Chinese and Global Food Security to 2030:
Reducing the Uncertainties

Final Report of

The Strategy and Action Project for
Chinese and Global Food Security

by Dr. Gerald O. Barney, Philip Bogdonoff,
and Dr. Weishuang Qu

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MILLENNIUM INSTITUTE. 1117 N. 19th Street, Suite 900; Arlington, VA 22209-1708 USA
Tel: (+1-703) 841-0048; Fax: (+1-703) 841-0050;
Email: millennium@igc.apc.org; Website: http://www.igc.apc.org/millennium

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SUMMARY AND ACKNOWLEDGEMENTS

Background

Since the publication of Lester Brown's book *Who Will Feed China?* in 1995, there has been a spirited debate about the future balance of China's future food imports and exports, but only limited progress has been made toward consensus.

Recognizing that professional responsibility—not to mention the needs of policymakers—requires progress toward consensus, representatives of key organizations convened the Strategy and Action Project on Chinese and Global Food Security. The organizations involved are the U.S. Department of Agriculture, the Worldwatch Institute, the World Bank, the International Food Policy Research Institute, and the Millennium Institute. The Washington Embassy of the People's Republic of China, the State Science and Technology Commission of China,[1] the Administrative Center for China's Agenda 21, and the Research Center for Rural Economy of the Chinese Ministry of Agriculture also contributed.

The Strategy and Action Project was not established to decide who was right and who was wrong; instead it was an interdisciplinary approach to identify the underlying causes of differences and reduce the uncertainties. The Convenors deliberately engaged both economic and natural resource experts. As a first step, the Convenors identified areas of uncertainty, commissioned resource papers, and analyzed and compared seven major models (including Lester Brown's model). In addition, workshops were held in Washington and Beijing, and a new six-region "ChinaAg" model was developed. The findings are brought together in this report.

Findings

The findings are of three types. First, analysis of the models explores why they differ so markedly. Second, findings in the areas of uncertainty (land and soils, water and irrigation, yields and agricultural productivity, livestock and other animal protein, and government policy) are explored. Third, issues of policy are discussed.

The Models

Seven of the major models[2] used to project supply and demand balances for China's future food security were analyzed.

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[1] Now renamed Ministry of Science and Technology.

[2] The models are: (1) the ERS's Country Projections and Policy Analysis (CPPA) model for China (Colby, Giordano, and Hjort, 1997), hereinafter referred to as the ERS China Projection Model; (2) the China Grain Model based on Lester Brown's *Who Will Feed China?* (1995), developed jointly by the Millennium Institute and Lester Brown, hereinafter referred to as the Brown model; (3) the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) developed by IFPRI (Rosegrant, Agcaoili-Sombilla, and Perez, 1995; Fan and Sombilla, 1997), hereinafter referred to as the IMPACT model, (4); Jikun Huang's model (Huang, Rozelle, and Rosegrant, 1997), hereinafter referred to as the Huang model; (5) the Purdue University's Global Trade Analysis Project (GTAP) model chosen by Albert Nyberg (World Bank, 1997), hereinafter referred to as the Nyberg/GTAP model; (6) the World Bank model built by Don Mitchell and Merlinda Ingco (Mitchell and Ingco, 1993), hereinafter referred to as the Mitchell model; and (7) the model used by the Overseas Economic Cooperation Fund of Japan (OECF, 1995), hereafter referred to as the OECF model.

All the models project that China will need to import some grain. The projected imports for 2020 range from 24 million metric tons (MMT) of grain to 258 MMT. The difference of 234 MMT amounts to 117% of total annual world food trade, which averaged about 200 MMT in recent years. The differences in projections of supply are much greater than in the projections of demand.

While different analytical methods and different levels of geographic aggregation contribute to the differences in projections, the most significant factors are differences in the structural content of the models and the assumptions and data used.

Structurally, there are five areas of major difference.

