Long-term Projections of China's Supply and Demand of Animal Feedstuffs

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China, with one-fifth of the world's population and rapidly rising incomes, is a country which has naturally been open to speculation about its ability to feed itself over the next several decades. Population will grow from 1.26 billion in 2000 to 1.40 billion in 2015 and 1.45 billion in 2030. Simultaneously, per capita income growth will lead to greater demand for meat, thus resulting in larger feed requirements for animals.

The objective of the research reported on in this paper was to determine the extent to which ***technically*** China will be able to maintain its current level of being essentially self-sufficient in animal feedstuffs and animal products.

This paper is divided into six main parts; overall results, model and methods, animal feedstuffs requirements projections, feedstuffs availabilities and crop projections, problems and prospects, and conclusions. The method used is to calculate all requirements and availabilities on the basis of metabolizable energy (ME) and crude protein (CP).

Overall Results

The conclusion is that ***technically*** China can maintain its current level of essentially being self-sufficient in animal products, and that it can meet its feedstuffs requirements with little or no additional imports. It can be expected that there will be years in which imports will likely be needed and other years in which there will be surpluses due to climatic problems and other factors.

Table 1 shows that ME availabilities of 1.93 trillion Mcal were 14 percent more than requirements for the base period 1996-98. This is a small difference considering the need to take into account all animals, trade and crop production. There are some animals unaccounted for (such as yaks and rabbits) as well as fish (discussed later). Furthermore

Table 1. Metabolizable energy and crude protein requirements and availabilities, China, 1996-98-2030 no change in trade from current levels

SPECIES	AVG 1996-98	2005	2015	2030
		Economy Robust		
		Metabolizable energy		
	Million Mcal			
Requirements	1,675,455	1,955,319	2,386,067	2,509,178
Availabilities	1,937,266	2,120,796	2,321,199	2,654,411
Availabilities over requirements	261,811	165,477	-64,869	145,233
	Percent			
Availabilities over requirements	14	8	-3	5
Increase over Avg 1996-98				
Requirements	--	17	42	50
Availabilities	--	9	20	37
		Crude protein		
	1,000 MT			
Requirements	71,891	79,714	87,619	94,512
Availabilities	71,654	78,525	86,701	100,285
Availabilities over requirements	-237	-1,189	-918	5,773
	Percent			
Requirements over availibilities	0	-2	-1	6
Increase over Avg 1996-98				
Requirements	--	11	22	31
Availabilities	--	10	21	40

some feedstuffs sources such as roadside grazing, garbage, non-specified forages, water plants, etc. are also not included in computations.

No attempt was made to balance requirements and availabilities. Rather, best judgments of the authors and those of experts on China in each field were used. The small absolute size of the difference between requirements and availabilities is gratifying, and attests to the robustness of the model. More important is that the differences in the projection years are reasonable. There will be rapid growth in meat consumption, which could lead to possible need for either feedstuffs or meat imports by 2015. However, the projection for 2030 is that availabilities will be 5 percent larger than requirements. These results include conservative changes in technical parameters of animal and crop production, but assume that imports and exports continue at base year current levels.

Crude protein requirements just equal availabilities in the base year, but are slightly greater than availabilities in the early years. The important point, again, is not the absolute size of the difference between the requirements and availabilities but rather the relation between years.

Model and Methods

This section is divided into two parts, animal requirements, and feedstuffs availabilities. One possible method for long-term projections to determine whether China can meet demand for animal products, in addition to fish and other human food requirements, is to extrapolate past trends in animal inventory and production. But, this approach does not capture human population dynamics, or technological development and adoption. Another possibility is to use an econometric model, such as the FAO World Food Model, the USDA model, the World Bank model or the IFPRI model. However, models of this nature are quite cumbersome to use, are restricted in use by the organizations, and some only project out 10 years or so. They are basically global and trade oriented rather than being specifically designed to analyze the impact of technological change and adoption in one country. Furthermore, econometric models are primarily based on price, a variable that loses meaning after a few years.

A major problem with models about China is that they are quite simplistic from a technical viewpoint. On the animal side constant feed/meat conversion ratios are the main variable used thus obviating the importance of technology development and adoption, and structural change. In general, maize is used as the energy source and soybeans as the protein source. This works well for the United States, but does not at all capture the considerable role played by by-product feeds and other feedstuffs. On the crop side, there is no detailing of reasons for yield growth rates. Rather, past tendencies are the norm. This can easily lead to erroneous results and misleading ideas about potential trade.

The model from which results reported on in this paper are derived is an attempt to supplement and complement other modeling efforts. It is especially developed for long-term projections of animal inventories and feedstuffs requirements. Simpson originally built it in the early 1990s, with the technical assistance of Cheng Xu of China Agriculture University. Simpson, Cheng and Miyazaki provided results in detailed form in a 1994 book. The program is a non-deterministic simulation spreadsheet programmed model originally done in Lotus 123. It was updated to a Microsoft Windows Excel application, with extensive revisions, during 2000. The model is very complicated and requires in-depth understanding of animal and crop science in addition to an extensive knowledge of Chinese agriculture. Furthermore, the program is very large with more than 5,000 lines of spreadsheet program, 800 variables and more than 2,200 parameters.

The original model was determined to be quite robust and, in fact, the original projections for 2000 using 1989-91 as the base period are quite close to the current situation. The original longer-term projections of requirements are similar to those presented in this paper. Comparison with the earlier results reinforces the conclusion that ***technically*** China can maintain its current degree of animal feedstuffs availabilities and animal product self-sufficiency.

The source of published data is FAO's on-line DATA STATS service rather than directly from Chinese publications because FAO, in line with its international data standards, has much greater availability of statistics. In any event, all FAO data are from official Chinese sources and comparison of that data with FAO shows no significant difference. The base period is 1996-98, as January of 1997 is when China's first agricultural census was carried out. Thus, the significant adjustments made to animal inventories and crop based parameters are incorporated in the current results presented in this paper.

Animal Side of the Model

The animal side of the model has about 2,000 lines in the spreadsheet, 250 variables and 700 parameters. The approach is basically a two-step procedure; determine animal inventories, and then the ME and CP requirements for them. The first step for inventory projections driven by demand for livestock products (such as poultry or pigs) was to exogenously develop per capita production projections of all livestock products (Figure 1). Per capita production rather than consumption was used because the objective was to project livestock inventory, from which ME and CP requirements were then derived. It was recognized that changes in trade flows for livestock products could affect per capita projections. However, this aspect was not considered to be a significant problem on the animal side in China, even to the year 2030, because trade in meat, milk and eggs is a very small proportion of total production. Thus, with the exception of imported powder based cow milk, per capita production is essentially equivalent to per capita consumption.

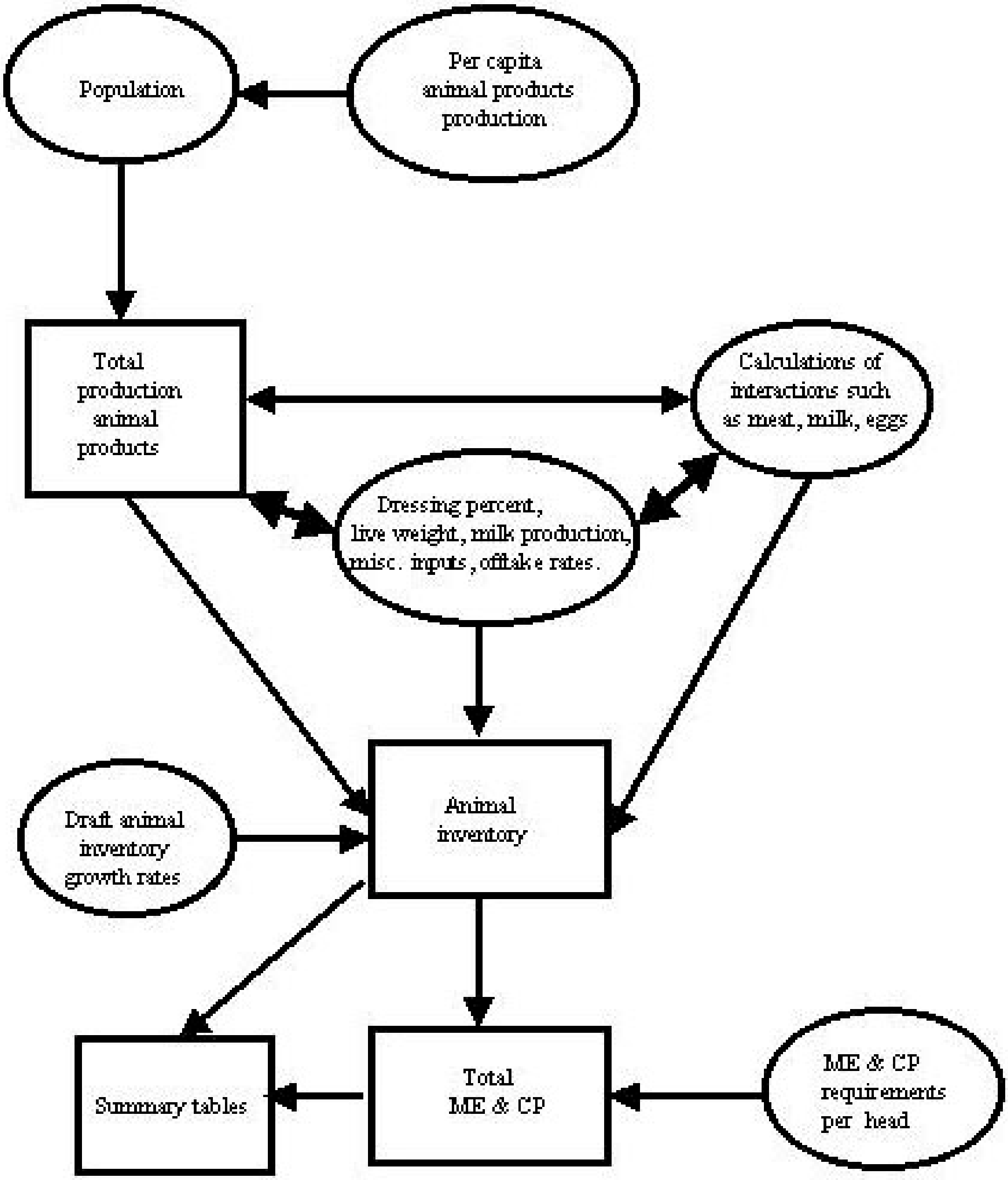

Figure 1. Model structure for inventory and feedstuffs requirement projections

Most of the major inventory parameters, such as carcass weight, offtake rates, slaughter, and some of the more detailed information such as specific types of poultry are available from FAO’s DATA STATS. Other parameters, like proportion of inventory in backyard versus commercial operations, which are not published in official statistics, were ascertained by discussions with specialists, through publications of other authors (c.f. Fang, et. al. 2000) and personal survey data collection (e.g. Simpson, et. al., 2000).

