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Future Arable Land Requirement of Pig Production in China

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Abstract

China's pig industry is experiencing a dramatic increase to meet increasing consumption demand. How these changes influence the limited arable land resources through consuming grain as feed has not been clearly understood. In this manuscript, we calculate the arable land requirement for pig industry (LRP) from 2001 to 2013 and forecast future demand towards 2050 from the point of production, in order to quantify the pressure in different scenarios. The results indicate that the LRP has increased from 22.0 Million Ha in 2001 to 31.6 Million Ha in 2013. LRP will be 23.7-29.4 Million Ha in 2030 and 11.6-18.7 Million Ha in 2050 according to different scenarios. Logarithmic Mean Divisia Index (LMDI) decomposition method is assessed to the effect of population, consumption and technology for three time periods e.g. 2010-2030; 2030-2050 and 2010-2050. And technology will become primary reason. These findings could help optimizing the relationships between limited arable land resources and development of pig industry, and promote sustainable development of the pig industry.

Keywords: arable land requirement, pig industry, food security, decomposition analysis

1. Introduction

Due to rapid urbanization, income growth, trade liberalization and expansion of western lifestyle, more livestock products are consumed by people globally (Steinfeld, Mooney, Schneider, & Neville, 2010). Arable land, where food and feed are grown, is a prerequisite for the normal functioning of the human society (Kastner, Rivas, Koch, & Nonhebel, 2012). However, arable land is scarcer due to ongoing industrialization, urbanization, infrastructural development, land degradation and desertification, globally (Gerbens-Leenes, Nonhebel, & Ivens, 2002). China, being the home for approximately 20% of the world's population but only account for 7.5% of world's arable land, is facing severe issue as well (Zhen et al., 2010; Kastner et al., 2012; Larson, 2013). Livestock products is related with arable land because of grain feed consumption (Gerbens-Leenes & Nonhebel, 2002; Elferink & Nonhebel, 2007; Kastner et al., 2012). And increasing livestock products consumption needs more feed which put more pressure on arable land (Elferink & Nonhebel, 2007; Kastner et al., 2012; Food and Agriculture Organization (FAO), 2006). And farming industrialization intensifies this circumstance (Erb, Mayer, Kastner, Sallet, & Haberl, 2012).

So far, only a few studies have estimate the arable land requirement of livestock products in China. The existing method of estimation can be classified into two types, i.e. production-based and consumption-based (Li, Zhao, & Cui, 2013). The latter is more popular, in which feed requirement is converted to grain consumption and then calculate the net arable land required to produce the equivalent amount of grain (Gerbens-Leenes et al., 2002; Kastner & Nonhebel., 2010; Zhen et al., 2010; Li et al., 2013). But there is a gap between supply and consumption caused by losses in food supply (Gerbens-Leenes, Nonhebel, & Krol, 2010). For consumption-based method, the loss needs to consider, which make the process complex and erroneous, but import and export are included. In fact, smaller proportion of import and export of meat have little effect on consumption side. Wolf, Bindraban, Luijten, and Vleeshouwers (2003) applied production method to study the future arable land area required for global food. Though this prediction method is rough (Li et al., 2013). In this paper, we explore future in this relatively simple method which could better avoid complex process. Some researches study arable land requirement of food in China, which includes whole country (Feng, Yang, & Zhang, 2008; W. M. Yang, Luan, C. Yang, & Cui, 2013), specific area (Zhen et al., 2010), driving factors (Li et al., 2013) and land requirement of nutrition (Wang, Yue, Lu, Du, & Xin, 2010; Wang et al., 2010).

In China, pork accounted 65.1% of total meat production in 2014 according to the statistics of National Bureau of Statistics of China (NBSC), i.e. the major share of livestock production. China, biggest pork production and consumption country, is experiencing losing arable land (Larson, 2013). So future LRP is related to arable land resources, food security and other major issues that is why we study in the manuscript. Meanwhile, the ruminant (cattle, goats, sheep) consume most roughage which have little effect on arable land compared with monogastric (pigs, poultry) (Erb et al., 2012). The manuscript predicts future LRP towards 2030 and 2050 based on FAO's prediction and compares different driving factors on LRP.

2. Data and Method

2.1 Data

2.1.1 Pork Production in the Past

Data are obtained from FAOSTAT.

