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**Article**

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Cogent Economics & Finance

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*Suggested Citation:* Rehman, Abdul; Jingdong, Luan (2017) : An econometric analysis of major Chinese food crops: An empirical study, Cogent Economics & Finance, ISSN 2332-2039, Taylor & Francis, Abingdon, Vol. 5, Iss. 1, pp. 1-23,  
<https://doi.org/10.1080/23322039.2017.1323372>

This Version is available at:

<https://hdl.handle.net/10419/194674>

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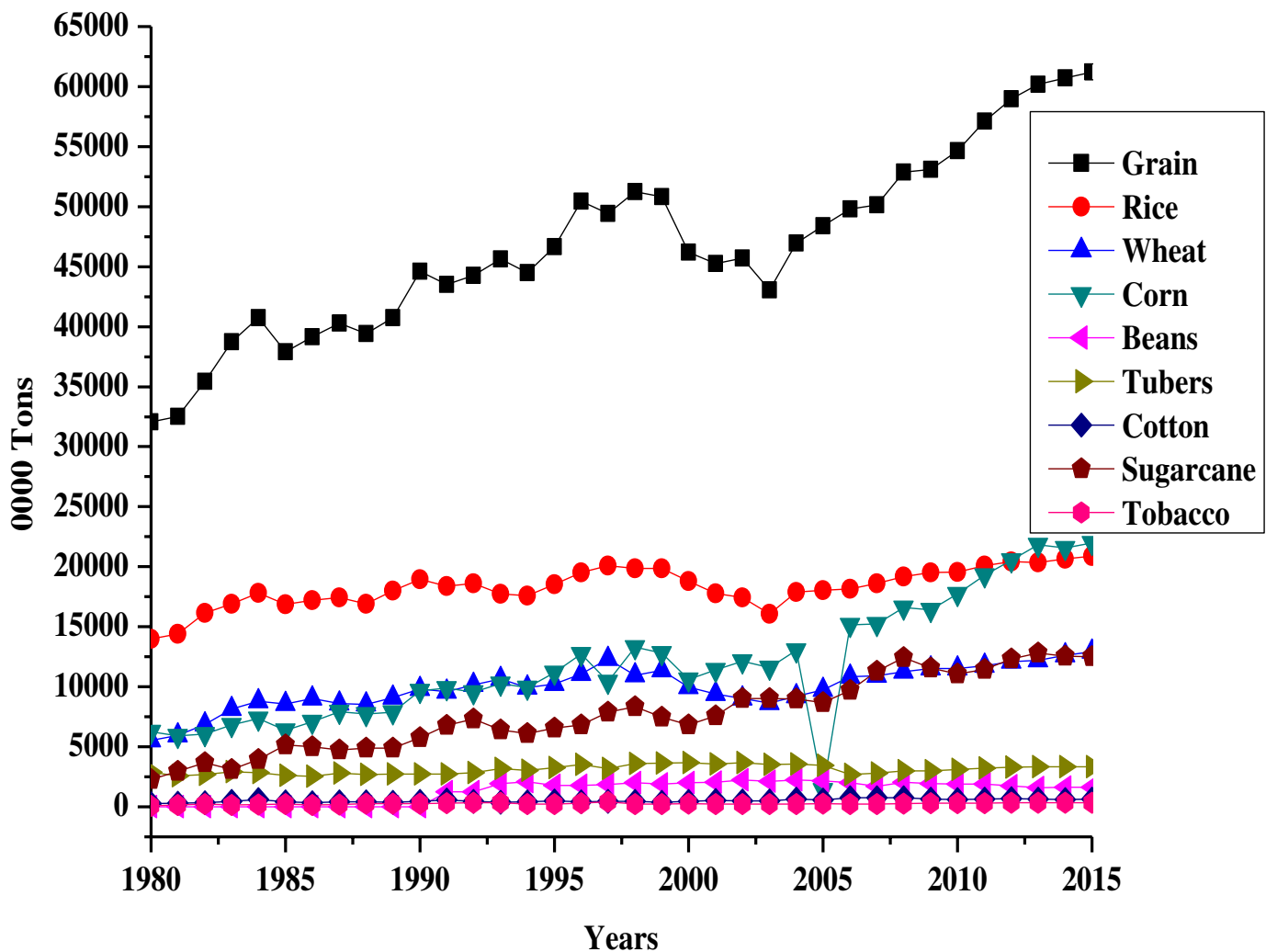
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## ECONOMETRICS | RESEARCH ARTICLE

# An econometric analysis of major Chinese food crops: An empirical study

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*Cogent Economics & Finance* (2017), 5: 1323372



Received: 14 January 2017  
Accepted: 23 April 2017  
Published: 02 May 2017

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Reviewing editor:  
Xibin Zhang, Monash University,  
Australia

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## ECONOMETRICS | RESEARCH ARTICLE

# An econometric analysis of major Chinese food crops: An empirical study

Abdul Rehman<sup>1\*</sup> and Luan Jingdong<sup>1</sup>

**Abstract:** The basic objective of this study was to investigate and explore the relationship between major food crops of China and their relationship with agricultural gross domestic product (GDP) using an econometric analysis. Agriculture is considered an important sector of the Chinese economy as it accounted for about 10% of GDP. The total agricultural land of China covers 36% of the area of the world. In order to highlight the actual performance of the agricultural production and the output of major food crops, this study explored the relationship between agricultural GDP and the major crops output including wheat, cotton, rice, sugarcane, corn, and tubers in China over the period of 35 years from 1980 to 2015. The time series data were collected from the China Bureau of Statistics, Ministry of Agriculture China and various publications. Crop data were analyzed using the Ordinary Least Square Method and Augmented Dickey Fuller test and results were interpreted using the Johansen co-integration test. Our study found that output of wheat, cotton, sugarcane, corn, and tubers has positive and significant relation with the agricultural gross domestic product of China, while the output of rice crop has a negative but no significant relation with agricultural GDP of China. The study suggests that the Government of China should start new funding schemes for the development and better production of rice crops.



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Abdul Rehman is the PhD research scholar in School of Economics and Management, Anhui Agricultural University Hefei, China. His major interests include Agricultural Economics, Agricultural Development, Applied Economics, Business Economics, Development Economics, Econometrics, Financial Economics, Financial Econometrics, Microeconomics, Macroeconomics, Regional Economics, Sustainable Agriculture, Regional Rural Development, Regional Agricultural Development. Due to his excellent work, he has been awarded with China Outstanding/Excellent International Student Award in 2016. He has good research publications in the world leading journals databases that having indexing of the Web of Science.

### PUBLIC INTEREST STATEMENT

The basic objective of this study was to investigate and explore the relationship between major food crops of China and agricultural GDP using an econometric analysis. In order to highlight the actual performance of the agricultural production and the output of major food crops, this study explored the relationship between agricultural GDP and the major crops output including wheat, cotton, rice, sugarcane, corn, and tubers in China over the period of 35 years from 1980 to 2015. Crop data were analyzed using the Ordinary Least Square (OLS) Method and Augmented Dickey Fuller (ADF) test and results were interpreted using the Johansen co-integration test. Our study found that output of wheat, cotton, sugarcane, corn, and tubers has positive and significant relation with the agricultural gross domestic product (AGDP) of China, while the output of rice crop has a negative but no significant relation with agricultural GDP of China.