Evaluation of the validation process for the base year indicates little reason for concern about misspecification of the parameters primarily because the model is used for projections, and parameter misspecifications are just carried through. If, for example, 40 percent of one species' inventory really were in a backyard system rather than the 50 percent specified, that error would be carried through the whole projection process even though the proportion between systems changes. It would be true that the structure would be misspecified, but the *changes* in inventories and feed requirements, which are the important aspect, would not affected to any degree. In any event, there is very little impact on the total feedstuffs requirement projections from any misspecification of parameters in the validation process. The intuitive terms, "backyard" and "commercial" were defined by the parameters assigned to each one.

Cattle used for draft are technically work type animals, such as mules. But, since beef was delineated as a demand driven variable, draft/beef cattle inventory was determined as described above despite some proportion of cattle mainly being work animals. A model of inventory by ages is included in the program (not shown in this paper) to better understand the dynamics of structural changes. Buffalo were grouped with cattle due to its meat widely eaten.

The poultry projection portion of the model separates egg-producing chickens from ones primarily raised for meat (broilers), and then separates each category by commercial and backyard. Other kinds of poultry, such a ducks and geese, are calculated separately. Pig projections are based on inputting backyard versus commercial inventory percentages and then projecting the proportions.

Work animals include asses, camels, horses, mules and buffalo. Inventory projections of these supply-oriented animals were made by first evaluating growth rates in three historical periods, and second by estimating the future impact from mechanization. Critical factors considered were urbanization and the pace of economic development. The parameters for the historical analyses were drawn from statistical data for the years 1979-81 through 1996-98.

Crop Projections and Feedstuffs Availabilities Side of the Model

The feedstuffs availabilities side occupies 3,200 spreadsheet lines, has 800 variables and 1,500 parameters. Calculations, again with the objective being determination of total ME and CP, required numerous steps (Figure 2). The first was to input ME and CP for each feedstuff and components of each feedstuff such as grain, straw, fodder, meals (cake), spent brewers grains, bran, treated product (such as ammoniated straw), etc., as well as grasslands. These unit values were multiplied by the extraction rates of each source by production (adjusted for imports and exports) of raw and processed commodities, to arrive at total potential ME and CP. The proportion available to animals (i.e. apart from that for humans, losses and other products) was then multiplied by total potential availabilities to arrive at actual total availabilities of ME and CP for animals.

Nine crops (termed "major") have detailed breakdowns on yield growth rates while the remainder (termed "minor") has no detailed explanation of growth rates. Crop yields were multiplied by sown (harvested) area to arrive at total production.

Crop yields and sown (harvested) area are inextricably bound together. A misspecification of one directly affects the other. Revision of sown area by crop was one of the major outcomes expected from the 1997 census. Unfortunately, there were serious problems with that aspect and thus un-revised numbers continue to be reported. The magnitude of this problem can be appreciated by understanding that cultivated area was revised upward from 95 million hectares to 130 million hectares. There should have also been a very large increase in sown area accompanied by a major decrease in published crop yields. But, this did not happen. The problem was then how to adjust yields and reconcile them with sown and cultivated areas.

The revision upward of 35 million cultivated hectares is now nationally and internationally accepted (Zhu, 2000). The multiple crop ratio of 156.9 for 1996-98 is also accepted, as are production figures. Consequently, Zhu Xiangdong, Director General of the

Rural Survey Office in the National Bureau of Statistics, reported at the final seminar on the census (2000) that yields based on published sown areas should be reduced by 20 percent.

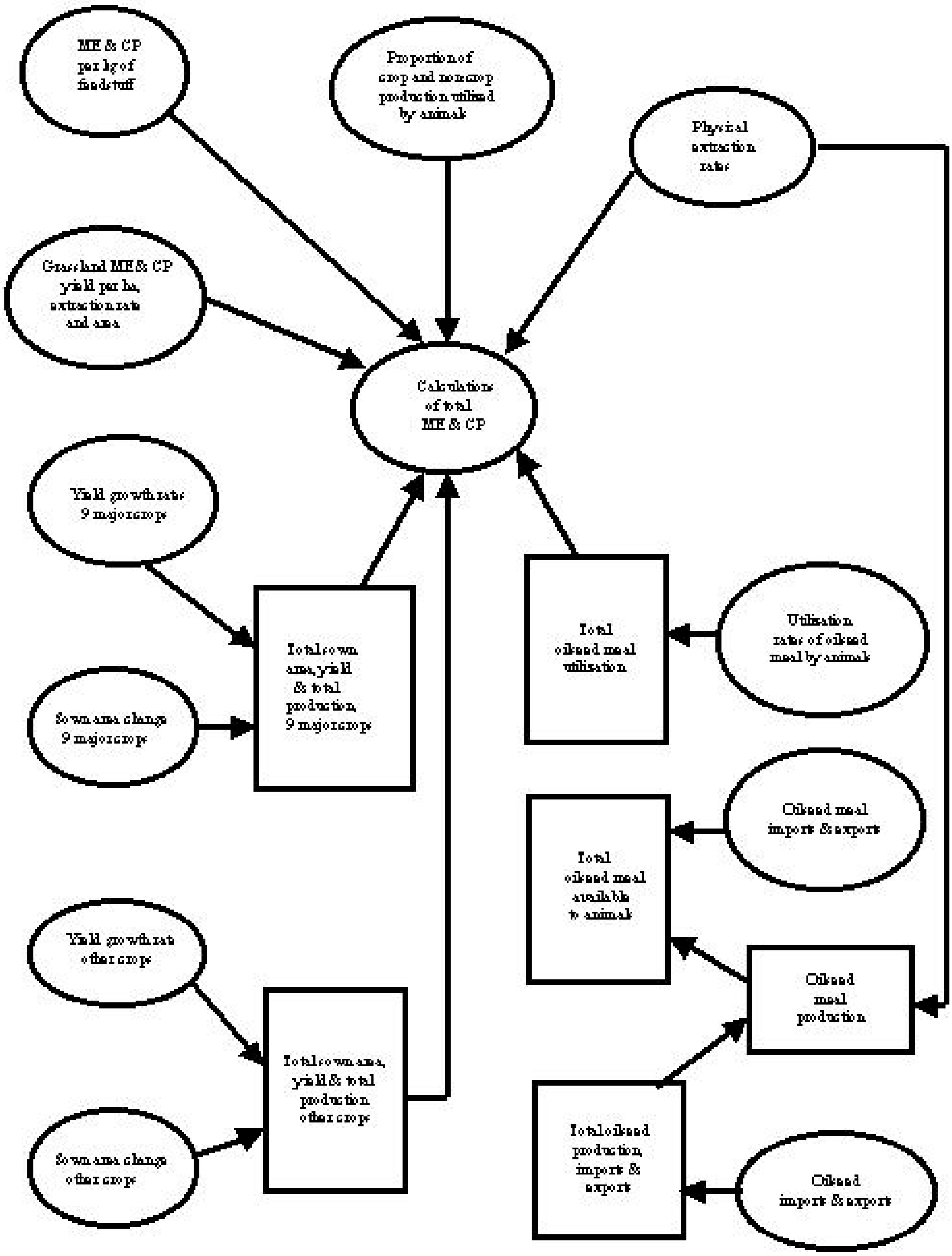

Figure 2. Model structure for feedstuffs availability projections

A yield adjustment had to be made in the modeling for projections. It was accomplished by revising all crop yields down 20 percent fully recognizing that 20 percent is only an estimated average and, clearly, each crop would be different. However, given the paucity of data on individual crops this was the only approach possible until the NBS can complete their revision of sown areas using base line surveys, a project which may not be accomplished until late in 2001. Apart from sown area the census results are quite acceptable. It is important to understand the monumental effort made in the first census and the extreme difficulty of working in a multitude of areas with different interpretations of cropland and use, as well as dealing with many layers of bureaucracy, in obtaining sown area data. In the modeling work presented in this paper sown area of each crop was revised upward 25 percent to correct for the 20 percent revision down in crop yields in order to attain the correct corresponding published total production for each crop.

Results on the Animal Side

Per Capita and Total Production Projections

Per capita projections of meat, milk, fish and eggs were obtained from an unpublished cross-country consumption analysis by Simpson and Li (2000) building on the method of Simpson and Ward (1995). Twelve countries or administrative areas were included; China, Germany, Hong Kong, Japan, Macao, Malaysia, Netherlands, Republic of Korea, Taiwan, Thailand, United Kingdom and the USA. An average of 1996-98 per capita consumption (derived from FAO DATA STATS) was used for each country and results regressed against purchasing power parity data for the year 1998. The purchasing power parity projections were compared with per capita GDP at exchange rates and consideration given to how structural changes will affect PPP over the next 3 decades. The 12 widely differing countries are used because (1) a wide range of per capita incomes is needed and (2) China is a multicultural country with vastly different diets depending on the region. It is mainly made up of Han Chinese, yet is different from Taiwan. It is certainly different than Hong Kong or Macao. It is an Asian nation, but is not like the Republic of Korea or Japan. It has Muslim minorities and is a major rice consuming country, yet it is not like Malaysia. China is a large country, and is a major meat eating country for its level of per capita income, yet is different than the United States. To a large extent it displays similarities to Germany in population density per hectare of arable land and in some food consuming habits. Selection of method and countries may not be optimal, but it is the one used, and per capita consumptions are deemed reasonable (Table 2).

