addition to tariff barriers, as part of China's WTO accession agreement, rice, wheat, maize, sugar, wool, and cotton are subject to the TRQ system, with high out-quota tariff and low

within-quota tariff rates. For the grain products, for most years since China's WTO accession, the final quota levels have not been exceeded, implying that the within-quota tariff of 1% applied to the imports of these products. For cotton, the quota level is set at a relatively low level as compared to recent import quantities and a sliding-scale tariff between 0 and 40% has been charged on over-quota imports. The notable omission from the TRQ coverage is soybean, which only faces an import tariff and has been imported heavily by China.[7] Some of the TRQs are also subject to state-trading enterprises. China's WTO accession agreement specifies the allocation of the TRQs for grain, cotton, and sugar between the various STEs and private enterprises.

5.3 Policy measures on supporting scale operations by family farms and specialized farm households and new agricultural service entities

In the 2015 and particularly the 2016 No.1 documents (CCCPC and State Council, 2015a and 2016), supporting scale operations by family farms and specialized farm households have been emphasized, together with supporting new agricultural service providers, for purposes of fully exploiting the benefits of agricultural mechanization, adoptions of technology, green development, and market development. On the production side, supportive policy on tax, credit, insurance, land and electricity are to be provided to allow for the growth of new operation entities such as family farms, specialized farm households, and agricultural cooperatives. At the same time, new agricultural service providers are also to be supported so that they can engage in large scale specialized professional services such as plowing, planting, harvesting, as well as land trust. In order to exploit potential scale economy in larger farms, various models of transferring and consolidating land operation rights are encouraged.

Specific measures include (MOA, 2015a):

- Policy directly supporting new agricultural operation entities such as specialized farms and family farms to engage in scaled up agricultural operations. In 2015 a series of existing measures were continued and new measures were rolled out to support the development of family farms, ranging from agriculture-related construction projects, financial subsidies, tax incentives, credit support, collateral, agricultural insurance, agricultural facilities construction. Government sponsored training programs were also directly targeting family farm operators and incentives are given to encourage migrated workers and agricultural college graduates to establish family farms.
- Policy on developing agricultural cooperatives: the central government pledges to support the development of large-scale and specialized agricultural cooperatives with modern

[7] Imports of agricultural products containing genetically modified organism are subject to approval by the Chinese authorities. So far, import licenses for four foreign GM crops have been granted, including cotton, soybean, corn and rapeseed. Only cotton is allowed to grow in China while the other three can be imported as raw materials (MOA, 2013). The majority of soybean imports into China are indeed GM soybean.

management, to allow funds from government finance to be invested directly in qualified cooperatives, and to allow the cooperatives to own and operate assets derived from government subsidies. In 2014, the central government allocated CNY 2 billion on assisting the development of agricultural cooperatives and in 2015, this support was continued with additional emphasis on modernizing the governance of agricultural cooperatives.

- Policy on supporting multiple modes of "appropriate" level of scale operation: to facilitate the development of scaled up agricultural operations, orderly transfer of the land operation rights are encouraged and innovative transfer methods are encouraged. In particular, consolidation of land operation rights into grain production by specialized farmers, family farms and agricultural cooperatives are supported and encouraged. Government assistance will be especially tilted towards farms with size equivalent to between 10 to 15 times of the average household contracted land area.
- Policy aiming at improving rural land contract/usage rights registration and certification: in connection with the drive to scale up agricultural operations, especially with respect to the size of farms, since 2014 an important step has been undertaken by the government to "clarify", register, and certify land operation rights, initially in Shandong, Sichuan, and Anhui and eventually expanded to another 9 provinces 2015 (Jiangsu, Jiangxi, Hubei, Hunan, Gansu, Ningxia, Jilin, Guizhou, and Henan). Moreover, land operation rights have been redefined to allow individual farmers and farmers' organizations to have expanded rights to their contacted land, including using land as collaterals and guarantees.