**Subjects: Sustainable Development; Economics and Development; Economics**

**Keywords: food crops; agricultural GDP; irrigation; crop production; food consumption; OLS**

### 1. Introduction

China has the world's largest population and also is the largest food consumer in the world: it feeds 20% of the population of the world and consumes an average of approximately 5 million tons of food annually. At present, the total agricultural land covered is 36% of the area of the world (Xiao, Mignolet, Mari, & Benoît, 2014). In broad concept, the agricultural crops and cultivation are important to the environmental evolution and socioeconomic growth of most countries in the world (WB, 2012). On the other hand, the challenges faced by developing countries and the constraints on agricultural development and food safety and security require livelihood security and rural development. This vigorous framework requires innovative facilities and operations for its management systems and agricultural output, if it is to be contributing to socioeconomic and conservational development. From this point of view it can be said that in the next 40 years agricultural output, facilities and operations will have to increase production of agriculture by at least 70% (Kilelu, Klerkx, & Leeuwis, 2013). Agricultural output is described as an essential constituent of social and economic development in some parts of the world (Delmotte, Lopez-Ridaura, Barbier, & Wery, 2013). In particular, the availability of widely spread major agricultural crops may have a significant role for the increasing population (Abebe, Bijman, Pascucci, & Omta, 2013). Similarly, agricultural growth and output of crops is vital for staple food security, increasing or improving income, particularly in agriculture where most of the major sectors of the economy and employment (FAO, 2013). So the question next to be answered is how much agricultural crop production should be expanded to meet the growing demand for future populations (Alexandratos & Bruinsma, 2012). In order to meet these requirements, agricultural strategies and policies must improve the necessary conditions and efficiency of agricultural productivity, make opportunities and ensure sustainability through new agricultural perceptions and standards such as special agricultural crops method innovation and direction (OECD, 2013).

China's water resource per capita is only 2100 cubic meters, about a quarter of the world average (MWR, 1998–2010). The uneven spatial and temporal water resources and distribution in the Yangtze River invites serious water shortage in the North. In addition, increased competition among water sectors as a result of social and economic development has brought about a sharp increase in domestic and industrial water demand, as well as the crop-growing burden on climate and environment. The extended crop concept for water use efficiency, and the looking at water efficiency was initially encouraged by Molden (1997) and the best way to achieve efficient use of water resources to produce better crops (Rodrigues & Pereira, 2009). Agriculture productivity can quantify the amount of water used in the production sector as the output per unit of production in different land areas (Ali & Talukder, 2008). The demand for grain in China is about 600 million tons a year and it has the largest food demand in the world, and its stability of demand should greatly affect the global food market and food security (Zhang, Li, Li, & Xu, 2012). Since the food imports by China are huge, food prices in the world and food markets are steady if the supply of food is stable. Furthermore, in South and Southeast Asia, the grain production of China is also limited due to inefficient water supply. The total water resources of China are abundant, but its sequential patterns do not satisfy the food. The total water supply is enough; source and demand do not match in terms of food production. Approximately 81% of the water resources are found in the South, while 64% of the arable land is in North China (Kang, Khan, & Ma, 2009).

## 2. Current major food crop scenario in China

### 2.1. Wheat crop

China is the major producer and largest consumer of wheat, following by the United States and India. Generally, the first Green Revolution had seen a stable rise in the production of wheat due to the development that led to better shelter and disease resistance as well as the potential for a high

quality, high yield, but also through improved management practices. The wheat production in China also experienced a dramatic increase over more than sixty years since the founding of modern China in 1949, with proper practices of mature theoretical guidance and a barren land policy (FAO, 2013; Yu, 2006). In the 1970s, it was generally agreed that more fertilizers were available for encouraging wheat farming in high yielding areas, with irrigation and especially higher planting densities were used to increase the wheat production (Yu, 1987). However, with improved soil conditions and irrigation, such as soil nutrients, the increase in the production of wheat encountered serious problems, including the excessive use of seed, excessive use of awnings and vulnerable species, leading to high vulnerability to poor shelter, inefficient and light harvesting and small shoots as well as small grain and low crop yields (Yu, 1990).

Agriculture is the major sector of the Chinese economy, accounting for approximately 70% of the total water removal (MWR, 2005). To ensure the improvement of crop yields, irrigation plays a vital role (Huang, Rozelle, Huang, & Wang, 2002). The total arable land of China is about 40% and the irrigated land for production of grain is about 75%. The application of chemicals increases the food production and also helps to increase the income of farmers (Jin & Young, 2001). Water shortages will significantly affect the national food production. As the largest wheat producer and consumer in the world, the national wheat production of China may have a significant impact on world food trade (Ahmadi-Esfahani & Jensen, 1994). Due to severe drought, cereal production fell by 20 million tons of grain imports in 1995, accounting for 10% of world total grain exports (FAO, 2005a). The five most stressful factors include water, nitrogen, temperature, phosphorus, and aeration. Crop yields are calculated for each specific crop with the water stress used to adjust the harvest index (Williams, Jones, Kiniry, & Spanel, 1989). Due to the high dependence on irrigation, wheat is preferred because of its importance to China. Chinese wheat (FAO, 2005a) is the second largest crop and uses more than 70% of the total irrigation water in the Northern China Plain (Li, Inanaga, Li, & Eneji, 2005). In 1995–1999, the import of wheat accounted for nearly 40% of the total cereal imports, and the production of wheat accounts for 85% of the acreage in China (FAO, 2005a).

The irrigation's effects on the production of crop are usually quantified through the use of a crop water production function involving crop yields for a large number of water applications (English & Raja, 1996; Yaron & Bresler, 1983). Just a reasonable irrigation can significantly increase the production yield (Gajri, Gill, & Chaudhary, 1997; Huang & Sun, 2006). Hagan, Howard, and Talcoh (1967) in their study emphasize that extreme irrigation interrupts growth, harvesting, and reduces GY. Jin, Zhang, and Sun (1999) state that extreme irrigation results in reduced crop water use efficiency and that effective Water Use Efficiency (WUE) could lead to higher yields. Similarly, Olesen, Mortensen, Jørgensen, and Andersen (2000) show that the impact on irrigated wheat crop is almost entirely due to increased transpiration, and that the water use efficiency and harvest index remained unaffected. There were significant differences between soil water content and irrigation rate under different irrigation conditions, and the yield and water use efficiency were significantly different (Kang et al., 2002). Limited irrigation and soil water stress on crop yield and water use efficiency are dependent on crop growth at a particular stage of growth (Singh, Mishra, & Imtiyaz, 1991).

The grain production in China has a dynamic role in the development of the national economy and agricultural policies which assist it is an essential component. Estimations show that the agricultural sector of China supports the essential food supply to maximum nearly 20% of the world population, and it produces 15–17% of the global wheat, rice, and maize (Winters & Yusef, 2007). The main challenges for maintaining and strengthening such outputs to meet a growing demand include maintaining a crop improvement and avoiding land degradation through agricultural technology, changes in food consumption patterns, population growth, competitive demands for agricultural land, and other uses for irrigation (Gale, 2002; Zhao, Luo, Deng, & Yan, 2008). With facing these challenges, it increases the focus on climate change impacts and interactions between climate change, water resources, land use alteration, and socioeconomic development and food security (Gregory, Ingram, & Brklacich, 2005; Rosegrant & Cline, 2003). Water resources are important to agricultural production and have been a major factor in China's food production pressures, particularly in the northern

part of the country (Fischer, Tubiello, van Velthuizen, & Wiberg, 2007; Li, 2006). Irrigation for agriculture in China is the main consumer of water, being more than 70% of its total use. China's grain production is 75% from irrigated land. Thus water has had the important role of irrigation for food security and poverty alleviation in China, and even in stabilizing the importance of grain imports in the world cereal market (Jin & Young, 2001).

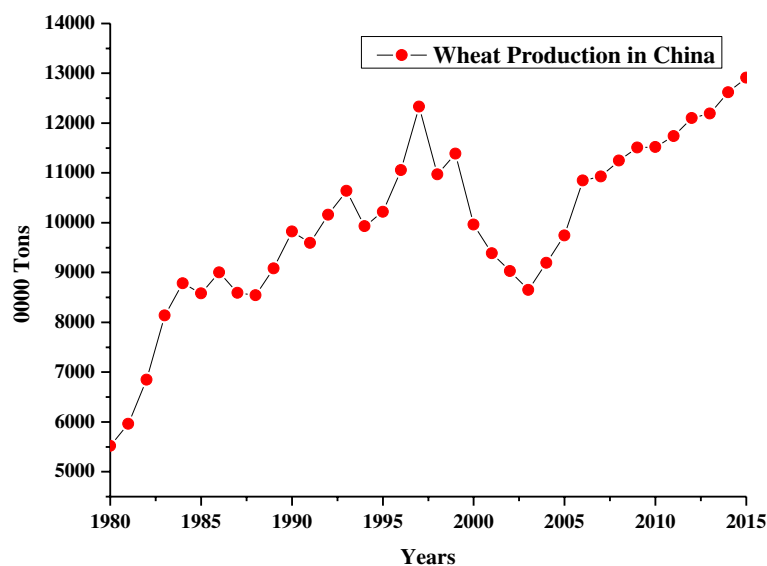
Over the past two decades, a middle-season drainage has been used as an alternative water management approach throughout China (FAO, 2004; Shen, Yang, & Pei, 1998). With conventional water management, grain paddies were maintained in a continuously flooded planting season, followed by mid-season drainage regularly or allowed to dry. Mid-season drainage or drying tends to increase the yield, also to increase the soil nitrogen mineralization and to increase the root development in plants (Lu et al., 2000; Wassmann et al., 2000). Field measurements in China indicated that mid-season drainage reduces CH<sub>4</sub> emissions, while increasing emissions without production (Cai et al., 1999; Zheng et al., 1997).