It is important to realize that the projected per capita consumptions were used in a simulation model, and that the purpose of the demand side analysis was not to determine

TABLE 2. PER CAPITA AND TOTAL PRODUCTION--HISTORICAL DATA AND PROJECTIONS
CHINA, ECONOMY ROBUST

ITEM	COMPOUND ANNUAL GROWTH RATE CHANGE FROM / TO 96-98 2005	2005 2015	2015 2030	BASE MIDPOINT OF THREE YEAR AVG 96-98	PROJECTION YEAR 2005	2015	2030
				--------MILLION--------			
	0.87	0.61	0.23	1,227.7	1,315.5	1,397.4	1,446.5
	--COMPOUND ANNUAL GROWTH RATE--			BASE YEAR 1998			
GDP PER CAPITA				--------$ US--------			
PPP BASIS	7.0	5.5	4.5	3,567	6,129	10,469	20,260
EXCHANGE RATE	7.0	5.5	4.5	722	1,241	2,119	4,101
	PER CAPITA PRODUCTION						
	COMPOUND ANNUAL GROWTH RATE CALCULATED			DATA ENTERED 96-98	2005	2015	2030
	--------PCT--------			--------KG--------			
BEEF AND VEAL	2.72	4.97	2.19	3.23	4.00	6.50	9.00
PORK (1)	0.52	0.47	0.30	29.75	31.00	32.50	34.00
MUTTON AND GOAT	0.29	0.11	0.07	1.71	1.75	1.77	1.79
MUTTON AND LAMB	0.14	0.21	0.14	0.94	0.95	0.97	0.99
GOAT	0.52	0.00	0.00	0.77	0.80	0.80	0.80
BUFFALO MEAT (2)	-0.36	-0.39	-0.67	0.24	0.24	0.23	0.20
TOTAL RED MEAT	0.70	0.99	0.60	36.64	38.74	42.77	46.78
POULTRY	2.30	3.42	2.06	8.34	10.00	14.00	19.00
TOTAL MEAT	1.01	1.54	0.99	44.97	48.74	56.77	65.78
FISH,FRESH	1.65	0.80	0.50	10.53	12.00	13.00	14.00
TOTAL MEAT & FRESH FISH	1.13	1.40	0.90	55.50	60.74	69.77	79.78
MILK							
COW (3)	5.02	4.14	3.46	5.41	8.00	12.00	20.00
GOAT	-0.87	-1.33	-1.02	0.17	0.16	0.14	0.12
BUFFALO (2)	-1.16	-0.64	-0.65	1.95	1.78	1.67	1.51
EGGS	0.03	0.09	0.02	16.26	16.30	16.45	16.50
	TOTAL PRODUCTION						
	NON-REVISED DATA 1979-81	1984-86	1989-91	REVISED DATA AVG 96-98	2005	2015	2030
	--------1,000 MT--------						
BEEF AND VEAL	229.0	367.9	1,128.5	3,963.2	5,262.0	9,083.2	13,018.5
PORK (1)	11,703.8	17,128.2	23,871.2	36,523.8	40,780.7	45,415.9	49,181.0
MUTTON AND GOAT	434.3	600.6	1,070.4	2,099.0	2,302.1	2,473.4	2,589.2
MUTTON AND LAMB	237.0	307.3	550.7	1,153.8	1,249.7	1,355.5	1,432.0
GOAT	197.3	293.3	519.7	942.0	1,052.4	1,117.9	1,157.2
BUFFALO MEAT	71.7	125.4	164.5	297.5	309.6	316.3	295.8
TOTAL, RED MEAT	18,822.7	27,305.0	27,305.0	44,979.3	50,956.6	59,762.2	67,673.8
POULTRY	1,601.5	2,014.1	3,765.8	10,236.1	13,155.1	19,563.8	27,483.5
TOTAL MEAT	20,424.2	29,319.1	31,070.8	55,215.4	64,111.7	79,326.0	95,157.3
FISH,FRESH	1,313.8	2,942.1	5,257.8	12,921.9	15,786.1	18,166.4	20,251.0
TOTAL MEAT & FISH	21,738.0	32,261.2	36,328.6	68,137.3	79,897.8	97,492.4	115,408.3
MILK							
COW (3)	1,143.1	2,616.2	4,409.6	6,636.9	10,524.1	16,769.0	28,930.0
GOAT	113.4	143.9	159.2	210.6	210.5	195.6	173.6
BUFFALO (2)	1,380.0	1,626.7	1,906.7	2,400.0	2,341.5	2,333.1	2,189.0
EGGS, PRIMARY (5)	2,911.6	5,263.2	8,347.5	19,967.4	21,442.8	22,987.4	23,867.3

(1) ADJUSTED BY TRADE
(2) VERY LITTLE IS USED FOR HUMAN CONSUMPTION.
(3) COW MILK IS FRESH MILK.
(4) INVENTORY DIVIDED BY PRODUCTION PER FEMALE IN LACTATION (INPUT 6)
(5) ALL SPECIES

income elasticity's. As a side note, great care must be used in use of income elasticity's in long-term projections especially if they were derived from historical data in a fast growing country like China, as the elasticity's change dramatically as incomes grow. Finally, the concept of using PPP and GDP in a cross-country model for long-term projections seems to be worthwhile pursuing and it is hoped that further work will follow.

The largest growth of any commodity in China takes place in beef, in which per capita production nearly triples from 3.2 kg in the base year to 9.0 kg in 2030 (Table 2). The main meat, pork, grows only slightly, from 29.8 kg to 34.0 kg over that period. Total red meat and fish production in China is projected to grow from 56 kg in 1996-98, to 80 kg in 2030. Total production of these commodities grows 70 percent over the 33-year projection period.

Inventory projections

Large work animal numbers, excluding cattle and buffalo, decline from 24 million head in 1996-98 to 16 million head in 2030. However, cattle numbers grow dramatically, from 98 million to 177 million (Table 3). Small ruminant numbers grow in the first part of the 21^{st} century from 257 million head to a high of 262 million head in 2005, and then decline to about the base period inventory in 2030.

Pig numbers grow slightly until 2005 and then decline, reaching 340 million head in 2030 compared to the base period of 393 million head. This is a 13 percent decline, overall. However, total pork production grows 35 percent.

Poultry numbers grow from 4.3 billion birds in 1996-98 to 4.8 billion in 2030, a 12 percent increase. In contrast, poultry meat production more than doubles although egg production grows only 20 percent.

Productivity and efficiency of feedstuffs use

The dichotomy between substantial growth in production and minimal growth or declines in all inventories, except cattle, is explained by improvement in productivity and efficiency in feedstuffs use. The improvement, which China has obtained since it's opening in 1978, is dramatic. The potential that still remains for improvement, even under the conservative assumptions in this modeling effort, is equally impressive. The plain fact is China is still a developing economy, albeit one which has had and continues to have very high growth in GNP, and equally impressive agricultural reform productivity growth.

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				--------MILLION--------			
	0.87	0.61	0.23	1,227.7	1,315.5	1,397.4	1,446.5
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EXCHANGE RATE	7.0	5.5	4.5	722	1,241	2,119	4,101

PER CAPITA PRODUCTION

	COMPOUND ANNUAL GROWTH RATE CALCULATED			DATA ENTERED 96-98	2005	2015	2030
	--------PCT--------			--------KG--------			
BEEF AND VEAL	2.72	4.97	2.19	3.23	4.00	6.50	9.00
PORK (1)	0.52	0.47	0.30	29.75	31.00	32.50	34.00
MUTTON AND GOAT	0.29	0.11	0.07	1.71	1.75	1.77	1.79
MUTTON AND LAMB	0.14	0.21	0.14	0.94	0.95	0.97	0.99
GOAT	0.52	0.00	0.00	0.77	0.80	0.80	0.80
BUFFALO MEAT (2)	-0.36	-0.39	-0.67	0.24	0.24	0.23	0.20
TOTAL RED MEAT	0.70	0.99	0.60	36.64	38.74	42.77	46.78
POULTRY	2.30	3.42	2.06	8.34	10.00	14.00	19.00
TOTAL MEAT	1.01	1.54	0.99	44.97	48.74	56.77	65.78
FISH,FRESH	1.65	0.80	0.50	10.53	12.00	13.00	14.00
TOTAL MEAT & FRESH FISH	1.13	1.40	0.90	55.50	60.74	69.77	79.78
MILK							
COW (3)	5.02	4.14	3.46	5.41	8.00	12.00	20.00
GOAT	-0.87	-1.33	-1.02	0.17	0.16	0.14	0.12
BUFFALO (2)	-1.16	-0.64	-0.65	1.95	1.78	1.67	1.51
EGGS	0.03	0.09	0.02	16.26	16.30	16.45	16.50

TOTAL PRODUCTION

	1979-81	NON-REVISED DATA 1984-86	1989-91	REVISED DATA AVG 96-98	2005	2015	2030
		--------1,000 MT--------					
BEEF AND VEAL	229.0	367.9	1,128.5	3,963.2	5,262.0	9,083.2	13,018.5
PORK (1)	11,703.8	17,128.2	23,871.2	36,523.8	40,780.7	45,415.9	49,181.0
MUTTON AND GOAT	434.3	600.6	1,070.4	2,099.0	2,302.1	2,473.4	2,589.2
MUTTON AND LAMB	237.0	307.3	550.7	1,153.8	1,249.7	1,355.5	1,432.0
GOAT	197.3	293.3	519.7	942.0	1,052.4	1,117.9	1,157.2
BUFFALO MEAT	71.7	125.4	164.5	297.5	309.6	316.3	295.8
TOTAL, RED MEAT	18,822.7	27,305.0	27,305.0	44,979.3	50,956.6	59,762.2	67,673.8
POULTRY	1,601.5	2,014.1	3,765.8	10,236.1	13,155.1	19,563.8	27,483.5
TOTAL MEAT	20,424.2	29,319.1	31,070.8	55,215.4	64,111.7	79,326.0	95,157.3
FISH,FRESH	1,313.8	2,942.1	5,257.8	12,921.9	15,786.1	18,166.4	20,251.0
TOTAL MEAT & FISH	21,738.0	32,261.2	36,328.6	68,137.3	79,897.8	97,492.4	115,408.3
MILK							
COW (3)	1,143.1	2,616.2	4,409.6	6,636.9	10,524.1	16,769.0	28,930.0
GOAT	113.4	143.9	159.2	210.6	210.5	195.6	173.6
BUFFALO (2)	1,380.0	1,626.7	1,906.7	2,400.0	2,341.5	2,333.1	2,189.0
EGGS, PRIMARY (5)	2,911.6	5,263.2	8,347.5	19,967.4	21,442.8	22,987.4	23,867.3