5.4 Policy measures targeting the livestock sectors

A variety of policy instruments has also been applied to specifically support the livestock sectors. Most of these programs provide assistance to breeding and genetic improvements, and standardized livestock farms. For instance, for the year 2015, the government planned a CNY 1.2 billion subsidy on cattle and sheep breeding. Another CNY 3.5 billion was budgeted to support pig farm construction and renovation as well as manure treatment in key pig producing counties. This subsidy thus has the duel goal of supporting pig production and addressing the waste management issue. To support the dairy sector, since 2012 the central government has also allocated CNY 300 million per year to support the construction of high yield alfalfa demonstration areas. The standard demonstration areas are to be built at the scale of 3000 mu per unit and receive a one-time subsidy at CNY 600 per mu for a total of CNY 1.8 million per demonstration area. This subsidy is meant to mainly promote the adoption of improved seed variety and standardized production technology. Subsidies are also provided on animal epidemic preventions such as mandatory animal disease vaccination and on culling infected animals and poultry.

5.5 Policy initiatives on ensuring food safety and quality

To address widespread public concerns, food safety and quality issues have been recently elevated to the national strategic level, with implementation details announced by various government agencies. In section 2 of the most recent No. 1 document (CCCPC and State Council, 2016), a national strategy on food safety and quality is outlined with respect to chemical residues in agricultural products, standardization in farm operations, food safety regulatory system, information platform for full traceability.

More specifically, it has been decided that by 2020 limits on pesticide and veterinary medicine residues must be close to those established in the Codex Alimentarius. To reach that target, strict regulations on agricultural inputs will be enforced and the use of pesticides with high-effectiveness, low-toxicity and low-residues will be more widely adopted. Standardized agriculture, horticulture, and livestock and aquaculture demonstration areas will continue to receive support for purposes of safety and quality assurance. In connection to this, China started a campaign to establish counties of agricultural products quality and safety, with focus on counties specializing in producing vegetable products. The central government set aside funds for supporting this initiative, mainly for establishing and designing institutions and rules and for personnel training.

In recent years, the government has also sped up the pace for creating quality and safety traceability system for agricultural products, which is supposed to cover the full supply chain ranging from production to final consumption. From 2015 and onwards, the priority has been on the construction of the national traceability information platform.

5.6 Policy initiatives supporting agricultural extension and training for professional farmers

In connection with the drive to modernize the agriculture sector, the government started various initiatives to strengthen the support for agricultural extension, farmers' training and agriculture cooperatives:

- In 2015, the central government arranged CNY2.6 billion for funding the rural agricultural extension system, which covers all agricultural counties in the country. These funds were mainly used for county level extension systems, with the aim to cover all villages and relate to all rural households;
- Policy on training professional farmers: in 2015 the central government arranged CNY 1.1 billion to carry out training programs for training large specialized farmers, operators of family farmers, leaders of agricultural cooperatives, personnel from agribusinesses and agricultural service providers, as well as returning migrated workers, This policy covers 4 provinces, 20 municipalities and 500 demonstration counties;

- Policy on training practical talents in the rural areas: continuing the training programs for rural practical talents and for rural leaders with university degrees; continuing the implementation of the “million vocational school students” plan to increase the annual enrollment to more than 70,000; and organizing and implementing the "National Top Ten farmers' funded projects.

5.7 Agriculture domestic support policy and agricultural trade policy in transition and potential implications on agri-environment and sustainability