The field of research into interactions between crop production, land use and climate change, and water availability has largely been deserted recently (Betts, 2005). The driving force behind the agriculture response to climate change is its straight biophysical trappings and socioeconomic processes through its arbitration. Enlarged per capita food consumption and populations generate pressure on the land and the water resources to determine its features. Future food security scenarios predict an increased risk of scarcity in the future (Slingo, Challinor, Hoskins, & Wheeler, 2005). Recent studies have used a variety of models and climate scenarios to integrate the impacts of climate change on food production. Some comprehensive assessments have been included in water availability studies and others have identified different socioeconomic development pathways (Fischer, Shah, Tubiello, & van Velthuizen, 2005; Parry, Rosenzweig, Iglesias, Livermore, & Fischer, 2004; Rosenberg, Brown, Izaurralde, & Thomson, 2003; Rosenzweig et al., 2004). Most of the comprehensive evaluations have been made in advanced countries on the improvement of production in the agriculture sector (Holman et al., 2005). Various studies have performed regional simulation using crop models (Hansen & Jones, 2000; Irmak, Jones, & Jagtap, 2005; Moen, Kaiser, & Riha, 1994). However, for a number of developing countries, especially for larger territories, such as China, only a few studies considered detailed regional simulations; there is a lack observational experiments, geographic studies, and statistical data (Matthews & Stephens, 2002). The lack of data is often compounded by studies being limited to selected application or a small number of crop models being used at selected stations (Tao, Hayashi, Zhang, Sakamoto, & Yokozawa, 2008; Yao, Xu, Lin, Yokozawa, & Zhang, 2007). Previously hindered, crop model evaluation at a larger scale and regional stimulations in developing countries is under way (Lin et al., 2005). The planted area for wheat cultivation has improved by 1.5 million hectares during the period 2009 to 2010, but it has been constant since then. With the help of widespread irrigation, high harvests were attained, yielding development of varieties, a good supply and adequate inputs, and strong government financial support. Wheat production in 2014–2015 was recorded as being 126.0 million tons and the quality was higher than for 2013–2014. The wheat crop production from 1980–2015 is shown in Figure 1.

## 2.2. Rice crop

Rice is the main food for more than 65% of the Chinese population, accounting for about 40% of the calorie intake in China. Over the previous three decades, the farming of rice accounted for about 27–29% of the total grain production; nearly 41–45% of the area being used for rice production of the total national grain production. Since 1970, China accounted for nearly a quarter of the rice planting area of the world (State Environmental Protection Administration, 2003). Throughout, the production of rice was challenged by shortages of water, global warming, and other constraints on farmers' cultivation of this crop (Peng et al., 2004; Tao, Yokozawa, Xu, Hayashi, & Zhang, 2006). Similarly, the susceptibility of production of rice to global warming has become a major worry. Research into several crop models and climate change scenarios has simulated the impact of climate change in Asia (Hayashi & Jung, 2000; Horie, Centeno, Nakagawa, & Matsui, 1997; Kropff et al., 1993; Lin et al., 2005; Matthews, Kropff, Horie, & Bachelet, 1997; Yao et al., 2007). Although the suitability and effectiveness of the techniques presented and their uncertain results are dependent on

**Figure 1. Wheat production in China from 1980 to 2015.**



the context, the probabilistic approach is considered to be valuable for this determination (Dessai & Hulme, 2003). Recently, probabilistic techniques using multi-model integration or Monte Carlo analysis have been used to solve various climatic probabilistic problems such as unexpected precipitation events, seasonal climate predictions, and the identification of dangerous human disturbances (Hagedorn, Doblas-Reyes, & Palmer, 2005; Mastrandrea & Schneider, 2004; Palmer & Räisänen, 2002). The application of multiple model predictions can improve forecasting and greatly benefit users (Cantelaube & Terres, 2005).

Land in China has become extremely important; it has attracted a lot of interest for global food security (Mannion, 1995; Matthews et al., 1997; Kaufmann & Seto, 2001). Farming in China has a long history for about 22% of the global population, but only 7% of the world's arable land. This ratio is so excessive that any change in land use will trigger global environmental changes and affect the world food market. For example, China is the world's second largest emitter of carbon dioxide. It will surpass the United States in 2015, due to its rapid economic growth and huge dollar reserves and use of inferior grade fuels such as coal (Balzhiser, 1998; Drennen & Erickson, 1998).

Rice, maize, and wheat crops account for about 85% of the world cereal exports. In addition, several studies have shown analytical correlations with land use changes in the use of fertilizer for major food crops. According to Cheng, Han, and Taylor (1992), in Chinese agriculture, the entire sector energy usage increased from 1965 to 1988, and growth in the total expenditure was mostly due to usage and manufacture of chemical fertilizers, accounting for 83% of the aggregate energy used in 1988. Ellis and Wang (1997), reveal that a significant increase in agricultural production was due to the extensive use of fertilizers: especially the introduction of new nitrogen and rice varieties which have heavy energy inputs.

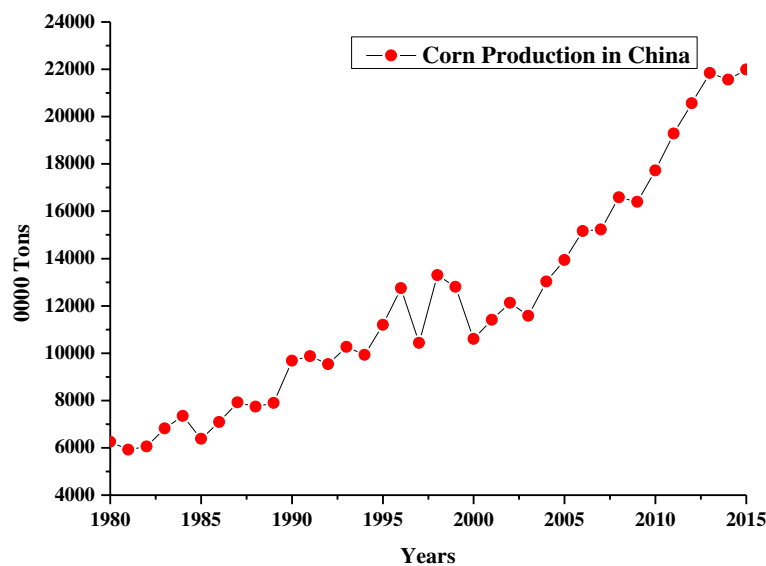
China presented the household contract concern system in 1978, which associated compensation with output, and began to dismantle the people's cooperative system, eradicating the association between economic organization and the state power establishments. The decline in cereal production and cereal crop in the region led to increased economic value to the agricultural market from the other categories of crops, particularly vegetables and cash crops, as well as to animal husbandry and fishery production. In addition, the labor force in rural areas began to move to urban areas (Gao, Liu, & Zhuang, 1998; Zhang, Wang, Li, & Cheng, 1989). Farmers wish to raise their income by buying other agricultural resources, particularly fertilizer, to increase the crop yields. In the meantime, the price of cereal crops was so flat that no farmers were ready to grow further cereal crops if they had enough food for their families.