(1) ADJUSTED BY TRADE
(2) VERY LITTLE IS USED FOR HUMAN CONSUMPTION.
(3) COW MILK IS FRESH MILK.
(4) INVENTORY DIVIDED BY PRODUCTION PER FEMALE IN LACTATION (INPUT 6)
(5) ALL SPECIES

TABLE 3. LIVESTOCK INVENTORY PROJECTIONS FOR CHINA, ECONOMY ROBUST

SPECIES	1979-81	1984-86	1989-91	AVG 96-98	2005	2015	2030
				YEAR			
	-----	-----	-----	1,000 HEAD	-----	-----	-----
LARGE WORK ANIMALS							
ASSES	7,567	9,942	11,129	9,906	9,235	8,352	6,168
CAMELS	597	542	470	350	256	209	167
HORSES	11,144	10,955	10,337	9,234	8,022	7,110	5,668
MULES	4,019	4,785	5,417	4,992	4,654	4,426	3,807
TOTAL, WORK ANIMALS	23,327	26,224	27,353	24,482	22,167	20,097	15,810
CATTLE							
MILK COWS	2,000	2,500	3,000	4,772	5,133	4,436	5,065
DRAFT/BEEF	52,567	62,907	79,282	93,092	111,899	144,338	172,385
SUBTOTAL	54,567	65,407	82,282	97,864	117,031	148,774	177,450
BUFFALO	23,597	19,647	18,622	20,622	19,224	18,285	15,726
TOTAL,CATTLE,BUFF	78,164	85,054	100,904	118,486	136,256	167,059	193,175
TOTAL LARGE ANIMALS	101,491	111,278	128,257	142,968	158,422	187,156	208,985
SHEEP	101,864	96,108	112,299	120,892	120,224	119,532	116,227
GOATS	78,457	64,521	95,615	136,165	145,007	143,413	138,554
TOTAL SMALL RUMIN.	180,321	160,629	207,914	257,057	265,232	262,944	254,781
PIGS							
COMMERCIAL				86,559	159,284	262,169	309,100
BACKYARD				306,892	238,927	87,390	30,570
TOTAL	313,660	318,618	360,247	393,452	398,211	349,558	339,671
	-----	-----	-----	MILLION BIRDS	-----	-----	-----
TOTAL POULTRY	1,147	1,579	2,552	4,294	4,484	4,693	4,824

As an example, in 1979-81 there was 37 kg of pork produced per pig in inventory (Table 4). By 1996-98 it had reached 93 kg, and it is projected to reach 145 kg by 2030. As a comparison, the average for 1996-98 in Germany was 150 kg, 136 kg in the United Kingdom and 138 kg in the USA. It is projected that in 30 more years 91 percent of China's pig inventory will be on commercial operations, compared with 23 percent in 1996-98. In brief, the productivity projections and the technical production assumptions on which they rest are reasonable.

Large animals accounted for 28 percent of ME consumed by all animals in 1996-98. Projections are for them to account for 28 percent in 2005, then 31 percent in 2015 and 36 percent in 2030 (Table 5). Small ruminant's (goats and sheep) proportion of ME use declines from 8 percent in 1996-98 to 6 percent in 2030. Pigs are the largest consumer of all ME by animals. Their proportion is projected to decline from 47 percent in the base period, to 43 percent in 2030. Poultry's proportion increases slightly, from 11 to 14 percent over the 33-year period. Crude protein proportions follow a similar pattern.

TABLE 4. PRODUCTION PER HEAD OF INVENTORY CHINA, ECONOMY ROBUST

SPECIES	1979-81	1984-86	1989-91	AVG 96-98	2005	2015	2030
	KG OF MEAT PER HEAD OF INVENTORY						
SHEEP	2.3	3.2	4.9	9.5	10.4	11.3	12.3
GOATS	2.5	4.5	5.4	6.9	7.3	7.8	8.4
CATTLE	4.2	5.6	13.7	40.5	45.0	61.1	73.4
BUFFALO	3.0	6.4	8.8	14.4	16.1	17.3	18.8
PIGS	37.3	53.8	66.3	92.8	102.4	129.9	144.8
POULTRY (JAN 1 INV)	1.4	1.3	1.5	2.4	2.9	4.2	5.7
	KG OF MILK PER HEAD OF INVENTORY						
GOATS	0.6	0.9	0.8	0.8	0.8	0.7	0.7
MILK COWS	571.6	1,046.5	1,469.9	1,390.8	2,050.4	3,780.0	5,712.0
BUFFALO	58.5	82.8	102.4	116.4	121.8	127.6	139.2
	Mcal OF METABOLIZABLE ENERGY PER KG OF MEAT PRODUCED						
SHEEP MEAT				54.1	51.7	49.6	47.4
GOAT MEAT				82.4	80.2	76.8	73.4
BEEF				74.9	71.1	63.7	58.7
BUFFALO MEAT				219.4	197.4	185.3	173.9
PORK				24.0	25.2	24.0	22.8
POULTRY				4.4	5.6	4.8	4.3
	KG OF CRUDE PROTEIN PER KG OF MEAT PRODUCED						
SHEEP MEAT				2.78	2.55	2.34	2.15
GOAT MEAT				3.84	3.66	3.40	3.18
BEEF				3.86	3.50	2.61	2.18
BUFFALO MEAT				8.93	8.05	7.55	7.08
PORK				0.93	0.92	0.85	0.82
POULTRY				0.30	0.27	0.26	0.24
	OFFTAKE RATES						
SHEEP	22.0	27.1	36.2	67.8	70.0	72.0	74.0
GOATS	23.6	39.0	40.8	54.8	56.0	58.0	60.0
CATTLE	4.6	5.8	8.5	29.2	30.0	31.0	32.0
BUFFALO	4.2	5.9	7.9	14.4	16.0	17.0	18.0
PIGS	63.2	69.1	74.2	120.8	130.0	155.0	170.0
POULTRY (JAN 1 INV)				0.0	0.0	0.0	0.0
LAYERS,COMMERCIAL				68.0	69.0	70.0	72.0
LAYERS,BACKYARD				63.0	64.0	65.0	66.0
BROILERS,COMMERCIAL				500.3	537.1	652.2	702.4
BROILERS, BACKYARD				375.0	380.5	388.6	410.4
DUCKS, GEESE AND TURKEYS				351.2	376.5	401.4	500.3
	BIRDS						
SLAUGHTER TO INVENTORY RATIO	1.15	1.04	1.06	1.71	1.90	2.45	3.09

Especially interesting is that while ME requirements for large animals grow 15 percent from 1996-98 to 2005, and have a total increase of 56 percent from 1996-98 to 2015, and 94 percent from 1996-98 to 2030, pig requirements actually decline 18,13 and 10 percent over those 3 periods (Table 5). In the case of large animals, mainly cattle, the growth is almost exclusively due to increased animal numbers. There are some productivity enhancements such as increased offtake (from 29.2 percent in 1996-98 to 32.0 percent in 2030), higher calf crop, improved breeding leading to larger size, etc., which lead to increased meat production per head (Table 4). In addition, the amount of energy required per kg of meat produced does decline, for example, from 75 kg in 1996-98 to 59 kg in 2030. The problem, as shown in Table 2, is that beef and veal consumption nearly triples while other meats have a much more modest increase. For example, pork production per capita only increases from 30 kg to 34 kg.

TABLE 5. METABOLIZABLE ENERGY AND CRUDE PROTEIN REQUIREMENTS
BY SPECIES GROUPS CHINA, ECONOMY ROBUST

SPECIES	TOTAL REQUIREMENTS ME	TOTAL REQUIREMENTS CP		SPECIES PROPORTION ME	SPECIES PROPORTION CP
	-Million Mcal-	-1000 MT-		--------PERCENT--------	
			AVG 96-98		
LARGE ANIMALS	469,445.0	23,147.7		28.0	32.2
SMALL RUMINANTS	140,111.5	6,818.8		8.4	9.5
PIGS	876,795.7	33,903.3		52.3	47.2
POULTRY	189,102.9	8,021.3		11.3	11.2
FISH					
TOTAL	1,675,455.1	71,891.1		100.0	100.0
			2005		
LARGE ANIMALS	539,845.3	25,811.6		27.6	32.4
SMALL RUMINANTS	148,968.5	7,035.7		7.6	8.8
PIGS	1,026,858.1	37,666.6		52.5	47.3
POULTRY	239,647.3	9,199.7		12.3	11.5
FISH					
TOTAL	1,955,319.3	79,713.6		100.0	100.0
			2015		
LARGE ANIMALS	731,650.5	30,516.2		30.7	34.8
SMALL RUMINANTS	153,035.6	6,975.1		6.4	8.0
PIGS	1,089,626.1	38,788.0		45.7	44.3
POULTRY	411,755.3	11,339.4		17.3	12.9
FISH					
TOTAL	2,386,067.5	87,618.6		100.0	100.0
			2030		
LARGE ANIMALS	908,786.1	34,370.2		36.2	36.4
SMALL RUMINANTS	152,837.8	6,758.5		6.1	7.2
PIGS	1,122,455.9	40,233.3		44.7	42.6
POULTRY	325,098.7	13,149.7		13.0	13.9
FISH					
TOTAL	2,509,178.4	94,511.6		100.0	100.0

Results on the Crop Side

Yield Projections

As explained, compound annual growth rates by yield enhancement variable were determined and inputted for the nine major crops (Table 6). Variables included fertilizer, land reclamation, irrigation, variety, soil improvement and one called "other" that includes shift to mechanization, technology improvement, management improvement, etc. This detailing of how and why yields will increase was based on discussions with experts on each of the crops and on review of literature about crop yield enhancement technologies (Simpson, Xu and Miyazaki, 1994). In addition, provisional results (unpublished) by FAO (April 2000) of projections for each of the same projection years with 1996 as the base were examined. In most cases the yield growth rates were similar between the two projections.

The yield projections adopted in this paper generally quite conservative. For example, the unrevised yield of maize in 1996-98 in China was 4,954 kg. Reducing it by 20 percent results in a base year yield of 3,963 kg. The projection for 2030 is 6,090, far below the 8,123 kg of the United States in 1996-98 or the 8,203 kg of Germany in that period.