2.1.2 Future Pork Production

Scenarios of future meat production and consumption have been provided by FAO (Alexandrtos & Bruinsma, 2012), International Food Policy Research Institute (IFPRI) (Rosegrant, Tokgoz, & Bhandary, 2013). The Agricultural Model Intercomparision and Improvement Projct (AgMIP) (Valine et al., 2014; von Lamp et al., 2014) and individual study as well (Pardey, Beddow, Hurley, Beatty, & Eidman, 2014). But only FAO provides China's pork production as a country unit which is used in this study. So in this manuscript, we adopt the prediction of FAO (Alexandratos & Bruinsma, 2012), which only provides prediction of total production in 2030 and 2050 yet. So, according to the value, growth rate are 1.54% and 0.35% in the period of 2010-2030 and 2030-2050, respectively.

2.1.3 Population

In the world, five institutions, i.e. the United Nations (UN), the United States Census Bureau (USCB), the World Bank (WB), the International Institute for Applied Systems Analysis (IIASA) and the Population Reference Bureau (PRB), undertake studying population projection (O'Neil, Balk, Brickman, & Ezra, 2001). Among these, UN's prediction is the most widely used and regular updates. That is why we select UN's population projection. And we adopt the medium variant scenario which is corresponding to production.

2.1.4 Carcass Weight Ratio (CWR)

CWR is the ratio of carcass weight and live weight of slaughter. Carcass weight is obtained from FAOSTAT. National Development and Reform Commission of China (NDRC) provides live weight in China; U.S. Department of agriculture provides live weight in America and Pig Cost of Production in Selected Countries (2003-2013) provides live weight of other countries. We consult data of American pig industry which are complete and witness the whole process during the future carcass ratio prediction. As shown in Figure 1, the carcass ratio in China exhibited a downward trend from 2001 to 2012. As shown in Figure 2, America firstly experienced a slightly decline with fluctuations, and reached the lowest point at nearly 0.55. Then it rose considerably to 0.7. After that, it went up slightly to 0.75. We applied the variation trend of USA to China in this manuscript. Shortened feeding time and decreased fat result in a decrease of the carcass ratio. Simultaneously, additional changes of foreign pig breeds, hybrid pigs and farming methods could also lead to the decrease in carcass ratio. But advanced feed, genetic and breeding technology will eventually lead to the development of carcass ratios in the future. So about change rate of future carcass ratio, we divide it into 3 periods which is displayed in Table 1. The first period will follow the previous decrease trend until to 0.55, and then we suppose the increase rate of period 2 equal to the rate of American rapid growth period. When carcass rate reaches to 0.7, the growth rate will drop slowly. And future carcass ratio in China is displayed in Figure 2.

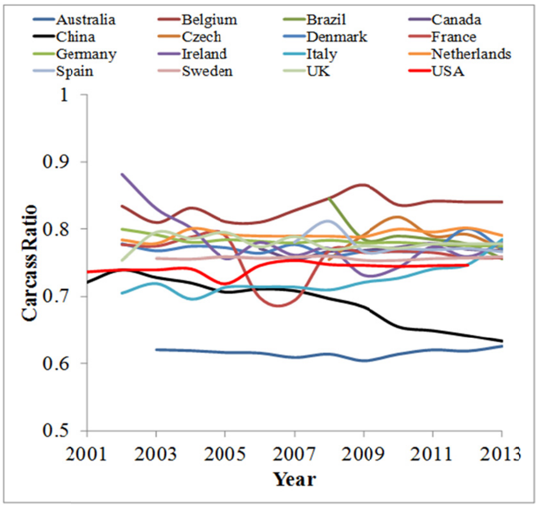

Figure 1. Change of carcass ratio

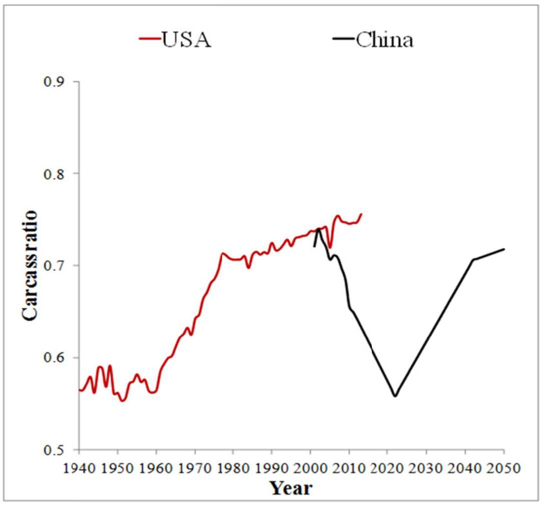

Figure 2. Carcass ratio of USA in the past and China in the future

Table 1. Change of carcass ratio in 3 periods

Period	Trend	Rate
1	Decrease	-0.008 4
2	Increase	0.007 4
3	Increase	0.001 5

2.1.5 Feed Conversion Efficiency (FCE)

FCE in other countries are obtained from Pig Cost of Production in Selected Countries (2003-2013). As for FCE in China, we calculate it according to the following formula:

$$FCE = \sum \frac{(Ci + Ri)}{Wi} \times Pi \quad (1)$$

Ci is concentrate feed consumption in type i farming; *Ri* stands for roughage consumption in type i farming; *Wi* represents live weight of slaughter in type i farming; *Pi* means the proportion of type i farming. And all of these data are provided by NDRC. From Figure 3, benefiting from arming industrialization with more roughage was replaced by concentrated feed, FCE experienced obvious progress from 2001 to 2012. In this manuscript, we consult the development of other advanced countries in pig industry. And we use the average progress i.e. 0.011 of these countries whose FCE is lower than 3.00 as future growth rate of China. As 2.60 is the lowest FCE of these countries, we assume 2.60 is the threshold value of China. When FCE reaches 2.60, it will remain stable.

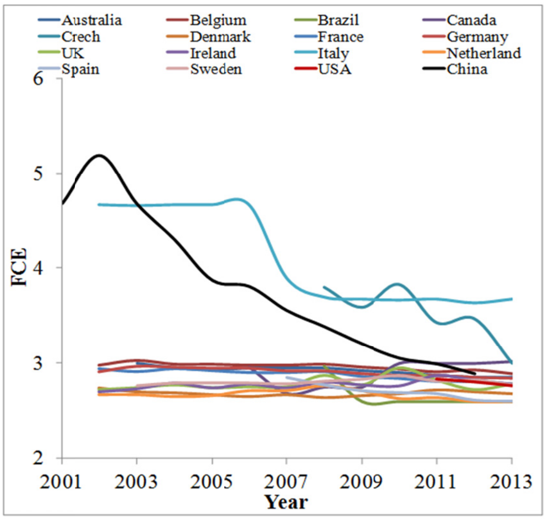

Figure 3. The change of FCE

2.1.6 The Grain Proportion in Feed

As shown in Figure 3, FCE experienced a dramatic progress in 2001-2012. More grain consumed along with the rapid application of concentrate feed. So we build the regression of grain proportion in feed on FCE, which is in Figure 4. As maize and soybeans have become the most important part of feed according to the FAO statistics, other ingredients could be ignored when compared with the above two. Therefore, we suppose feed is made of maize and soybeans which are the sole source of energy and amino acid and high in digestible energy concentration (National Research Council [NRC], 2012; U.S. Pork Center of Excellence, 2010). About the proportion of maize and soybeans, we calculate it according to the typical maize-soybean meal based diet, which the proportion of maize and soybeans is 74.44% and 23.32% respectively (U.S. Pork Center of Excellence, 2010). So the proportion of maize and soybeans are 76.15% and 23.85%, respectively.

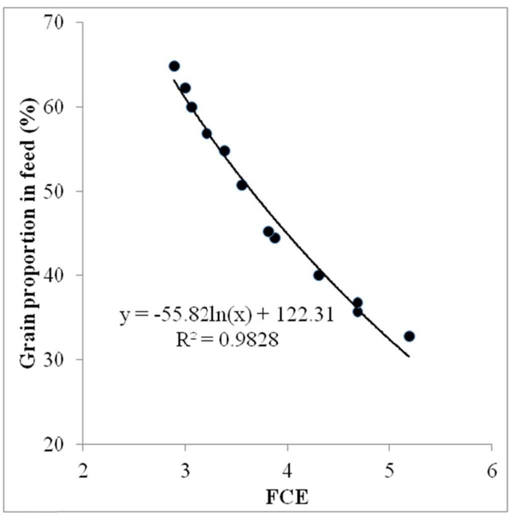

Figure 4. The regression of grain proportion in feed on FCE

2.1.7 Future Yield of Maize and Soybean in China

In this manuscript, we assume feed ingredients are supplied by China's arable land in order to reflect influence of arable land by pig industry and design 3 scenarios for future growth rate of maize and soybeans according to the previous change of world, China and America in order to stand for the development rule of world, developing countries and developed countries. Yield of maize and soybeans are obtained from FAOSTAT and growth rates in different scenarios are in Table 2. Figure 5 shows the yield of maize and soybeans in different scenarios.