Except for Qinghai, a rice crop is cultivated in every province of China. Several varieties of rice were grown in the Japonica variety and the rest with Indica rice varieties. The varieties of Indica rice are cultivated mostly with the Southern and Northern Japonicas crop traits. The varieties of hybrid rice account for about 50% of China's rice-growing areas (Yuan, 2003). Two to three varieties of rice crops can be planted in the southern provinces of China within a year but in the North only a single rice crop is planted. More than 95% of the rice is produced under flooded irrigation conditions (Maclean, Dawe, Hardy, & Hettel, 2002). An increase in grain production resulted from the growth of new varieties of rice in the 1950s and hybrid rice varieties in the 1970s due to improved crop management practices in irrigation and nitrogen fertilization. The yield prospect of rice increased by about 30% in the semi-dwarf varieties and increased by an extra 15–20% through the use of heterosis (Fang, Zhang, Wang, & Liao, 2004; Yuan, 2003). In 2006, the national average of rice crop per hectare was 6.27 tons per hectare as compared with the world average of 4.11 tons per hectare. However, a stagnation of rice production in China has been observed over the past decade. In 2006, the total production of rice was 9% which is lower than production in 1997, when the production of country was the highest in history (FAOSTAT, 2007). Based on the projected population growth, China is required to produce about 20% more rice to meet its domestic needs by 2030, if the per capita rice consumption remains at its current level (Cai et al., 1999).

In the past 20 years, the arable land of China has decreased by 0.25 million ha per year (Zhai, 2000). More importantly, an additional reduction of arable land occurred in fertile soils (Tong, Hall, & Wang, 2003). This reduction in arable land was mostly caused by the construction of new buildings or roads and by marginally arable land for cultivation. In competition for land, rice is frequently at a disadvantageous position with the cultivated area for cash crops. Therefore, much of the forthcoming growth in rice production must arise from superior yields on existing crop lands to avoid conservation degradation, damage to natural bionetworks, and loss of biodiversity (Cassman, 1999).

China is recognized for its scarce resources of water, less than a quarter of the world average per capita and alone for its rice production consuming about 50% of the freshwater resources (Li, 2006). Flood irrigation of rice at field level requires two to three times more water than other cereal crops such as maize and wheat (Bouman, Humphreys, Tuong, & Barker, 2007). Freshwater resources scarcity is now threatening the production of rice in China, mainly due to the freshwater resources required in the city and the industrial sector's from fierce competition for water. Drought stress is considered to be the most important limiting factor for rice production in China (Zhang, 2007). According to available estimations, the consumption of rice crop per capita declined from 78 kg per year in 1995 to 76.5 in 2009. The rice crop production from 1980 to 2015 is shown in Figure 2.

Figure 2. Rice production in China from 1980 to 2015.





### 2.3. Cotton crop

The cotton crop in China is characterized by a limited labor-intensive arable land for cultivation and the availability of a large number of agricultural laborers. In the basin of the Yellow River, intensive production systems were involved in planting, protecting, and restrained plant densities of 4.5 plants/m<sup>2</sup> with plant pruning being common in China's largest cotton-growing areas (Dong, Li, Li, Tang, & Zhang, 2005). Plant trimming mainly refers to the manual vegetative removal of sprouts in late June before the flowering, core stem tip, and fruit shoots in the middle or late July peak-fruit period. Several studies have exposed that plant pruning can mitigate over veiling and over somatic growth of cotton under insignificant plant populations (Dong, Li, Li, Tang, & Zhang, 2003). In most cotton-growing countries, cotton planting dates are being studied. Extensive studies have shown that late planting frequently results in a decreased yield and fiber performance, a reduced fruit duration, and delayed maturation relative to normal cultivation (Bange & Milroy, 2004; Davidonis, Johnson, Landivar, & Fernandez, 2004; Shastry, Sharma, & Mandloi, 2001). Similarly, Munk (2001) reported that the cotton crop partially compensated for the delayed planting by reducing the number of scattered branches and preserving high growth rates in the late season. The later sowing of cotton crops with a higher elongation of fiber resulted, also with a larger fiber extent and low micronaire (Bauer, May, & Camberato, 1998). Most of these early studies were conducted by planting densities in rows, as well as with a little focus on planting densities and sowing interactions, so it is not clear if increasing plant density would compensate for late sowing in yield and fiber quality. The frequency of cotton premature senescence increased in many cotton-growing countries. This may come from the poor ability of cotton to take up other nutrients and potassium from the surface soil at the end of the season (Brouder & Cassman, 1990), or unbalanced sources and sinks (Wright, 1999).

Cotton is an important fiber crop in the world, grown in tropical and subtropical areas in almost in all countries. The world's most important cotton producers are China, United States, India, Pakistan, and Uzbekistan. Cotton is an important economic source for many developing countries. Nearly 55 million tons of cotton seed were produced on 33.7 million hectares from 1996 to 1998. The average per-unit area yield area was 1.63 tons/ha, fluctuating from less than 0.5 ton/ha in some African countries to 5.1 tons/ha in Israel. China, the largest cotton producer, produced an average of 2.82 tons/ha.

Recognizing the negative externalities, the Chinese leadership started a number of steps to control some of the most harmful aspects of pesticide use. Plant breeders of China have successfully improved and host plant's resistance to insects and disease for thousands of varieties (Stone, 1993). In China, for almost all of the newly released varieties, there are higher levels of resistance in the host plants to disease over the past 20 years. At least in the case of rice, the usage of these species leads to a reduction in the need for pesticides (Widawsky, Rozelle, Jin, & Huang, 1998). Inappropriately, despite this success, more and more problems still exist with crop pests in China. The effectiveness of the old breed has been improved over time to ensure the increased resistance to insect pests in China and improved varieties having natural defences and through chemical pesticides (Crook, 1999). In response to cumulative insecticide resistance in the late 1980s, the Chinese research and investigation system, led by scientists in the United States, initiated the growing of crops that are genetically contrived to be resistant to imperative pests (Huang, Wang, & Zhang, 2001). In the early 1990s, greenhouse testing began. At present, the seed companies in China develop and test different varieties of corn, cotton, rice, and vegetables. The usage of pesticides dramatically increased and has proven to have extensive benefits and expenses beyond the direct influence on cotton crop resources. Current studies on pesticides in China reveal that the use of pesticides has shown that they make an important contribution to the agricultural production of major crops such as rice (Huang et al., 2000). The Official Pest Management of China estimated that pest control methods and the spraying of pesticides save millions tons of food and fiber annually from pest attrition (Ministry of Agriculture, 2000).

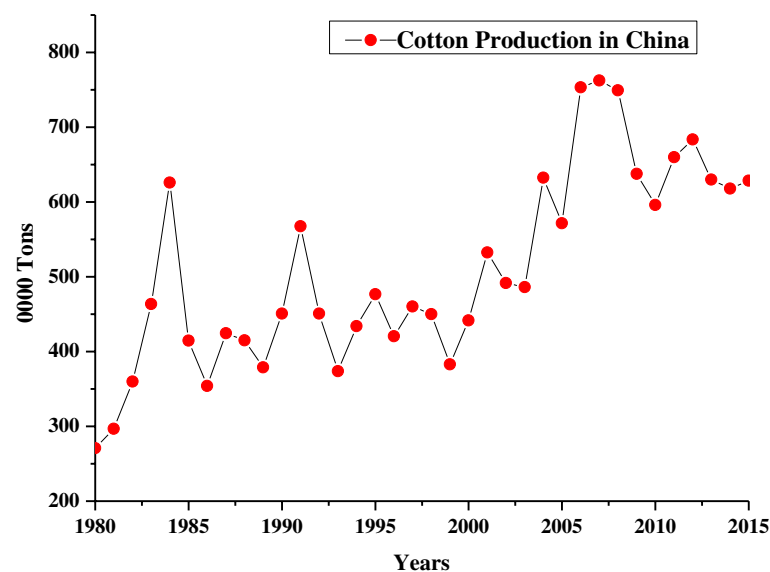
The rural economy of China is rapidly evolving. Thus, in recent years, the environment in the rural areas has undergone great changes. The costs and benefits to Chinese peasants from the transgenic cotton may also have changed. Since 2000, the government has allowed natural cotton price fluctuations and market conditions. Cotton mills are now allowed to purchase cotton directly from the growers. Government officials report that the rapid spread of Bt cotton into the major cotton-producing regions in China. An analysis of survey data shows that transgenic Bt cotton continued to increase the yield per hectare in 2000–2001, and the rate of return compared to the expected output expanded in all provinces. More importantly, the transgenic cotton farmers have increased the use of pesticides and labor, in order to reduce payment to farmers. However, the success of the transgenic cotton reduces its benefits. The yield and expanding field has begun to push up the price of cotton.