Projections were also made for 22 other minor crops and their yields adjusted down by 20 percent, as with the 9 major crops. However, no attempt was made to detail the reason for yield growth as was done with the major crops. Rather, experts, FAO projections, analysis of historical data for China, and comparison with other country's yields were relied upon.

TABLE 6. YIELD PER HECTARE OF MAJOR CROPS (GROWTH RATE IN TECNOLOGY DETAILEI CHINA, ECONOMY ROBUST

TECHNOLOGY (1)		COTTON(1)	MAIZE	RAPE SEED	RICE	SORGHUM	SOYBEANS	WHEAT	BARLEY	GROUND NUTS (PEANUTS)
		GROWTH RATE IN TECHNOLOGY & ADOPTIO AVG 1996- TO 2005								
		COMPOUND ANNUAL GROWTH RATE IN PERCENT								
FERTILIZER		0.40	0.50	0.50	0.50	0.45	0.50	0.50	0.50	0.50
LAND RECLAMATION		0.00	0.10	0.10	0.05	0.00	0.05	0.00	0.00	0.00
IRRIGATION		0.10	0.05	0.20	0.20	0.10	0.05	0.05	0.00	0.00
VARIETY		0.30	0.60	0.45	0.55	0.60	0.55	0.60	0.70	0.60
SOIL IMPROVEMENT		0.10	0.05	0.05	0.00	0.05	0.05	0.05	0.05	0.05
OTHER(2)		0.10	0.20	0.20	0.20	0.30	0.30	0.30	0.35	0.35
TOTAL		1.00	1.50	1.50	1.50	1.50	1.50	1.50	1.60	1.50
		GROWTH RATE IN TECHNOLOGY & ADOPTIO 2005 TO 2015								
		COMPOUND ANNUAL GROWTH RATE IN PERCENT								
FERTILIZER		0.30	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.30
LAND RECLAMATION		0.00	0.10	0.05	0.00	0.05	0.05	0.00	0.00	0.00
IRRIGATION		0.10	0.05	0.10	0.15	0.00	0.05	0.00	0.00	0.00
VARIETY		0.30	0.50	0.50	0.35	0.40	0.45	0.50	0.70	0.40
SOIL IMPROVEMENT		0.10	0.05	0.05	0.10	0.00	0.05	0.05	0.05	0.05
OTHER(2)		0.10	0.30	0.30	0.20	0.15	0.25	0.25	0.35	0.15
TOTAL		0.90	1.40	1.40	1.20	1.00	1.25	1.20	1.50	0.90
		GROWTH RATE IN TECHNOLOGY & ADOPTIO 2015 TO 2030								
		COMPOUND ANNUAL GROWTH RATE IN PERCENT								
FERTILIZER		0.10	0.35	0.30	0.10	0.10	0.20	0.10	0.30	0.10
LAND RECLAMATION		0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IRRIGATION		0.10	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
VARIETY		0.10	0.45	0.40	0.15	0.25	0.30	0.15	0.40	0.05
SOIL IMPROVEMENT		0.10	0.00	0.10	0.00	0.00	0.05	0.00	0.05	0.00
OTHER(2)		0.10	0.30	0.20	0.00	0.15	0.20	0.05	0.25	0.05
TOTAL		0.50	1.15	1.00	0.30	0.50	0.75	0.30	1.00	0.20
		YIELD PER HECTARE (PUBLISHED DATA SERIES THAT OVER ESTIMATES)								
		KG								
AVG 1996-98		2,924	4,954	1,371	6,290	3,738	1,788	3,840	2,696	2,777
		YIELD PER HECTARE (REVISED DOWN TO ADJUST FOR SOWN (HARVESTED) AREA INACCURACIES))								
		PERCENT								
ADJUSTMENT		20	20	20	20	20	20	20	20	20
		KG								
REVISED AVG 1996-98		2,339	3,963	1,097	5,032	2,990	1,430	3,072	2,157	2,222
	2005	2,533	4,465	1,236	5,669	3,369	1,611	3,461	2,449	2,503
	2015	2,770	5,130	1,420	6,387	3,721	1,824	3,899	2,842	2,737
	2030	2,986	6,090	1,648	6,680	4,010	2,041	4,078	3,299	2,820

(1) LINT BASIS
(2) E.G. SHIFT TO MECHANIZATION, TECHNOLOGY ADOPTION, MANAGEMENT IMPROVEMENT.

Figure 3. Maize yield in China and selected countries, 1979-81 to 2030

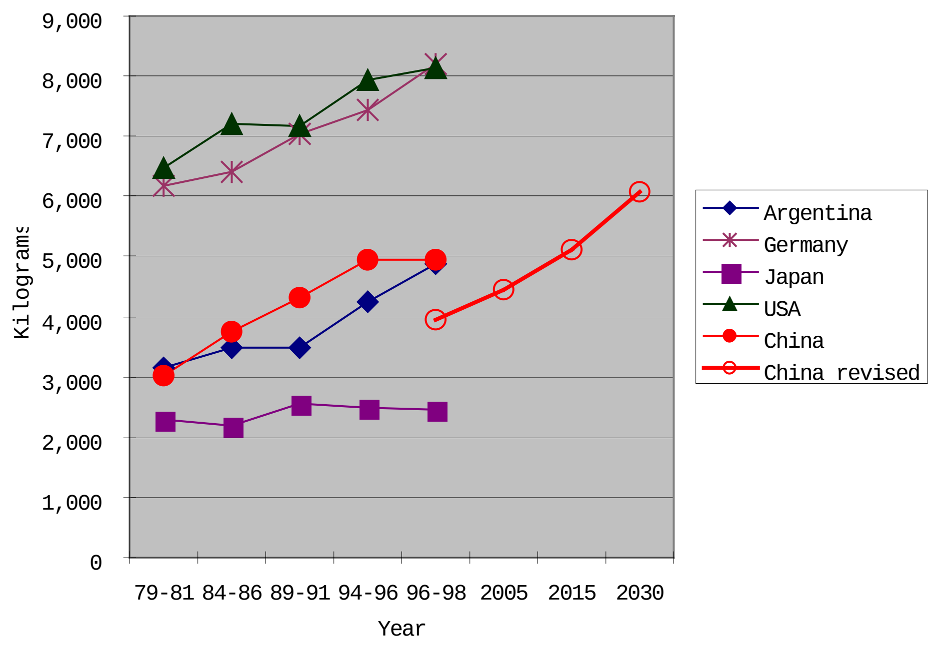

TABLE 7. PRODUCTION AND SOWN (HARVESTED) AREA OF ALL CROPS — CHINA, ECONOMY ROBUST

	SOWN AREA (REVISED) OF MAJOR CROPS			SOWN AREA (REVISED) OF MINOR CROPS		
	TOTAL	AREA CHANGE FROM 96-98	PERCENT CHANGE FROM 96-98	TOTAL	CHANGE FROM 96-98	CHANGE FROM 96-98
	----------MILLION HA--		-PCT-	----------MILLION HA--------		-PCT-
AVG 1996-98	139.9	-	-	45.4	-	_
2005	138.8	-1.1	-0.75	46.6	1.2	2.5
2015	138.3	-1.5	-1.08	47.3	1.9	4.2
2030	138.9	-0.9	-0.65	47.3	1.9	4.1

SOWN AREA (REVISED) OF ALL CROPS BASED ON CALCULATIONS FROM MAJOR AND MINOR CROPS

YEAR	TOTAL	CHANGE FROM 96-98	CHANGE FROM 96-98	SOWN (HARVESTED) AREA PUBLISHED	PUBLISHED DIFFERENCE FROM REVISED	YEAR	SOWN (HARVESTED) AREA PUBLISHED
	----------MILLION HA--		-PCT-	---MILLION HA--	-PCT-		---MILLION HA--
AVG 1996-98	185.3	-	_	153.9	20.35	1980	146.4
2005	185.4	0.1	0.1			1985	143.6
2015	185.7	0.4	0.2			1990	148.4
2030	186.2	1.0	0.5			1995	149.9
						1996	152.4
						1997	153.7
						1998	155.7

ESTIMATED TOTAL SOWN AREA WITH ADJUSTMENT FACTOR USED IN MAJOR AND MINOR CROPS

	AVG 1996-98 ---MILLION HA--
PUBLISHED	153.9
ADJUSTMENT FACTOR	25
ESTIMATED AREA WITH ADJUSTMENT	192.4
CALCULATED AREA, MAJOR AND MINOR	185.3
DIFFERENCE ESTIMATED AND CALCULAT	7.2
MULTIPLE CROP INDEX	156.9
CULTIVATED AREA (1997)	130.0
SOWN AREA USING MULTIPLE CROP IND	204.0
DIFFERENCE FROM USE OF MULTIPLE CROP INDEX	
ESTIMATED AREA WITH ADJUST	11.6
CALCULATED MAJOR AND MINOR	18.7

	MULTIPLE CROP INDEX	PUBLISHED CULTIVATED AREA
1979-81	148.0	99.3
1984-86	149.0	97.0
1989-91	155.0	95.7
1994-96	0.0	0.0
1996	159.7	0.0
1997	154.4	130.0
1998	156.6	0.0
1996-98	156.9	

PRODUCTION OF CEREAL CROPS

	PUBLISHED AVG 1996-98	PROJECTIONS AVG 1996-9	2005	2015	2030
	-----1,000 MT-----				
CEREAL CROPS					
RICE	200,126	200,135	213,131	230,698	234,162
WHEAT	114,528	114,486	121,920	131,969	135,978
MAIZE	121,904	121,685	140,402	164,600	198,349
MILLET	2,813	2,807	2,921	3,010	3,148
SORGHUM	4,460	4,422	5,184	5,842	6,391
OTHER GRAINS	6,506	6,506	7,000	7,500	8,000
TOTAL	450,337	450,041	490,558	543,620	586,028

Sown (harvested) area projections

The next step was to adjust sown (harvested) area in the base period. Published production figures have generally been accepted, but cultivated area is another matter. Cultivated area was reported to be 99.3 million ha in 1979-81, 97.0 million in 1984-86, and 95.7 in 1989-91 (Table 7). Results of satellite imagery in the mid-1990s revealed what Chinese officials had known for a long time—that cultivated area was much larger than reported in official statistics. The 1997 census verified that, and the cultivated area for 1997 determined to be 130 million ha, a 35 percent increase from the published data for 1996. Thus, sown area has to be much larger than reported and, for this reason, yields were adjusted downward.