China’s agricultural domestic support and trade policy in the recent decade has been very much supportive of stimulating domestic agricultural production, especially with respect to food grains, while also targeting farm income. By restricting imports through border measures, domestic market prices have been maintained at relatively high levels, resulted in positive market price support, especially in the more recent years where domestic prices have been higher than the corresponding world market prices. Domestic subsidies paid to grain production, purchased inputs, improved seeds, and agricultural machineries have also shown to augment farm income or reduce farmers cost. The majority of existing studies suggest that such subsidies have helped raising producers’ incentives. For instance, Yu and Jensen (2010) find that these subsidies help increasing grain production and raising farm income. Meng (2012) finds that these subsidies increase the probability for farmers to stay in the rural area rather than migrating to cities, thereby increasing labor inputs in grain production. Yu *et al.* (2012) finds that these subsidies together with the abolishment of China's agricultural taxes solicited increased grain outputs. Xu *et al.* (2012) confirm that reductions of agricultural taxes (which is similar to introducing subsidies) in China helped raise farm income through increased grain production responses via increased labor inputs, increased planting areas, and/or increased intermediate input uses. The interactions of China’s trade policy and domestic support policy in maintaining producer incentives are also explored in Yu and Jensen (2014).

While these domestic subsidy programs help grain production and farm income, as some of the elements promote the use of purchased inputs, they may also lead to undesirable environmental consequences, such as those caused by the overuse of chemical fertilizers and pesticides. Moreover, as domestic subsidies and market price support programs (such as the minimum support prices) tend to focus on food grain productions as mandated by the drive to maintain high level food grain self-sufficiency, China’s agricultural production pattern is not necessarily configured in line with its agricultural comparative advantages. As the major grain products are typically intensive in land resource and some of them also rely on irrigation especially in areas where surface and underground water supply has already been stressed, the continued pursuit of food grain self-sufficiency may become more challenges vis-à-vis the sustainable use of land and water resources.

Recognizing these challenges, not only due to mounting environmental pressures and natural resource stresses, but also against the backdrop of rising rural labor costs, higher domestic

prices, and rising pressure to import more from the world markets, the most recent policy statements from the CCCPC and State Council (2016) signals a new approach to support agricultural production and farm income while at the same time addressing agri-environment and natural resource concerns. One of the key changes proposed is to turn the three types of subsidies supporting grain production (i.e. direct subsidy to grain production, subsidy on improved seed varieties, and comprehensive subsidy on purchased inputs) into one single "agricultural support and protection subsidy" which is supposed to "focus on supporting the maintenance of arable land productivity and grain production capacity", rather than promoting grain output itself. If this is indeed implemented, then the single subsidy may very well become an income transfer payment that is *neither* specifically tied to any particular input (such as fertilizers or pesticides) *nor* broadly linked to their prices.

Moreover, the same document contains two additional important messages regarding domestic and trade policy instruments on agriculture. First, China's market price support programs are to be detached from their income transfer functions. Although the minimum procurement prices for rice and wheat are to be continued, cotton from Xinjiang and soybean from the Northeast are subject to the newly established Targeted Price System, which functions more as an income transfer instrument than the previous floor price system that were backed by government stockpiling policy for cotton. For maize, proposed reform will separate maize price formation from government support so that the former will mainly rely on the market. By separating the income transfer function from the price formation mechanism, it is expected that such transfers will become less production- stimulating.

Second, on the trade front, it is explicitly mentioned that both the domestic and the international markets will be utilized, with the latter being used to supplement the former. More specifically, despite the continued pursuit of "absolute security" of food grains, international resources and markets will be utilized to help optimize domestic agricultural structure and ease the pressure on the environment and national resource. This statement can be understood as a probable relaxation of China's agricultural trade policy to the extent that products that are intensive in land and other natural resources may not necessarily have to be produced at home. This would indeed mitigate the pressure on both land and water demand and reduce the damage to the environment caused by the overuse of chemical inputs. For example, the official website of the *People's Daily* (2015) discussed in details how maintaining productive land capacity, as opposed to grain storage, can be used as an effective instrument to ensure grain security. As part of that discussion, when favorable supply situation is assured internationally, domestic crop rotation and fallow land are mentioned as new methods for avoiding high cost domestic production (and high cost storage) and for rehabilitating land and other natural resources. At the same time, the so-called arable land "red line" will be maintained and strengthened in terms of both quantity and quality to ensure more sustainable use of land resource.