In cotton production, China is the highest producing country in the world. In China, 34 provinces out of 35 are involved in cotton production, and more than 300 million people are engaged in the cotton crop industry. In 1984, the output of the cotton crop increased progressively and become an historic high of 6.26 million metric tons. Cotton is the main input for the textile industry of the country which accounted for 80% of its use. Government estimates show that the cotton production was 7.6 million tons in 2012–2013 but it decreased in 2013–2014 to 7 million tons. The major regions for cotton production in China are the Xinjiang Autonomous Region, Yangtze River Basin, and Huang-Huai Regions. The cotton production figures from 1980 to 2015 are shown in Figure 3.

#### 2.4. Sugarcane crop

As a cereal crop, sugarcane is the main crop producing sugar and biofuels for the world (Robinson et al., 2011). Sugarcane is a high biomass crop that grows mostly in rainy environments. Water is a main determinant of sugarcane production and in most production areas, differing and sometimes severe water stress occurs. Nearly 75% of the sugarcane production is globalized and sugarcane is the most economically viable biofuel and biomass crop and for cogeneration energy production (Buckeridge, Souza, Arundale, Anderson-Teixeira, & DeLucia, 2012; Seabra & Macedo, 2011; World Sugar Statistics, 2014). Sugarcane has a relatively short breeding history compared to other major broad-acre crops. The sugarcane production worldwide has breeding programs that place a high priority on disease resistant sugarcane manufacture and sugar content. Sugarcane is the main economic crop cultivated in a wide range of environments in the tropics and subtropics (FAO, 2014; Roach, 1989). Genotype Environment (GE) interactions are important in most breeding programs in many countries where sugarcane’s yield variability can strongly influence selective breeding (Milligan, Gravois, Bischoff, & Martin, 1990; Ramburan, Zhou, & Labuschagne, 2011). Water supply is

Figure 3. Cotton production in China from 1980 to 2015.



the most important factor affecting the variability in sugarcane production (Inman-Bamber, 2007), as with many other crop species. Sugarcane sprout growth appears to be sensitive to a water deficit: for example, the threshold fraction of plant-available soil-moisture content at the plant mitigation and tip is found to be 0.92 compared with sorghum's 0.54 (Singh & Gilman, 1999). In China, like many other countries, most sugarcane plants are under rain-fed irrigation conditions and cash crops often experience prolonged water stress, especially during spring and the early summer rainfall during the rainy season (Wu et al., 2012).

However, the debate on the social impact of biofuels has become increasingly concerned with labor rights, cultural heritage, food security, working conditions, and access to modern energy products in the supply chain (Silalertruksa, Gheewala, Hünecke, & Fritsche, 2012). The current indicators for the social aspects of the related biomass system in East Asia have revealed that the human development index can be used as a national indicator (Gheewala, Bonnet, Prueksakorn, & Nilsalab, 2011; Sagisaka et al., 2011). In another study, the results of appropriate social and socioeconomic indicators were aggregated into nine areas of concern, based on geographical location and including farmers' paid wages, land rights; workers: working conditions, health and safety, discrimination; local communities: local employment, and health, safety and food security (Sawaengsak, Assavaruk, & Gheewala, 2015). It is noteworthy that sugars are natural intermediates for organic waste alteration into forested agriculture, but access to sugar is often prevented by the plant cell walls (Jiang et al., 2016). Wheat bran and cotton stalks are all full of roughage, including cellulose, lignin, and extracts (Ingram & Doran, 1995). Lignin as a matrix and stuffing material cannot be reused into reducing sugars (Sun & Cheng, 2002).

Agricultural wastes are organic wastes generated during agricultural activities. The rapid growth in the economy and population of the world causes agricultural wastage to increase each year, particularly in Asian countries, where the consequences are a big problem of how to deal with wastes. Wheat, rice, corn, and sugarcane are the four major agricultural crops in China with the largest acreage dedicated to production with the resulting mainstream of lignocellulosic agrarian wastes. Traditional approaches for treating these wastes include incineration, land-filling, and composting. Inappropriately, the capacity of landfills is inadequate and new landfill area opposes the idea of growth and development (Othman, Zainon Noor, Abba, Yusuf, & Abu Hassan, 2013). Recent studies have stated that lignocellulosic agricultural wastes and resource usage can potentially be converted to high value chemicals (Avci, Saha, Dien, Kennedy, & Cotta, 2013; Gajalakshmi & Abbasi, 2008; Saini, Saini, & Tewari, 2015). Chemical conversion and biotransformation are generally safer, friendlier to the environment, and easier to scale than oil-based processes with and stringent reaction conditions. By converting lignocellulosic agricultural wastes into a valuable platform, fermentable sugars, and chemicals such as citric acid, lactic acid, and di-nitrobenzene are used (Carvalho, Roca, & Reis, 2014; Liu, Lv, Zhang, & Deng, 2015; van Heerden & Nicol, 2013; Yadav, Chaudhari, & Kothari, 2011).

The production of sugarcane and biofuels is an important crop grown widely in tropical and subtropical regions (Rios do Amaral & Molin, 2014). Sugarcane contributes about 80% of global sugar and 35% of ethanol in the world (FAO, 2011). In general, sugarcane is an exhaustive crop, using a large amount of soil nutrients, especially nitrogen. Zende (1990) estimated that per ton of sugarcane produced the nitrogen absorbed was 0.56 to 1.20 kg. Generally, in order to maintain productivity, a large amount of nitrogen is replenished into the soil; however, the amount absorbed into sugarcane accounts for only about 20–40% of the total N supplementation (Robinson et al., 2011). Some studies have shown that intercropped legumes/cereals can induce legumes to address more atmospheric N<sub>2</sub> triggering with intercropping crops (Hauggaard-Nielsen, Ambus, & Jensen, 2003; Nasielski et al., 2015).

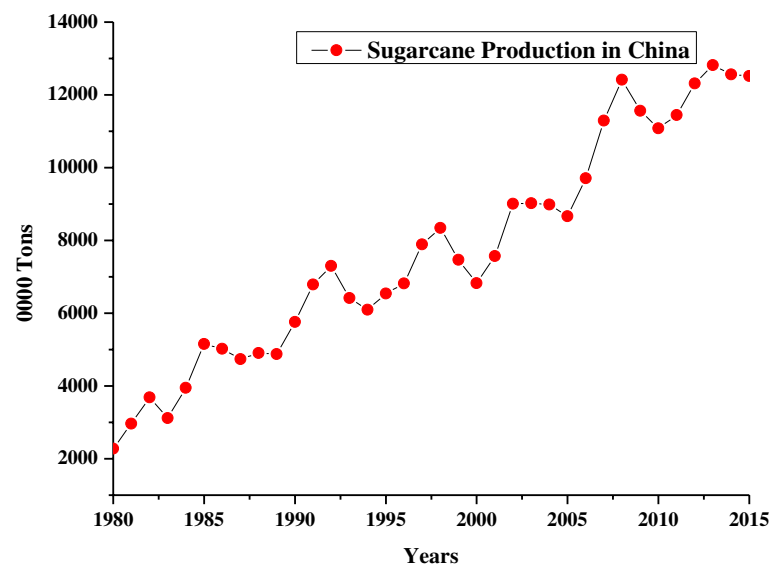
The production of sugarcane has increased. The major sugarcane producing countries are Brazil and India, with 33 and 22.4% share of the world sugarcane production, respectively. The other major sugarcane producers are China, Thailand, Pakistan, Colombia, Mexico, and Australia, which together