China's sown area grew from 146.4 million hectares in 1980, to 153.9 million in 1996-98 (non-revised, published statistics) (Table 7). As explained, yields were decreased by 20 percent in the base period to offset sown area under-reporting. Thus, increasing sown area for each crop 25 percent led to the same production for each crop. The published sown area for 1996-98 was 153.9 million ha. Increasing it 25 percent gives a revised estimated area of 192.4 million ha. The calculated sown area of the 9 major and 22 minor crops included in the projections was 185.3 ha, which is 7.2 percent less than the revised estimated area. This difference is due to not all crops, nor non-planted areas, being included in the projection calculations.

An alternative method to determine actual sown area is to use the multiple crop index, a generally accepted figure, which grew from 148.0 in 1979-81, to 156.9 in 1996-98. Multiplying cultivated area for 1996-98 of 130.0 million ha times the multiple crop index of 156.9 gives a sown area of 204.0 ha (Table 7). That is 18.7 million ha above the area calculated for the 9 major crops and 22 minor crops. The conclusion is that (1) considerable work will be required by the National Statistics Bureau to resolve the discrepancies between published statistics on sown area and (2) the basic data used in the model is acceptable, at least because sown area utilized in the projections does not exceed the actual probable sown area as calculated by either method .

The model includes growth rate of sown area by crop as well as yields, which is very useful in analysis of potential land use and cropping changes. The projections are for a 0.65 percent decline in sown area of major crops, but a 4.1 percent increase for minor crops. Overall, the projection is for a 0.5 percent increase in all sown area by 2030.

Total Production of Cereal Crops

Total production of cereal crops is projected to increase from 450 million tons in 1996-98, to 586 million tons in 2030 (Table 7). There is relatively little difference between volume and weight for cereal crops and thus they can be aggregated to determine total changes over time. But, there is great variation in weights of other crops (for example between vegetables and maize) and thus comparisons of totals between years is meaningless.

Oilseed Production, Imports and Exports

Production of cottonseed, the largest oilseed crop, is projected to grow from 23 million tons in 1996-98, to 27 million tons in 2030 (Table 8). Soybean production, the second largest crop is projected to reach 29 million tons in 2030, double that of the base period. Groundnut production is also projected to double.

TABLE 8. OILSEED IMPORTS, EXPORTS AND PRODUCTION

CHINA, ECONOMY ROBUST AVG 1996-98 TO 2030

ITEM	AVG 1996-98	2005	2015	2030
	----------1,000 TONS----------			
	OILSEED PRODUCTION			
COTTONSEED	22,657	23,570	24,766	25,514
GROUNDNUTS	10,622	14,020	16,606	18,717
RAPESEED	9,020	10,744	12,849	15,371
SOYBEANS	14,322	17,890	21,936	26,444
SUNFLOWER	1,303	1,654	2,099	2,297
OTHER OILSEEDS (1)				
	----------1,000 TONS----------			
	OILSEED IMPORTS			
COTTONSEED	5	5	5	5
GROUNDNUTS	13	13	13	13
RAPESEED	0	0	0	0
SOYBEANS	4,875	4,875	4,875	4,875
SUNFLOWER	14	14	14	14
OTHER OILSEEDS (1)	5,506	5,506	5,506	5,506
	OILSEED EXPORTS			
COTTONSEED	1	1	1	1
GROUNDNUTS	233	233	233	233
RAPESEED	2	2	2	2
SOYBEANS	183	183	183	183
SUNFLOWER	16	16	16	16
OTHER OILSEEDS (1)	622	622	622	622
	NET OILSEED IMPORTS			
COTTONSEED	4	4	4	4
GROUNDNUTS	-220	-220	-220	-220
RAPESEED	-2	-2	-2	-2
SOYBEANS	4,692	4,692	4,692	4,692
SUNFLOWER	-2	-2	-2	-2
OTHER OILSEEDS (1)	4,884	4,884	4,884	4,884
	OILSEED AVAILABILITIES			
COTTONSEED	22,661	23,574	24,770	25,518
GROUNDNUTS	10,402	13,800	16,386	18,497
RAPESEED	9,018	10,742	12,847	15,369
SOYBEANS	19,014	22,582	26,628	31,136
SUNFLOWER	1,301	1,652	2,097	2,295
OTHER OILSEEDS (1)	4,884	4,884	4,884	4,884
	----------PERCENT OF PRODUCTION----------			
	OILSEED IMPORTS			
COTTONSEED	0.0	0.0	0.0	0.0
GROUNDNUTS	0.1	0.1	0.1	0.1
RAPESEED	0.0	0.0	0.0	0.0
SOYBEANS	34.0	27.3	22.2	18.4
SUNFLOWER	1.1	0.8	0.7	0.6
OTHER OILSEEDS				
	OILSEED EXPORTS			
COTTONSEED	0.0	0.0	0.0	0.0
GROUNDNUTS	2.2	1.7	1.4	1.2
RAPESEED	0.0	0.0	0.0	0.0
SOYBEANS	1.3	1.0	0.8	0.7
SUNFLOWER	1.2	1.0	0.8	0.7
OTHER OILSEEDS	0.0	0.0	0.0	0.0

(1) INCLUDES OILSEEDS-22 AND OILSEEDS NES.

Oilseed imports and exports were held constant at base year levels in all projection years. For example, soybean imports of 4.9 million tons in 1996-98 were held constant at that level out to 2030, as the purpose of the projections was to determine the ability of China to produce enough of its own feedstuffs. Other (non-specified) oilseed imports were 5.5 million tons. China exports relatively little oilseeds and is a net importer. Soybeans are the principal import, reaching the equivalent of 34 percent of domestic soybean production in the base year. If imports remained at that level, they would account for 17 percent of production in 2030.

Oilseed Meal (Cake) Production, Imports and Exports

Oilseed meal production is projected to expand from the base period 34.7 million tons to 51.7 million tons in 2030 (Table 9). Part of this production is from crushing imported oilseeds. Those imports were held constant, so the growth is from domestic production. China mainly imports soybean meal (3.0 million tons in 1996-98) and fish meal (1.3 million tons in that base period). Holding these imports, as well as exports, constant resulted in total meal availabilities growing from 38.9 million tons to 53.2 million tons.

Grain and Other Feedstuffs Imports and Exports

Trade levels were maintained at base period levels for all production years, the same as for oilseeds. China's main grain imports have been wheat and barley, both of which are primarily used for non-animal feedstuff use (Table 10). There were significant exports of maize and rice in the base period which roughly offset wheat and barley imports. Significant imports of cassava products were recorded.

Fish

The authors have limited knowledge of fish production. They were unable to find studies or estimates of energy and protein requirements for freshwater fish in China. However, Dr. Cremer of the American Soybean Association in Beijing was quite helpful in providing basic information from which a model could be prepared and estimates made. Dr. Cremer was emphatic that due to the size and complexity of freshwater fish production and rapid changes taking place in the industry, any estimates would likely be subject to considerable error. It is with this caution that estimates are provided in this paper (Table 11). They are presented as an addendum to the ones for which the authors feel relatively confident in an effort to determine the extent of freshwater fish energy and protein requirements.

TABLE 9. MEAL PRODUCTION, IMPORTS, EXPORTS AND AVAILABILITIES FOR ANIMALS
CHINA, ECONOMY ROBUST AVG 1996-98 TO 2030

TYPE MEAL	YEAR AVG 1996-98	2005	2015	2030
	----------------------------------1,000 TONS-------------------------			
	MEAL PRODUCTION			
COTTONSEED MEAL	9,967	10,637	11,293	11,634
GROUNDNUT MEAL	2,080	2,758	3,275	3,698
RAPESEED MEAL	5,201	6,262	7,568	9,054
SESAME	251	295	342	369
SOYBEAN MEAL	12,713	11,737	14,391	17,348
SUNFLOWER MEAL	711	908	1,161	1,295
LINSEED MEAL	302	344	381	406
PALM OIL MEAL				
OTHER TREE OILSEED MEAL				
COCONUT (COPRA) MEAL	65	67	70	75
FISH MEAL	467	467	467	467
POULTRY FEATHER MEAL	307	395	587	825
OTHER OILSEED MEAL	2,634	2,663	2,691	2,719
TOTAL	34,701	36,532	42,226	47,890
	MEAL IMPORTS			
COTTONSEED MEAL	0	0	0	0
GROUNDNUT MEAL	0	0	0	0
RAPESEED MEAL	191	191	191	191
SESAME	0	0	0	0
SOYBEAN MEAL	3,038	3,038	3,038	3,038
SUNFLOWER MEAL	0	0	0	0
LINSEED MEAL	0	0	0	0
PALM OIL MEAL	3	3	3	3
OTHER TREE OILSEED MEAL	0	0	0	0
COCONUT (COPRA) MEAL	0	0	0	0
FISH MEAL	1,311	1,311	1,311	1,311
POULTRY FEATHER MEAL	0	0	0	0
OTHER OILSEED MEAL (1)	127	127	127	127
TOTAL	4,670	4,670	4,670	4,670
	MEAL EXPORTS			
COTTONSEED MEAL	266	266	266	266
GROUNDNUT MEAL	2	2	2	2
RAPESEED MEAL	85	85	85	85
SESAME	0	0	0	0
SOYBEAN MEAL	36	36	36	36
SUNFLOWER MEAL	0	0	0	0
LINSEED MEAL	3	3	3	3
PALM OIL MEAL	0	0	0	0
OTHER TREE OILSEED MEAL	0	0	0	0
COCONUT (COPRA) MEAL	0	0	0	0
FISH MEAL	22	22	22	22
POULTRY FEATHER MEAL	0	0	0	0
OTHER OILSEED MEAL (1)	55	55	55	55
TOTAL	469	469	469	469
	TOTAL MEAL AVAILABILITIES			
COTTONSEED MEAL	9,701	10,371	11,027	11,368
GROUNDNUT MEAL	2,078	2,756	3,273	3,696
RAPESEED MEAL	5,307	6,368	7,674	9,160
SESAME	251	295	342	369
SOYBEAN MEAL	15,715	14,739	17,393	20,350
SUNFLOWER MEAL	711	908	1,161	1,295
LINSEED MEAL	299	341	378	403
PALM OIL MEAL	0	0	0	0
OTHER TREE OILSEED MEAL	0	0	0	0
COCONUT (COPRA) MEAL	65	67	70	75
FISH MEAL	1,756	1,756	1,756	1,756
POULTRY FEATHER MEAL	307	395	587	825
OTHER OILSEED MEAL	2,706	55	55	55
TOTAL	38,899	38,050	43,716	49,351

(1) INCLUDES CAKES OF OILSEEDS N+B276, AND OILSEED CAKE NES.