- Two of the models (Brown and Nyberg/GTAP) include constraints on water availability. Water constraints are very significant because about 50% of China's grain land is irrigated and about 70% of the crop comes from irrigated land. Water for irrigation is in increasingly short supply, especially in northern China.
- Five of the models (ERS China Projection Model, Brown, IMPACT, Huang, Nyberg/GTAP) include livestock feed sectors implicitly or explicitly. Livestock feed is important because the Chinese diet has shifted to increased meat consumption and, as a result, demand for grain as feed for animals is growing rapidly.
- Two of the models (ERS China Projection Model and Brown) incorporate the multicropping index (MCI). The MCI is important because significant parts of China use abundant, low-skilled labor to grow more than one crop per year and because the agricultural labor sector is changing rapidly.
- Five models (ERS, IMPACT, Nyberg/GTAP), Mitchell) include prices and find low imports without significant price increases. Brown *assumes* no price increase and finds insufficient domestic production to prevent very large imports, implying that low imports *without* significant price increases are inconsistent findings. Price is important because it influences both supply and demand.
- The models include a wide range of assumptions about future yields, many based on comparisons with yields in other parts of the world. Agroeconomists explained that such comparisons are misleading and recommended that to reduce the differences among the projections, yield potential be based on calculations with agronomic models using agrobiological data specific to the regions of China.

Data and Assumptions

All seven models use a large number of exogenous inputs (data and assumptions) that constitute the baseline scenarios for each model. The baseline assumptions are not all documented, and for those that are, there are wide differences among the assumptions on both the supply and demand sides, on price responsiveness, and on policy. In particular, the models contain very different assumptions about future yields and the contribution of investment in agricultural research to increasing yields.

In an effort to clarify the uncertainty about some of the data and assumptions needed by the models, areas of uncertainties were identified by the Convening Group and scholars recruited to prepare resource papers. These papers were discussed at the Washington and Beijing workshops.

What follows is a synthesis of the best information from the papers and discussions.

Land and Soils

- The official statistic of 95 million hectares (ha) of current cropped land is 30–40% too low. Our "best estimate" for the correct number is 135 million ha.[3]
- Cropped area is decreasing gradually. Since good quality land is being lost to industrial and urban use and is being replaced by reclaiming land of poor quality, average soil quality could be declining.[4]
- The grain area sown is increasing slightly: 87.5–92.5 ha over the five years ending in 1996.[5]
- The MCI is rising slowly and may reach 1.67 by 2030.
- Cropland quality probably did not decline from 1930 to 1980. However, cropland quality is now deteriorating, but so far not enough to reduce yields seriously.

Water and Irrigation

- Irrigated area per person peaked in 1978 at 0.047 ha and dropped 11% by 1995.
- Irrigation water needed for grain will jump from 465 billion tons in 1995 to about 650 billion tons by 2030.
- The participants were very divided about water prospects, and no one provided projections of irrigation water availability.

There is evidence of unsustainable pumping of water. Underground water tables are falling, and the Yellow River now regularly runs dry, cutting crop yields in Shandong province and much of northeast China. Parts of the Yangtze are so polluted that the water is not well suited even for irrigation, and deforestation is disrupting the drainage and recharge process to the point that sections of the river may run dry in the future.

A south-north water transfer project is expected to deliver up to 20 billion tons per year to North China by 2005 or later, enough to grow 20 MMT of grain a year if all the water were used for irrigation. However, the economic benefit for water used in industry is about 70 times higher than water used in agriculture, and water use is shifting away from irrigation toward industrial and urban users. Nonetheless, irrigated land is expected to increase partly as a result of increased efficiency in using water.

Yields and Agricultural Productivity

- Since China's croplands are limited and shrinking, increased agricultural production will depend primarily on yield growth.
- Because of the error in official statistics on cropped land, yields are probably lower than previously thought—perhaps by as much as 30%.
- While the lower yield estimates may mean that there is more potential for increasing yields,

[3] While there is still uncertainty in this statistic, the number given here is near the center of the range of numbers discussed at the Beijing workshop.
[4] Soil quality was used in only one of the models (Huang).
[5] State Statistical Bureau, 1996.

potential yield growth should not be based on international comparisons but rather on yield ceilings calculated with crop models from location-specific agronomic data.

- Raising yields involves both fertilizers and water; fertilizer cannot be used without water.
- No technological breakthroughs are expected to double or triple yields; nonetheless, gradual increases in yields are foreseen.