Another important dimension that is emphasized in the current No. 1 document is to "exploit the leading role of various forms of appropriate scale operations". In primary agricultural production, this essentially means the consolidation of land resources to be operated by "new agricultural operation entities" such as family farms and specialized farm households, and to be assisted by "new agricultural service providers". Institutional innovations promoted by the government have already allowed land consolidations in recent years. According to Ji *et al.* (2016), there is an emerging class of middle-sized and larger-sized farms among mostly small-scaled farms in China. These larger farms are typically run by younger and better educated farmers. Huang and Ding (2015) also document similar changes in China's farm size and explore their main determinants such as institutional innovations through land transfer service centers, policy support for land consolidations, and innovated mechanization services. They also observe rising labor and land productivity in rice, wheat and maize production, with rising farm size provided that farm size is not excessive large.

According to the 2016 No. 1 document, the rationale behind recent policy development on supporting scale operations is that larger farms operated by professional farmers can better take advantage of agricultural technology, may be more rational in (reducing) the use of agricultural inputs such as fertilizer and pesticide, have easier and closer access to extension services such as the adopting of slow releasing and high effective fertilizer and pesticide, economy of scale in exploiting specialized commercial services. Additionally, government assistance in terms of tax, credits, insurance, access to land for building necessary production and processing facilities, and support in specific projects, all points to further improvement in productivities and more efficiency exploitation of inputs, and consequently less impact on the environment.

In summary, the newest development of China's agricultural policy and strategy seems to suggest a fundamental transition from the pursuit of quantity targets without regard to agri-environment and natural resources to a more nuanced and open approach based more on comparative advantages and market mechanisms. It is also possible that such an approach will be more environmentally friendly.

6. Conclusions

This background paper provides a review on China's current agricultural and agri-environmental policy in relation to sustainable agricultural development. An assessment of China's natural resource constraints and selected agri-environment indicators reveals a host of concerns on sustainable agricultural development, ranging from fast growing nutrient inputs and pesticide use, rising energy consumption, inefficient water use especially in irrigation, contaminations and pollutions to soil and water resources, to increasing ammonia and GHG emissions. If these trends continue, sustainable growth of China's agriculture would be highly uncertain, especially against the backdrop of climate change.

Although China does have a series of laws and regulations in place aiming at protecting the environment and key natural resources, their implementations in agriculture have largely relied on specific government policy that have until recently not been prioritized as compared to the drive to achieve agricultural output growth and food security targets. Moreover, recent government policies aiming at boosting outputs and ensuring food security, while largely successful in keeping up with increasing food demand due to rising population and income, may well be among the reasons behind the aforementioned concerns regarding agri-environment and sustainable development. In fact, growth of China's agriculture outputs in recent decades have been mainly driven by institutional reforms, productivity growth, intensive use of chemical inputs, and exploitation of the land and water resources. Current domestic agricultural policy and trade policy also generate incentives for maintaining this resource and input intensive model of agricultural production, thereby contributing to the observed environmental and sustainability performance.

More recently, however, it appears that the Chinese government is crafting a new approach for supporting agricultural production while addressing its environmental and sustainability performance. This paper therefore provides a detailed account of a large number of new government projects and initiatives on reducing chemical inputs and on protecting and rehabilitating land and water resources. In connection to these new programs, the government is also changing the way to support agricultural production, seemingly deviating from the long-held position on using mainly domestic natural resources to achieve food security targets to a new approach emphasizing the utilization of both domestic and international resources and the protection of agri-environment and agricultural natural resources. Several key observations can be made in this regard: first, there appears to be a strong intention to detach the income support function of agricultural subsidies and market price support programs from producers' production decisions, thereby possibly dampening the tendency to use more natural resources such as land as well as chemical inputs; second and more broadly, the new strategy towards "storing grains in land" coupled with possible relaxations towards grain imports will likely ease the pressure on land and water and allow for resource rehabilitation programs to be implemented; third, the campaign to support scale operations will likely increase farm size and support productivity growth, and may also result in environmental benefits, especially if this is successfully complemented by measures contained in the "storing grains in technology" plan.

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