share 22.7% of the world sugarcane production (FAOSTAT, 2007). Sugarcane is a perennial crop and an economically viable crop, because from the same root the cane is cultivated 3–8 times each year. Through field-buried stems to build a new stock, sugarcane is a highly effective assimilator and it might be expected to produce more than 200 tons of biomass per ha under optimal theoretical conditions. However, the individual commercial extremes and marketable average yields are maintained at one half and three quarters of the optimum. While there are reports of even higher returns, their comparability is difficult to ascertain (Waclawovsky, Sato, Lembke, Moore, & Souza, 2010). Traditionally irrigation is based on furrows, but new tendencies favor drip or sprinkler irrigation. By working continuously, water is saved using drip irrigation. Consequently, its usage is economically maintainable, even if the drip irrigation hose is spoiled; with plantation burning treatment, it must be replaced after harvest (FAOSTAT, 2008). From the sugar industry, bagasse is a biomass residue and one of the richest agricultural residues in the world. The production of sugarcane is presently 1.1 billion tons per year in the world, with Brazil, India, Thailand, China, the United States, and other tropical and subtropical countries being the key producers (Canilha et al., 2012; Das, Ganesh, & Wangikar, 2004). Sometimes bagasse is composed of about 38–50% of the 22–32% of cellulose, and 17–32% of the lignin, making it which is an ideal raw material for the production of butanol (de Souza, Leite, Pattathil, Hahn, & Buckeridge, 2013). The main bottleneck to the adaptation of lignocellulosic biomass is the high cost for pre-treatment and low hydrolysis efficiency (Ding et al., 2012). According to government estimate, sugarcane production in 2004–2005 and 2013–2014 was 11.6 million tons, which is 49.8% higher than previous periods. Sugarcane makes a contribution of 90% of the total production of sugar. The production of sugarcane in 2007–2008 reached 14.8 million tons and is the major source of socioeconomic development. The normal consumption of sugarcane in China is about 7.0 million tons. The sugarcane crop production from 1980 to 2015 is shown in Figure 4.

### 2.5. Corn (maize) crop

On a global scale, corn is important as a food crop, livestock feed, and for biofuels (Edgerton, 2009; Landis, Gardiner, van der Werf, & Swinton, 2008). In China, corn accounts for about 57% of the total cereal feed consumption (Yin, 2009). As economic growth and living standards increase, more livestock consumption will lead to a higher demand for cereal feed. As a result, the future corn demand is expected to grow rapidly in China (Delgado, 2003; Wang, Zhang, & Cai, 2009). Although China has substantially increased corn production over the past three decades, the highly exhaustive corn harvesting systems have resulted in adverse ecological influences that could threaten its sustainability in the long term by reducing soil quality (Liu & Diamond, 2005). Efforts to improve corn yield with continued growth and maintaining soil quality are therefore key to ensuring future food security in China (Jin, Xu, & Huang, 2005). In 2007, about 66–68% of the maize and sown area was

Figure 4. Sugarcane production in China from 1980 to 2015.



reported for corn production in North and Northeast China, respectively (National Bureau of Statistics, China, 2008). However, the rapid increase in the production of pigs and with greater consumption of pork, maize is very scarce (Yin, 2009). In China, although intensive and continuous maize harvesting systems have created substantial soil degradation, pollution of groundwater, and substantial greenhouse gases between the main areas of maize consumption and maize production (Huang & Sun, 2006; Li et al., 2010). These adverse effects will exacerbate the production of corn in North and Northeast China and have been linked to a wide range of regional degradations (Xiong et al., 2010). In Southern China, there are 15.3 million hectares of dry land including 40% of the total cultivated land (Huang, 1995). Furthermore, climatic situations in Southern China are favorable for corn cultivation with abundant precipitation and high temperatures (Wang et al., 2009).

Due to its high agricultural production, China is rated one of the world's largest agriculture countries. Corn is one of the three main crops grown in China, producing 100 million tons of corn stalks annually (Wang, Dai, Tian, & Qin, 2007). Though there are several methods available for corn straw reuse, more than 50% of corn stalks are still unused, leading to serious safety and environmental problems due to field burning (Pang, Liu, Li, Wang, & Yuan, 2008). Developing a pragmatic approach to minimize the pollution associated with reusing corn stover has become a major challenge for the government and for local farmers. Two thirds of the Chinese people are farmers living in rural areas and it is estimated that farmers themselves will consume 60% of China's total energy consumption in 2010 (Deng & He, 2000). Corn stover is a biomass material that can be converted into a liquid or gaseous biomass such as ethanol and biogas through biomass procedures. However, the ethanol production cost from lignocellulosic feedstocks is comparatively high, based on currently available technology, and a major challenge is the small yield and high rate of the hydrolysis process (Sun & Cheng, 2002).

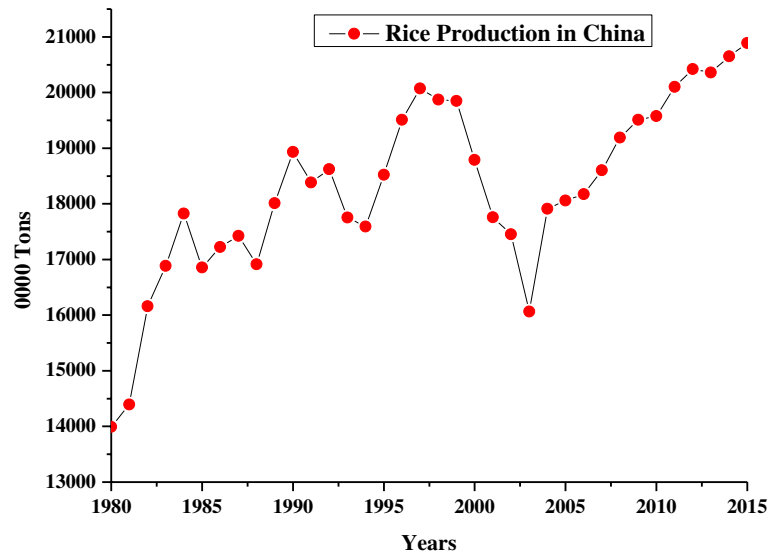
In Southern China, the soils are mainly characterized by oxidized soils and old soils, which have a low yield production and a high risk of severe weathering caused by improper use (Zhang & Xu, 2005). Therefore, improved fertilizer management, especially organic manure, can restore the productivity of crop and its sustainability via reducing soil quality degradation (Bi et al., 2009; Hao et al., 2008; Xu, Zhao, Li, Kong, & Ji, 2003). Different studies have demonstrated that fertilizer application leads to augmented soil organic content and nutrients, which improved the structure and permeability of the soil and raised soil contagious activity (Li & Zhang, 2007).

Anaerobic assimilation has been with a variety of bio solid waste streams, included agricultural wastes, industrial wastes, sludge and municipal solid wastes (Toreci, Kennedy, & Droste, 2008). This equipment is of major commercial interest for both the recycling and the treatment of biomass waste, from the perspective of environmental and bioenergy sources (Forster-Carneiro, Pérez, & Romero, 2007). However, some attempts have been made to investigate the prospect of using corn stalks as the sole raw material for biogas production. The major reason is that corn stover consists generally of lignin and polysaccharides, which form complex three-dimensional structures and have many microbes existing (Chaudhry, 2000). An anaerobic absorption pre-treatment has been shown to be a simple and effective method to enhance the biodegradability of the woody material because it can break down hemicellulose and cellulose into comparatively biodegradable products, while breaking polysaccharides and lignin. Lignin makes the hemicellulose and cellulose more susceptible to bacteria (Chen, Liu, Yang, & Li, 2005; Curreli et al., 1997; Pavlostathis & Gossett, 1985). The corn crop production from 1980 to 2015 is shown in Figure 5.

## **2.6. Tuber crop (sweet potato)**

Tubers are considered an important food crop for the world. The per capita consumption of tubers ranges from 55 kg per year in the richest countries down to 11 kg in developing countries (Fabeiro, Martín de Santa Olalla, & de Juan, 2001). In the last few years, China's potato acreage grew fast from 2.45 million hectares in 1982 to 4.42 million hectares in 1999. The annual average growth reached 11% (Agricultural Yearbook of China, 2000). In 18 years the average yield production of potatoes was 12.1 tons per ha. In Northwest China's Gansu province, the area of tuber production and cultivation

Figure 5. Corn production in China from 1980 to 2015.