TABLE 10. GRAIN AND OTHER FEEDSTUFFS IMPORTS AND EXPORTS
CHINA, ECONOMY ROBUST AVG 1996-98 TO 2030

	AVG 1996-98	2005	2015	2030
	--------------------------1000 TONS--------------------------			
	IMPORTS			
BARLEY	1,779	1,779	1,779	1,779
DRY BEANS	40	40	40	40
MAIZE	230	230	230	230
RICE	820	820	820	820
SORGHUM	86	86	86	86
WHEAT	4,866	4,866	4,866	4,866
BRAN OF MAIZE	76	76	76	76
BRAN OF PULSES	280	280	280	280
BRAN OF RICE	35	35	35	35
BRAN OF WHEAT	149	149	149	149
ALFALFA MEAL AND PELLETS	104	104	104	104
CASSAVA EQUIVALENT	2,543	2,543	2,543	2,543
	EXPORTS			
BARLEY	5	5	5	5
DRY BEANS	538	538	538	538
MAIZE	3,814	3,814	3,814	3,814
RICE	1,770	1,770	1,770	1,770
SORGHUM	50	50	50	50
WHEAT	2	2	2	2
	0	0	0	0
BRAN OF MAIZE	0	0	0	0
BRAN OF PULSES	0	0	0	0
BRAN OF RICE	0	0	0	0
BRAN OF WHEAT	65	65	65	65
ALFALFA MEAL AND PELLETS	0	0	0	0
CASSAVA EQUIVALENT	195	195	195	195
	NET IMPORTS (1)			
BARLEY	1,774	1,774	1,774	1,774
DRY BEANS	-498	-498	-498	-498
MAIZE	-3,584	-3,584	-3,584	-3,584
RICE	-950	-950	-950	-950
SORGHUM	36	36	36	36
WHEAT	4,864	4,864	4,864	4,864
BRAN OF MAIZE	76	76	76	76
BRAN OF PULSES	280	280	280	280
BRAN OF RICE	35	35	35	35
BRAN OF WHEAT	84	84	84	84
ALFALFA MEAL AND PELLETS	104	104	104	104
CASSAVA EQUIVALENT	2,348	2,348	2,348	2,348

(1) PARENTHESES INDICATE NET EXPORTS.

The estimates for energy requirements by freshwater fish are 145 million Mcal, which is equivalent to 9 percent of animal requirements in the base period, although the proportions decline over time (Table 12). In effect, fish are of major significance when attempting to make total feedstuffs projections. There was 6 percent more energy available in feedstuffs than needed by animals and fish in the base period, requirements just equal availabilities in 2005 and there is a slight deficit in 2015, which almost disappears by 2030.

TABLE 11. FRESHWATER AQUACULTURE AND TOTAL METABOLIZABLE ENERGY AND CRUDE PROTEIN REQUIREMENTS CHINA, ECONOMY ROBUST

	YEAR			
	AVG 96-98	2005	2015	2030
FRESHWATER FISH PRODUCTION (1,000 MT)	12,921.9	15,786.1	18,166.4	20,251.0
CRUDE PROTEIN				
PROTEIN CONVERSION RATIO (KG PROTEIN/KG FISH)	0.8	0.8	0.8	0.7
PROTEIN REQUIRED (1,000 MT)	10,958	12,850	13,716	13,568
METABOLIZABLE ENERGY				
FEED CONVERSION RATIO (DRY MATTER BASIS)	3.7	3.5	3.0	2.4
METABOLIZABLE ENERGY (Kcal) PER KG FEED	3,000	3,000	3,000	3,000
METABOLIZABLE ENERGY (MILLION MEGACALORIES)	144,945	164,191	164,315	147,022
CRUDE PROTEIN				
TRADITIONAL FEEDS				
FEED CONVERSION RATIO (DRY MATTER BASIS)	1.0	1.0	1.0	1.0
PROPORTION OF PRODUCTION	50	40	25	10
IMPROVED FEEDING				
FEED CONVERSION RATIO (DRY MATTER BASIS)	0.7	0.7	0.7	0.7
PROPORTION OF PRODUCTION	49	57	65	60
HIGH LEVEL FEEDING				
FEED CONVERSION RATIO (DRY MATTER BASIS)	0.5	0.5	0.5	0.5
PROPORTION OF PRODUCTION	1	3	10	30
METABOLIZABLE ENERGY				
TRADITIONAL FEEDS				
FEED CONVERSION RATIO (DRY MATTER BASIS)	5.0	5.0	5.0	5.0
PROPORTION OF PRODUCTION	50	40	25	10
IMPROVED FEEDING				
FEED CONVERSION RATIO (DRY MATTER BASIS)	2.5	2.5	2.5	2.5
PROPORTION OF PRODUCTION	49	57	65	60
HIGH LEVEL FEEDING				
FEED CONVERSION RATIO (DRY MATTER BASIS)	1.4	1.4	1.4	1.4
PROPORTION OF PRODUCTION	1	3	10	30

Fish mainly need protein. This is much in evidence as they accounted for the equivalent of 15 percent of animal requirements in the base period and about the same during all projection years. The calculations indicated that while protein requirements just equaled availabilities in the base period when only animals are considered, there was a 14 percent deficit when fish were also considered. The proportion grows slightly to 2015 and then declines to 13 percent in 2030. Clearly, currently, there is sufficient protein for requirements even though a large proportion of all animals are on a minimal growth level of energy and protein intake. Also, there is considerable feeding of water plants, manure and other feedstuffs to fish. Furthermore, as mentioned earlier, there is considerable roadside grazing and feeding of garbage and water plants to animals, none of which, plus feeding urea, were accounted for.

Table 12. Metabolizable energy and crude protein requirements and availabilities with estimates for freshwater fish, China, 1996-98 to 3030, no change in trade from base period levels Economy Robust

Item	AVG 1996-98	2005	2015	2030
	Metabolizable energy			
	Million Mcal			
Requirements				
Animals	1,675,455	1,955,319	2,386,067	2,509,178
Fish	144,945	164,191	164,315	147,022
Total	1,820,400	2,119,510	2,550,382	2,656,201
Availabilities	1,937,266	2,123,388	2,285,878	2,476,911
Availabilities over requirements				
Ani mals only	261,811	168,069	-100,190	-32,268
Animals and fish	116,866	3,878	-264,505	-179,290
	Percent			
Fish as a proportion of animal requirements	9	8	7	6
Availabilities over requirements				
Ani mals only	16	9	-4	-1
Animals and fish	6	0	-10	-7
	Crude protein			
	1,000 MT			
Requirements				
Animals	71,891	79,714	87,619	94,512
Fish	10,958	12,850	13,716	13,568
Total	82,849	92,563	101,334	108,080
Availabilities	71,654	78,577	85,355	93,581
Availabilities over requirements				
Ani mals only	-237	-1,136	-2,263	-931
Animals and fish	-11,195	-13,986	-15,979	-14,499
	Percent			
Fish as a proportion of animal requirements	15	16	16	14
Availabilities over requirements				
Ani mals only	0	-1	-3	-1
Animals and fish	-14	-15	-16	-13

Scenarios of Changes in Requirements and Availabilities

Four scenarios of changes to parameters were prepared. Freshwater fish is included on the demand side, but ME and CP requirements and availabilities for fish were not included. The first scenario was a 10 percent increase in per capita production of each commodity in all three of the projection years. For example, in 2005 consumption of nationally produced beef, i.e. production per capita, would be 4.4 kg rather than 4.0 kg (Table 2). The result is that ME availabilities over requirements change from 16, 9, -4, and –1 percent from 1996-98 to 2030 in the base scenario, to 16, -1, -12, and –10 for these years, respectively (Table 13). Protein changes in a similar fashion. There is a dramatic change in the net availabilities. If this scenario were to occur, and China did not substantially increase its crop production and its animal production productivities over those specified in the basic scenario described throughout this paper, substantial feedstuffs or animal products would have to be imported.

Table 13. Metabolizable energy and crude protein requirements and availabilities, China, 1996-98-2030 scenarios, no change in trade from current levels — Economy Robust

Item	Average 1996-98	2005	2015	2030
	Metabolizable energy			
	-----Percent-----			
Availabilities over requirements				
Base projections	16	9	-4	-1
Per capita production only, up 10 percent	16	-1	-12	-10
Crop yields only, up 10 percent	16	10	-2	2
Percapita and crop yields, both up 10 percent	16	0	-10	-7
Per capita up 10 percent, crop yield up 30 percent	16	3	-6	0
	Crude protein			
Availabilities over requirements				
Base projections	0	-1	-3	-1
Per capita production only up 10 percent	0	-1	-11	-9
Crop yields only up 10 percent	0	0	-1	2
Percapita and crop both up 10 percent	0	-9	-9	-6
Per capita up 10 percent, crop yield up 30 percent	0	-7	-5	0

The second scenario was a 10 percent increase in yield per hectare of each crop. The impact is much less than on the demand side since not all of a crop is used for animal feeds. Metabolizable energy net availabilities change from 16, 9, -4, and –1 in the base scenario to 16, 10, -2, and 2 (Table 13).

The third scenario was for both per capita and crop yields to change 10 percent. The result is a substantial decline in net availabilities, in the case of ME from 16, 9, -4 and –1 percent in the base to 16, 0, -10 and -7 percent (Table 13). The fourth scenario reveals that crop yields would have to increase about 30 percent in order to make up for the 10 percent increase in animal product production per person. These results clearly demonstrate the potentially precarious situation faced by China in attempts to maintain current levels of animal feedstuffs self-sufficiency. They also serve as a “wake up call” to China that research and extension efforts, combined with appropriate governmental policies to stimulate adoption and expansion of production technologies is vital if the country to maintain it stated food security level.