Livestock and Other Animal Protein

- Survey data for 1981–1995 show that China's red meat consumption has increased 40%. The trend is expected to continue as long as incomes rise, but at a slower rate.
- The dietary shift to a higher meat consumption increases demand for feed grains, which is becoming a larger fraction of total demand.
- The amount of grain needed to produce a kilogram (kg) of meat is a very important statistic. Nonetheless, there are no official statistics on how much grain is fed to animals annually, and estimates differ by 20–35%.

Policy

Maintaining 95% grain self-sufficiency is the cornerstone of Chinese agricultural policy, which means, in practice, limiting food imports to 4–8% of production. Given the current 400 MMT harvest, this policy implies current imports of 16–32 MMT and of 24–48 MMT by 2025, when China's grain production is expected to reach 600 MMT.

As noted above, model projections of China's supply/demand balance for grain in 2025 all project imports. The total imports range from a low of 24 MMT to a high of 258 MMT. Subjectively taking into account the changes needed in each model to address China's future food security adequately would, in the opinion of the authors, reduce the range of projections somewhat, perhaps to 50 MMT to 200 MMT.[6] This is much higher than the 24–48 MMT range implied by Chinese policy.

It is difficult to tell how large or serious the difference is, however, because of the poor quality of key statistics available from China's State Statistical Bureau. Until the State Statistical Bureau is able to improve the quality of its statistics on cropped land, yields, meat consumption, feed conversion ratios,[7] and sustainable water supplies, China's policymakers will continue to operate with inadequate information on vital food security issues.

If the apparent difference between projected import needs and import policy is real, it could be reduced by careful attention to a range of related policies:

[6] Authors' note: This range is a subjective judgement by the authors based on careful assessment of the structures and assumptions of all seven models. Since new model runs have not been made based on what was learned in this report, it is not possible to say precisely how much the range would be reduced. Furthermore, policy is a large and unknown factor. In fact, there is new evidence since this report was first drafted suggesting China has substantially increased its agricultural research in the past three years. Another factor to consider is the transportation bottlenecks of the ports and railroads. Currently transportation might constrain imports to about 20 MMT/year.

[7] Convening Group comment: Feed conversion ratios are not reported currently by the State Statistical Bureau (SSB), but these numbers are vitally important to understanding China's grain needs. It would be very useful for the SSB to add those ratios to its published statistics. USDA.

1. Preserving the best agricultural land from loss to industry and urban expansion.
2. Preserving irrigation water from loss to industry and urban uses.
3. Helping farmers adopt best management practices, including water conservation measures. One participant argued that yield increases of 150–200% could be achieved with existing technology if all farms were managed as efficiently as the best farms.
4. Creating stronger incentives (including longer land tenure and reduced tax burden) for farmers to invest in preserving and building soil quality.
5. Investing in advanced yield-enhancing technologies, as called for in the 1993 Agricultural Law.

Recommendations

Models

Recommendations for improvements to the models include:

- The OECF and Mitchell models need to add a livestock/meat/feed grains sector.
- The ERS China Projection Model, Huang, IMPACT, OECF, and Mitchell models need to add water constraints or at least diminishing returns to investment in irrigation.[8]
- The work of Worldwatch Institute would be stronger and more understandable if it were based on computer models rather than just mental models.

Model development plans:

- IFPRI: Strengthen water and natural resource representation in IMPACT.
- World Bank: No immediate plans for further work with GTAP.
- ERS: Improve livestock component of ERS China Projection Model.
- Worldwatch Institute: Would like to see a simple model used to assess production potential for both exporters and importers.
- Millennium Institute: Seeks collaborators to refine and apply the ChinaAg model.
- RCRE: Wants to develop a China model.

Data and Assumptions

<u>Land and Soils</u>

There is some evidence that land loss and soil erosion might not be as severe as we had feared, but we need to invest in the data and analysis to understand it much better. Priorities include:

- Build a comprehensive Geographic Information System (GIS) inventory of land use by crop, as well as information about the quantity of land and quality of the soil (depth and structure). Include climate information (precipitation and humidity profiles) and whether the land is irrigated or rain-fed. Also monitor rates and causes of land use change.