Table 2. Scenarios about yield growth rate of maize and soybeans

Type	Scenario	Growth rate (%)	
		Maize	Maize
1	World average increase in the past	1.98	1.49
2	China average increase in the past	3.11	1.97
3	America average increase in the past	1.78	1.03

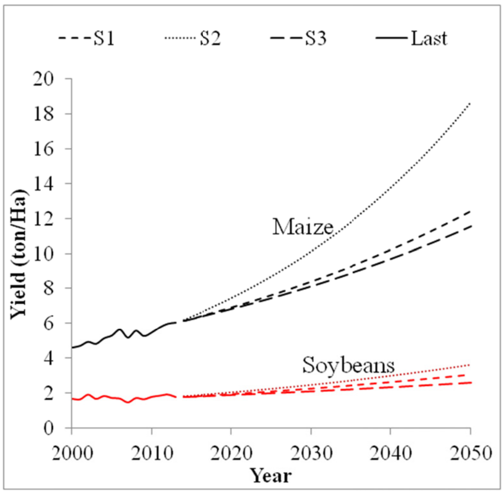

Figure 5. The yield of maize and soybeans in different scenarios

2.2 Methods

2.2.1 LRP in the Future

$$L_t = \frac{(P_t / CWR) \times FCE_t \times R}{Y_{m,t} \times P_m + Y_{s,t} \times P_s} \tag{2}$$

L_t is LRP in period of t; P_t (kg) stands for production of pork in period of t; FCE_t (kg/kg) represents Feed conversion efficiency in period of t; R (kg/kg) means the ratio of grain in feed; P_t (%) and P_s (%) are the proportion of maize and soybeans in feed, respectively; $Y_{m,t}$ (kg/m^2) and $Y_{s,t}$ (kg/m^2) stand for the yield of maize and soybeans in period of t.

2.2.2 Contributions of Different Factors to Grain Consumption

The amount of arable land required depends on population, average food consumption patterns and technology (Kastner et al., 2012). When analyzing the contribution factors on LRP, we summarize these 3 factors, i.e. population, consumption and technology. In this manuscript, per capita pork production is used to stand for per capita consumption as we study LRP from the point of production. As containing waste from production to consumption, per capita consumption is more suitable than per capita production. LMDI decomposition method (Ang, 2005) is assessed to calculate these three contributions for three time periods, i.e. 2010-2030, 2030-2050 and 2010-2050. Based on the following formula of LRP, LMDI method was used to decompose.

$$T = P \times C \times S \tag{3}$$

T (kg) is total production in pig industry; P (capita) represents population; C (kg/capita) means per capita pork consumption; S (m^2/kg) stands for technology effects. And LMDI method is used to analyze different factors

(Ang, 2005).

Population effects:

$$\Delta P=\ln\left(\frac{P_1}{P_2}\right)\times\left(\frac{T_1-T_2}{\ln(T_1)-\ln(T_2)}\right) \tag{4}$$

Consumption effects：

$$\Delta C=\ln\left(\frac{C_1}{C_2}\right)\times\left(\frac{T_1-T_2}{\ln(T_1)-\ln(T_2)}\right) \tag{5}$$

Technology effects：

$$\Delta W=\ln\left(\frac{S_1}{S_2}\right)\times\left(\frac{T_1-T_2}{\ln(T_1)-\ln(T_2)}\right) \tag{6}$$

T_1 and T_2 mean period 1 and 2. P_1, C_1 and S_1 represent population (capita), consumption (kg/capita) and technology (m^2/kg) in T_1 period, respectively. P_2, C_2 and S_2 stand for population (capita), consumption (kg/capita) and technology (m^2/kg) in T_2 period, respectively.

3. Results

3.1 Future LRP

Based on the above analysis, LRP of 3 scenarios is calculated which is shown in Figure 6. Past LRP grew rapidly from 22 Million Ha in 2001 to 31.61 Million Ha in 2013. After 2013, 3 scenarios have different performances. LRP will increase rapidly in scenario 1 and scenario 3, reaching the peak of 33.4 Million Ha and 34.0 Million Ha in 2021, respectively. Both scenarios will witness a fast decline, arriving at 17.2 Million Ha and 18.7 Million Ha in 2050. On the contrary, scenario 2 will see a slight decrease in the early part, and then a rapid decline, reaching 11.6 Million Ha in 2050. According to land survey report by Ministry of Land and Resources of China in 2009, there was 135.39 Million Ha of arable land in China. So, the peak LRP in scenario 1 and scenario 3 equal to 24.7% and 25.1% of total arable land, respectively. Therefore, arable land resource still face serious strain from grain feed of pig industry before 2030. After 2030, benefit the advance of technology, population decrease and slight increase of pork consumption, the threat of pig industry will fall.