Positive and Negative Aspects, Problems and Prospects

One conclusion drawn is that even with fish taken into account, technically, there does not appear to be a great additional need for imports of energy feedstuffs. However, as fish production increases—and becomes more sophisticated—and thus utilizes a greater amount of processed feedstuffs, domestic production of protein feeds may not be able to keep up with demand. The parameters of yield, and enhancement of digestibility and protein content of low quality feedstuffs by ammoniation or urea treatment are quite sensitive to change and thus are of major interest to policy makers interested in research and extension.

There are, of course, many other factors that impinge on the projections. Following are some that warrant careful consideration.

Population Density

There is a general belief that China is an “overpopulated” country. It is most unfortunate that some well-known public figures, and even academics that specialize in the area, use East Asian economies as points of reference for China’s population and geography. It seems that these comparisons have evolved as a result of geographical proximity as well as some similarities in racial phenotype and writing systems.

On a person’s per hectare basis, China shares more similarities with the United Kingdom and Germany than with other Far Eastern economies. For example, in terms of persons per hectare of arable land, while China had about 10 persons in 1998, Japan had 28; the Republic of Korea had 27; and Taiwan 26 (Table 14). On the other hand, the United Kingdom had 9 persons, and Germany had 7. Arable land is equivalent to cultivated land.

While China does have a substantial population density when compared to a country like the United States, where there are just 1.5 persons per hectare of arable land, density in

China is not as great a concern as many investigators would lead one to believe. Population is growing much more slowly than projected even a few years ago, to the extent that arable land density is projected to grow from 10.1 persons per hectare in 1998 to just 10.7 in 2005, to 11.4 in 2015 and 12.1 in 2030. Another point is that, in contrast to temperate climates like the United Kingdom and Germany, a substantial portion of China's cropland is situated in warm areas and thus China's multiple crop index is much higher than those temperate countries. There are, of course, well-recognized differences in soil capabilities and geographical features.

Table 14. Population density in China compared with selected countries and regions, 1998

Country or region	Total land area	Agricultural area (1)	Arable and permanent crops	Arable land area	Permanent crops	Permanent pasture
	Persons per ha					
1998						
World	0.4	1.2	3.9	4.3	44.9	1.7
France	1.1	2.0	3.0	3.2	50.8	5.6
Germany	2.3	4.7	6.8	6.9	360.2	15.6
India	3.0	5.4	5.8	6.1	122.8	88.5
Japan	3.3	23.4	25.7	27.8	341.3	252.6
Korea, Republic of	4.6	23.4	24.1	27.0	228.3	781.5
Taiwan	6.1	24.4	25.5	25.5	NA	4,653.4
United Kingdom	2.4	3.4	9.3	9.4	1,436.0	5.3
USA	0.3	0.7	1.5	1.5	133.7	1.1
China, 1998	1.3	2.3	9.3	10.1	110.0	3.1
China, 2005	1.4	2.5	9.8	10.7	116.2	3.3
China, 2015	1.5	2.6	10.5	11.4	124.1	3.5
China, 2030	1.6	2.8	11.0	12.1	131.0	3.7

Source: All except for Taiwan derived from online www.fao.org. Taiwan from online www.coa.gov.tw

(1) Agricultural area includes arable, permanent crops and permanent pasture.

The amount of permanent pastures is especially important for cattle and small ruminant production. This aspect is of particular interest since the projections in this paper reveal China's cattle inventory will double by 2030. China had a density of 3 persons per hectare of permanent pastures in 1998 while Japan had 253, and the Republic of Korea had 782 (Table

13). Taiwan had an astounding 4,653. In contrast, there were 5 persons per hectare of permanent meadows and pastures in the United Kingdom and 16 in Germany. This is another reason these two countries share much more similarity with China than the other Far Eastern countries and administrative regions. Much of China's permanent pasture is the vast grassland on which cattle, sheep and goats are fattened on grass. As the economy develops and transportation infrastructure improves there will be considerable improvements in animal systems (for example to cow-calf), environment (for example to changes in the mix of cattle, sheep and goats), and productivity (Simpson and Li, 1996) much like there was in the western United States a century ago.

Other Considerations

One key to making long-term projections about China's ability to feed itself is the realization that, not withstanding remarkable economic growth, it is a developing country with very low income. Consequently, despite remarkable achievements by the rural labor force, much of China's agriculture is still in what is termed the eras of hand power and horsepower. In actuality, substantial portions of China are only now entering the era of mechanical power, a period that characterized the United States between World War I and II. The next most advanced era, science power, lasted in the United States for about 40 years. The US and a number of other developed countries are now moving into what can be referred to as the science and knowledge power era. China will progress through the eras much more rapidly than the United States or other developed countries did. Barring severe political and/or economic setbacks, Chinese agriculture will be completely different in a few decades than it is now.

China has substantial segments of large-scale crop and livestock agriculture left from the commune period although even they are very labor intensive. Furthermore, many small individual vegetable production plots will be consolidated over the years. Even the most cursory trip through major grain growing areas quickly convinces one that due to large size fields (albeit operated by many landholders), the potential for economies of scale is large, both from an institutional and land-base viewpoint. As an increasing proportion of rural inhabitants shift from farming as a primary occupation to off-farm work, there will be increasing use of mechanical based contract services such as land preparation and harvesting. China is and will leap across the smallholder restraint, which is a major problem, if not *the* major problem, of many developing countries.

It is important to understand that, because much of China's farm work is still carried out by hand labor and animal power, there is a *de facto* labor shortage during critical farming periods. This has become more acute through a vast migration of able-bodied people to urban areas and through the development of rural enterprises as a part of the nation's industrialization. However, this is a necessary part of economic development and, as urbanization continues, there will be expanded mechanization and creation of farmers with higher management skills that will help alleviate this critical period labor shortage.

Land tenure is clearly a problem of substantial proportions that is a barrier to rapid technology adoption (Posterman, Hanstad and Ping, 1996). Nevertheless, the problem is recognized by the central government and efforts are being made to overcome it. Land tenure solutions, along with urbanization, will also serve to both expand the multiple crop index and will lead to increased yields. One cannot stress too emphatically the importance that mechanization, capital development, and management improvement will have on long-term crop yield improvement, production sustainability, synergistic use of inputs, and reduction of crop losses in China.

Ironically, another source of optimism for long-term yield increases is the variable quality and availability of inputs such as seeds, fertilizers, and chemicals. As the country develops, so will dependability of these inputs. One need only look at the remarkable improvements of the past two decades. Processed feed production will double in the next 10 years requiring more feedstuffs. However, quality of processed feed is low, which is one reason for excessive amounts of feed used per kg of product produced. As quality improves, processed feeds will be used more successfully and efficiently (Simpson, 1998).

Storage of agricultural commodities is generally rudimentary, and large losses are the norm partly because of transportation problems, and partly because of a lack of infrastructure. Huge investments by international lending agencies, China's agricultural bank, national agencies, provincial governments, county and city governments, not to mention farmer-owned cooperatives, are alleviating this massive problem, still estimated at about 8-10 percent of crop production. These losses, and their reduction, were accounted for in determination of feed availabilities in the projections.

Water

There is a water problem in China, but is there a water crisis? Quite a number of papers have been written on is very important aspect in long-term projections of agricultural production. The topic deserves deep consideration but only two sources are cited, Dr. James Nickum (1998), and Crook, et al, (1999). Both conclude that water will not be a binding constraint on agricultural production although there are a number of areas worthy of concern. The problem is basically an institutional one. Further rationalization of water rights and pricing systems are the critical elements in whether or not water will be a limiting factor in grain production. Nickum (1998, p.28) stated, “We need to account for the strong regional differences in China. Hydrologically and agriculturally, China is one country, many systems. Problems confronting irrigation are particularly pronounced in areas which, despite advances in the past two decades, are not usually the dominant grain-producing regions.” Crook and his team reported, “The country is only water deficit in comparison with the situation in other countries. And of course within China's river basins some basins have more water than others. The primary problem is one of adequately managing China's scarce water resources.” (1999, p.7).

In addition to use rights and pricing, government is placing great attention on improvement of dryland agriculture. "About 46 percent of grain in the country, 61 percent of cotton, 72 percent of soybean and 46 percent of oilseeds are produced in dryland areas…. Thus, water-saving dryland agriculture is one of the major agricultural development strategies emphasized by the central government, and implemented mainly through MOA, among the other two strategies: variation development and utilization of bare mountain area." (Crook, et. al., 1999, p. 106).

It can be concluded that the government of China recognizes the water problems and is making efforts to rationalize them. As with all developing countries, there are too many things to do at once and too little money to do them. Additionally, water, as in almost every country is a politically very sensitive issue and time is needed to deal with it. Yes, water is an issue, but not a constraint in the long-term projections presented in this paper.

Research and Development

There is a wide array of technologies, such as the use of biotechnology already available nationally and internationally to expand animal and crop productivity. In addition, the very large population base is one of China's assets in that it allows for critical masses in agricultural research and development. The main question is government priorities on it versus other pressing needs such as infrastructure development. These aspects are adequately covered in Simpson, Cheng and Miyazaki (1994).

Conclusions

It is concluded that *technically* China can maintain its position of being essentially self-sufficient in animal feedstuffs, and likely in most of fish production feedstuffs, although there is likelihood that protein feedstuffs for fish feed will need to be imported. The term technically is italicized because this study does not take Chinese and potential exporter production costs into account, a factor that will become very important in the upcoming round of WTO negotiations assuming China does participate in them. The projections do not take politics into account nor do they take world economic conditions into account. Lack of inclusion of these factors is disturbing to economists. But, it is just because economists and trade specialists DO focus on these aspects that a technical model is important and useful. The next major steps are to do careful comparative cost of production studies on the animal and crop side taking into account technical factors inherent to the modeling process described in this paper.

There will never be “correct” numbers of energy and protein as China is just too vast and the structure too complicated. In addition the country is changing quickly—and in fact it is this rapid change that underlines the reason why technical models are needed. There was need for considerable estimation or best guesses on many of the technical parameters in the projections, which may seem a fault, but just underscores the need for even greater national statistical development and studies on them. The approach used in the model and the research has been to provide all of the variables and parameters as a way to give the utmost transparency into methods, data and results and to facilitate discussion.

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