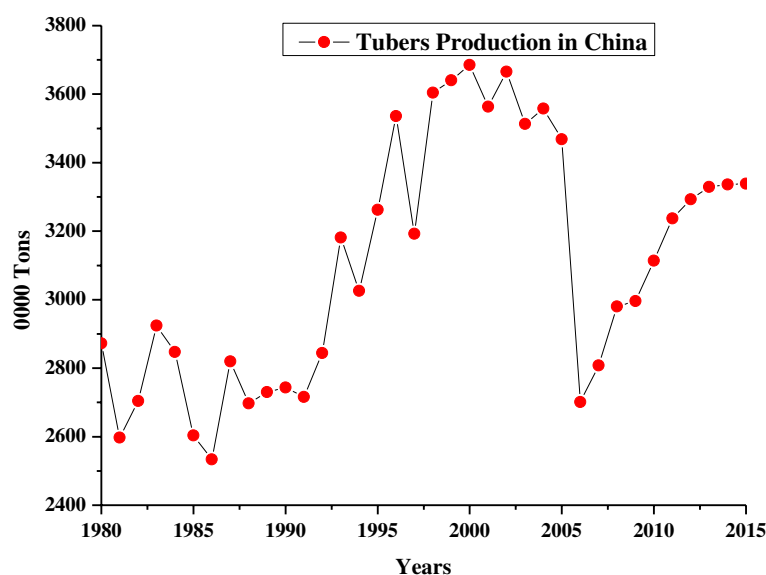


ranks third in the country. To solve domestic water problems and irrigation water shortages in semi-arid areas, rainwater and harvesting has been used for many years (Zhu, Wu, & Jin, 1994). Several methods have been used to exploit natural precipitation (Abu-Awwad, 1999; Boers, Zondervan, & Ben-Asher, 1986). Among them, a combination of ridges and furrows is a unique operating practice (Li, Gong, & Wei, 2000). In China, the traditional method of tuber cultivation in semi-arid, hilly areas of Gansu province give an output of about 12 tons per ha. In the growing season, unique cultivation practices are to use the outer layer of the tuber plant around the heap of soil. In current years, use has been made of elastic film, and film mulching as a technique of planting. In order to guarantee higher yields, new culture types such as ridge planting and hole-planting were carried out (Duan & Pu, 1999).

In China, sweet potato is the next most major essential crop after wheat, rice, soybean, and corn, and is generally used as food, for feed, as a vegetable, and also for industrial ingredients (Zhang, Wang, & Wang, 2009). Currently, China is the world's largest producer of sweet potatoes. The acreage and production reached about 106 million metric tons and 5.6 million hectares (FAO, 2004; 2005a), respectively, accounting for about 70% and 85% of the entire land area and output in the world, respectively. Sweet potatoes are extensively grown in China, from the North to the South, and from the East to the West and its wide production extent is concentrated in the basins of the Yellow River and the Yangtze River (Gao, Gong, & Zhang, 2000). The main productive areas for the sweet tubers were dependent on the cropping system used and climatic conditions (Anonymous, 1984). The major tubers production provinces of China are Sichuan, Henan, Chongqing, Anhui, Guangdong, and Shandong. In the past decade, with improvement and expansion of processing technology, several processed crops have emerged, for instance, sweet potatoes, vermicelli, table jelly, starch, chips, and organic products including ethanol. Recent research reported that the orange pulp of sweet potatoes contains a high content of b-carotene, vitamin A, and has an antioxidant activity (Komaki & Yamakawa, 2006).

In the production of tubers, China has been the world's lead since 1993 (Wang & Zhang, 2004). According to 2007 estimates, nearly 19.3 million hectares produced 326 million tons of potatoes worldwide, with an average tuber yield of 16.8 tons per ha. The relevant statistics for China are 5 million hectares area and 72 million tons production, with an average tuber yield of 14.5 tons per ha. China's trade in potato and potato products has greatly increased in the world over the past two years. Recently, China has become a major importer and exporter of frozen potato chips. In 2007, 81 million USD values of tuber products and tubers were imported and exported. The upward trend in

**Figure 6. Tuber production in China from 1980 to 2015.**



the imports and exports of tuber products and fresh tubers is expected to continue in China over the next few years (Jansky, Jin, Xie, Xie, & Spooner, 2009).

Tubers provide a substantial portion of food to the world and are also known as a vital crop source for industrial products and animal feed. Approximately 45% of the root and tuber crop production is concerned with production for food and the remainder is used for animal feed. In China, minor quantities less than 20% are used to feed livestock and the remainder is used locally as diet. The tuber crop production from 1980 to 2015 is shown in Figure 6.

### 3. Materials and methods

In order to study the relationship between the agricultural AGDP and outputs of major crops included wheat, cotton, rice, corn, sugarcane, and tubers, the annual time series data from 1980 to 2015 was used. The data was collected from the China Bureau of Statistics (Statistical Year Books) various statistical supplements, and Government Publications. The variables used in this study were: agricultural gross domestic product (AGDP) in (million RMB), output all in (0000 tons) of wheat, cotton, rice, sugarcane, corn, tubers, and cropped area.

#### 3.1. Model specification

In order to analyze the relationship between the AGDP and outputs of major crops, the following model estimated is specified as:

$$Y = AX_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} X_6^{\beta_6} X_7^{\beta_7} \tag{1}$$

Taking the natural logarithm of Equation (1) and considering seven explanatory variables, the Equation (1) converts to the following form:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + \mu \tag{2}$$

where  $\beta_0$  = Natural logarithm of A = Intercept;  $\ln Y$  = Natural logarithm of AGDP per year in (million Yuan);  $\ln X_1$  = Natural logarithm of output of Cotton in (0000, tons);  $\ln X_2$  = Natural logarithm of output of Cropped area in (0000, tons);  $\ln X_3$  = Natural logarithm of output of Corn in (0000, tons);  $\ln X_4$  = Natural logarithm of output of Rice in (0000, tons);  $\ln X_5$  = Natural logarithm of output of Sugarcane in (0000, tons);  $\ln X_6$  = Natural logarithm of output of Tubers in (0000, tons);  $\ln X_7$  = Natural logarithm of output of Wheat in (0000, tons);  $\mu$  = error term.

So, Equation (2) can also be written as;

$$\begin{aligned} \ln(\text{AGRGDP}) = & \beta_0 + \beta_1 \ln(\text{OPCOTTON}) + \beta_2 \ln(\text{CROPEDAREA}) + \beta_3 \ln(\text{OPCORN}) \\ & + \beta_4 \ln(\text{OPRICE}) + \beta_5 \ln(\text{OPSUGARCANE}) + \beta_6 \ln(\text{OPTUBERS}) \\ & + \beta_7 \ln(\text{OPWHEAT}) + \mu \end{aligned} \quad (3)$$

The present study is based on the time series data from 1980 to 2015. First of all, we checked the variable's stationarity using the Augmented Dickey Fuller (ADF) unit root test. After checking the stationary of the series, to check the long-run relationship between the dependent and independent variables, the Johansen Co-integration test was used. Finally, the Ordinary Least Square (OLS) econometric method was used to examine the impact of wheat cotton, rice, sugarcane, corn, tubers, and area output under these crops and their relationship with the agricultural GDP of China for the period 1980–2015.

### 3.2. OLS method

The OLS method's results will indicate the predictive ability of the model as well as the relative values of the parameters in the short run. To check the long-run relationship between the dependent and independent variables, the Johansen Co-integration test was used.

## 4. Results and discussion

### 4.1. Results of unit root test

The results of the ADF unit root test are presented in Table 1. The results show that all variables did not attain stationarity at their level form, whilst all variables became stationary after taking the first difference  $I(1)$ , as indicated by the values of ADF statistics test which are greater than the critical values at the 5% significance level.

### 4.2. Results of the co-integration test

For examining the co-integration based on Johansen, two tests are used such as trace statistics and the maximum eigenvalue. The presence of a co-integration shows that the AGDP, output of wheat, output of cotton, output of rice, output of sugarcane, output of corn, and output of tubers has a long-run equilibrium relationship. The results estimated by the Johansen Co-integration tests are presented in Tables 2 and 3. The values of Trace statistic (328.4223) and the values of Max-Eigen statistic (136.5310), which were greater than their critical values (159.5297) and (52.36261), indicate that there exists a long-term relationship between the dependent and independent variables. This means, the values reject the null hypothesis of no co-integration. In both tests, the Trace statistic and the Max-Eigen statistic reveal 1 co-integrating equation at the 5% level.