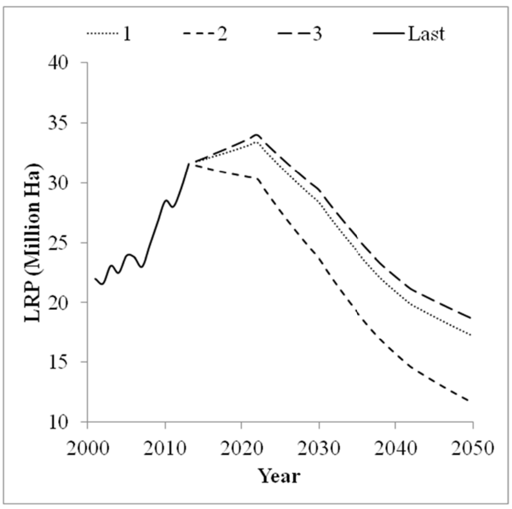

Figure 6. Future LRP in 3 scenarios

3.2 Contributions of Different Factors to Grain Consumption

Table 3 shows the added effects of population change (△P), consumption change (△C), and technological growth (△S) on LRP according to LMDI decomposition method in three time periods (2010-2030, 2030-2050, 2010-2050). All of these scenarios, technology plays a mojor role, and then comes consumption. That is why future LRP will decrease. During the period of 2010-2030, the technology improvements are sufficient to compensate for increase in population and consumption in scenario 1 and 2, which is contrary to scenario 3. Comparing the first half of study period, technological improvements are sufficient to mitigate increasing LRP during the 2030-2050 in all 3 scenarios and the contribution of population and consumption decline.

Table 3. Additive decomposition according to contributions of changes in population, consumption, technology to over changes in LRP

Item	S1				S2				S3			
	∆P	∆C	∆S	∆T	∆P	∆C	∆S	∆T	∆P	∆C	∆S	∆T
2010-2030	1.9	7.8	-9.8	-0.1	1.7	7.2	-13.7	-4.8	1.9	8.0	-9.0	0.9
2030-2050	-1.1	2.6	-12.7	-11.1	-0.8	2.0	-13.3	-12.1	-1.1	2.8	-12.4	-10.8
2010-2050	0.4	8.8	-20.5	-11.3	0.3	7.4	-24.6	-16.9	0.4	9.1	-19.4	-9.8

Note. Unit: Million Ha.

4. Discussion

Our results show that 31.61 Million Ha of total arable land has been used to feed pigs in China in 2013. And arable land resource still face serious strain from grain feed of pig industry before 2030. After 2030, the threat of pig industry will fall. If other livestock products are included, the percentage share will be much higher. Feed compete with grain for food, which threatens food security in China. As China has limited arable land and is facing a variety of pressures (Khan, Hanjra, & Mu, 2009; Larson, 2013), increasing livestock products is a serious threat. For the sake of food security, some scientists appeal to decrease livestock products consumption (Ilea, 2009; Eshel & Martin, 2006). In fact, livestock products contribute significantly to reduce poverty, enhance nutrition and support crops planting in smallholder systems (Thornton, 2010). Increasing number of ruminants (cattle, sheep and goat) which consume large roughage is a good way, especially for little ruminants' consumption and affluent roughage in China. On the other hand, increasing yields and density of higher crops is another way (FAO, 2013).

There are limitations about our prediction and should be improved in future studies for a more accurate estimation. Firstly, we only take two main constituents of feed materials, i.e. maize and soybeans into account when analyze feed composition. In fact, many kinds of raw materials are used to feed, such as wheat and rice which have different yield and growth. When predict future yield, we suppose growth is fixed in scenarios and the growths are estimated on the basis of preceding regular pattern. But statistics of TAOSTAT indicate a significant decline in yield increase in recent years when compared with previous years.

5. Conclusions

China is experiencing rapid increase of meat consumption due to income growth and urbanization and facing strained arable land resources. In this manuscript, we calculate past LRP and forecast future LRP to evaluate arable land pressure from pork consumption. LRP has increased from 22.0 Million Ha in 2001 to 31.6 Million Ha in 2013. In addition, future LRP in 2030 is during 23.7-29.4 Million Ha and 11.6-18.7 Million Ha in 2050 according to different scenarios, respectively. This means future arable land will still face serious pressure from pork consumption before 2030 given the possible increase of productivity. Chinese government should pay more attention to balance the relationship of meat consumption, grain production and arable land resources. This study illustrates the relationship between pig meat production and arable land requirement. These findings could help optimizing the relationships between limited arable land resources and development of pig industry, and promote sustainable development of the pig industry.

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