### 4.3. Results of regression

To examine the relationship between the output of the major crops and agricultural GDP in China, the OLS method was employed. The results of the regression analysis are reported in Table 4. From the OLS regression result, the high values of  $R^2$  are 0.874 or 87.4% and the Adjusted- $R^2$  is 0.843 or 84.3%. This implies that about 84% of total change in AGDP is explained by the independent variables. The computed value of the  $F$ -statistic was 27.94631 with a probability value of 0.000000, which shows that the overall goodness of fit of the model is significant.

An analysis of the regression results shows that the coefficient of output of wheat crop is highly significant at both the 1 and 5% of significance levels, which means that there is a strong and positive relationship between AGDP and the output of wheat. This implies that a 1% increase in the output of wheat crop showed an increase in AGDP of 5.62%. The results further show that the coefficient of output of tubers is also highly significant at both the 1 and 5% of significance levels, which indicates that it also proves a positive, and strong relationship between the outputs of tuber with AGDP. This suggests that a 1% increase in the output of tubers leads to an increase in AGDP of 5.17%. Similarly, the coefficient of output of cotton crop is also significant and has a positive relationship



**Table 1. ADF unit root test including (trend and intercept)**

Variables	At level		First difference	
	t-statistic	Critical values	t-statistic	Critical values
ln GDP	-0.863039	1% -4.284580	-3.684241**	1% -4.284580
	(0.9478)	5% -3.562882	(0.0387)	5% -3.562882
		10% -3.215267		10% -3.215267
ln OPCOTTON	-3.621234**	1% -4.243644	-6.298653*	1% -4.262735
	(0.0423)	5% -3.544284	(0.0001)	5% -3.552973
		10% -3.204699		10% -3.209642
ln OPCORN	-5.538038	1% -4.243644	-9.910920*	1% -4.252879
	(0.0003)*	5% -3.544284	(0.0000)	5% -3.548490
		10% -3.204699		10% -3.207094
ln OPRICE	-3.021694	1% -4.243644	-5.303921*	1% -4.252879
	(0.1409)	5% -3.544284	(0.0007)	5% -3.548490
		10% -3.204699		10% -3.207094
ln OPSUGARCANE	-4.790393*	1% -4.243644	-9.794996*	1% -4.262735
	(0.0025)	5% -3.544284	(0.0002)	5% -3.552973
		10% -3.204699		10% -3.209642
ln OPTUBERS	-2.273653	1% -4.243644	-6.777595*	1% -4.252879
	(0.4365)	5% -3.544284	(0.0000)	5% -3.548490
		10% -3.204699		10% -3.207094
ln OPWHEAT	-3.125710	1% -4.243644	-4.573942*	1% -4.252879
	(0.1163)	5% -3.544284	(0.0045)	5% -3.548490
		10% -3.204699		10% -3.207094
ln LANDAREA	-1.655467	1% -4.252879	-4.278114*	1% -4.252879
	(0.7489)	5% -3.548490	(0.0094)	5% -3.548490
		10% -3.207094		10% -3.207094

\*Level of significance at 1%.

\*\*Level of significance at 5%.

**Table 2. Johansen co-integration test using Trace Statistic**

Eigenvalue	Trace statistic	5% Critical value	Prob**	Hypothesized No. of CE(s)
0.981968	328.4223	159.5297	0.0000	None*
0.793591	191.8913	125.6154	0.0000	At most 1*
0.733736	138.2429	95.75366	0.0000	At most 2*
0.683398	93.25184	69.81889	0.0002	At most 3*
0.585857	54.14809	47.85613	0.0114	At most 4*
0.282078	24.17562	29.79707	0.1931	At most 5
0.250454	12.90820	15.49471	0.1182	At most 6
0.087316	3.106436	3.841466	0.0780	At most 7

Note: The Trace test indicates that the 5 co-integrating equation at the 0.05 level is appropriate.

\*Denotes rejection of the hypothesis is at the 0.05 level.

\*\*Indicates values are accurate.

**Table 3. Johansen co-integration test using Max-Eigen statistic**

Eigenvalue	Max-Eigen statistic	5% Critical value	Prob**	Hypothesized No. of CE(s)
0.981968	136.5310	52.36261	0.0000	None*
0.793591	53.64843	46.23142	0.0068	At most 1*
0.733736	44.99105	40.07757	0.0129	At most 2*
0.683398	39.10375	33.87687	0.0109	At most 3*
0.585857	29.97247	27.58434	0.0242	At most 4*
0.282078	11.26742	21.13162	0.6207	At most 5
0.250454	9.801768	14.26460	0.2253	At most 6
0.087316	3.106436	3.841466	0.0780	At most 7

Note: The Max-eigenvalue test indicates that the 5 co-integrating equation at the 0.05 level is appropriate.

\*Denotes rejection of the hypothesis is at the 0.05 level.

\*\*Indicates values are accurate.

**Table 4. Regression analysis**

Dependent variable: ln (AGDP)				
Method: least squares				
Sample: 1980–2015 Included observations: 36				
Explanatory variable	Coefficient	Std. error	t-statistic	Prob.
C	-37.50079	53.81423	-0.696856	0.4916
ln (OPWHEAT)	5.625429	2.462039	2.284866	0.0301
ln (OPRICE)	-9.346193	5.726903	-1.631980	0.1139
ln (OPCOTTON)	2.673763	0.735022	3.637665	0.0011
ln (OPSUGARCANE)	0.489134	0.653759	0.748186	0.4606
ln (OPCORN)	0.490809	0.280599	1.749148	0.0912
ln (LANDAREA)	1.136971	3.697611	0.307488	0.7607
ln (OPTUBERS)	5.179403	1.380525	3.751765	0.0008
R <sup>2</sup>	0.874790	Adjusted R <sup>2</sup>	0.843487	
F-statistic	27.94631	(F-statistic)	0.000000	
Durbin-Watson stat	0.942394			

with agricultural (AGDP). This means that a 1% increase in the output of cotton crops leads to an increase in AGDP with 2.63%. Results further show that the output of sugarcane and corn also has positive relationship with AGDP of 0.48 and 0.49%, but statistically both are insignificant. However, the output of the rice crop shows that there is a negative relationship with agricultural GDP and the result is insignificant with a coefficient of -9.34%. The output of land area shows a positive relationship with agricultural (AGDP) and it is significant with a coefficient of 1.13%. Furthermore, the results show that there is a negative relationship between the output of rice crop and agricultural GDP. This result was not expected. The reason for the negative relation was probably due to climatic conditions and the ups and downs of prices to support it.

### 5. Conclusion and recommendations

Agriculture is an important sector of the Chinese economy and it contributes nearly 10% to the GDP. This study examined the relationship between agricultural GDP and the output of major food crops namely wheat, cotton, rice, sugarcane, corn, and tubers in China over the period 1980–2015. The time series data used for this study was collated from the China Bureau of Statistics, the Ministry of Agriculture (MOA) of China, and various other publications. Crop data was analyzed using the OLS Method and the ADF test and the results were interpreted using the Johansen co-integration test.

Our study found that the output of wheat, cotton, sugarcane, corn, and tubers has positive and significant relation with the AGDP of China, while the output of the rice crop has a negative and no significant relation with agricultural GDP of China. This result was not expected, and the reason for the negative relation is probably due to climate conditions and the ups and downs of a support price. Hence, the study recommends and suggests that the Government of China should focus on and start new funding policies for the better growth, development and production of rice crops. In the next decade, China should adapt new policies to increase the yield production and become the major factor in grain production. The output of these major crops of grain, wheat, cotton, rice, sugarcane, corn, tubers, and even livestock products should witness a steady progress.

#### Acknowledgements

The authors are grateful to the School of Economics & Management, Anhui Agricultural University Hefei, China for its financial and moral support. Moreover, the authors are also indebted to the reviewers for their positive suggestions that helped to improve the content of this study.

#### Funding

The authors received no direct funding for this research.

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#### Citation information

Cite this article as: An econometric analysis of major Chinese food crops: An empirical study, Abdul Rehman & Luan Jingdong, *Cogent Economics & Finance* (2017), 5: 1323372.

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