[8] Authors' note: The Convening Group members agree with this point for North China, but not all are persuaded for South China. Nonetheless, while water is generally much less of a problem in the south than in the north, there are reports that even the Yangtze River may soon run dry in some stretches for part of the year because of the adverse impact of deforestation on aquifer recharging. The flooding is exacerbated by the deforestation, and when the runoff is fast (during floods), the recharge is reduced. See, for example, Welcomme, 1995 and FAO, 1995.

- Collect information on the factors that affect the multicropping index.
- Collect data on the rates of urbanization and income growth and its impact on land use.

Water and Irrigation

We are more concerned about water as a result of what we have heard. This area needs investment in data and in models. We recommend:

- Determine how much water is needed for growing grains and other crops by region, including in-field water response functions.
- Determine price elasticities of demand for irrigation water for each area.
- Build a hydrological inventory by region; include storage capacity, stream flows, water table levels, and current versus sustainable withdrawal rates.
- Delineate China's water policy and infrastructure plans as they are expected to affect future water availability.

Yields and Agricultural Productivity

We recommend:

- Determine current yield levels by crop and region.
- Incorporate agronomic submodels and weather data into the models to predict yield ceilings.
- Collect information on factors that can positively and negatively affect yields—prices, technology, soil degradation, salinization, etc.

Livestock and Other Animal Protein

We are encouraged by the trends in feed conversion ratios, but we need further data and investment in the analyses. We recommend:

- Determine current and expected meat demand.
- Add the new feed conversion rates into the models.
- Expand livestock models to encompass the three major production systems in use—backyard, specialized household, and enterprise.

Statistics

Generally there is a need for better and more timely data, and for more consistent data collecting and reporting systems, which might best be achieved through cooperation with China's State Statistical Bureau. While data have improved, we need further support for a data system that collects more data at lower costs. Recommendations:

- Sampling rather than the old comprehensive reporting system.
- Standardize definitions (e.g., of "grain") and data collection methods; where possible, conform to international standards and practices.
- Compile improved estimates and evaluation of food consumption by region, and by urban and rural populations.
- Continue to refine statistics on grain inputs, conversion ratios, numbers of livestock operations, and impact of technology by region.

Government Policy

We recommend that:

- Modelers include policy variables to test policy changes vis-à-vis:
    - land tenure
    - trade policy
    - food self-sufficiency requirements
    - consumer and producer prices
    - agricultural investment

- Modelers provide the information policymakers need to make cost trade-off comparisons—for example, on the use of land for producing food or feed grain.

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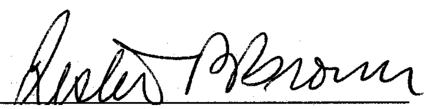
The Convening Group

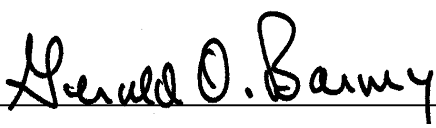
Katherine R. Smith, Director
Commercial Agriculture Division
Economic Research Service
US Department of Agriculture

Per Pinstrup-Andersen, Director-General
International Food Policy Research Institute

Alex F. McCalla, Director
Agriculture and Natural Resources
World Bank



Lester R. Brown, President
Worldwatch Institute



Gerald O. Barney, President
Millennium Institute

INTRODUCTION

Context

A major debate has been going on for several years among agriculture and natural resource professionals about China's future food supply-demand balance and its implications for world food security. Since China's food security is closely related to world grain trade and food security, professionals need to move toward consensus on the agricultural outlook for China.

The disagreement started in 1994 with the publication of Lester Brown's article "Who Will Feed China?" in *World Watch* magazine, which was followed in 1995 by his book *Who Will Feed China?* Brown asserted that China's rising income (up 56% over the 1990–94 period) and population (projected to reach 1.5 billion by 2030[9] from 1.2 billion in 1997), together with declining cropland (1.25 million ha per year from 1990–94)[10] and reduced water availability, will make China a major food importer. He maintained that by 2030 China will want to purchase—and will have the funds to purchase[11]—all the grain now available in international trade. Since other suppliers will not be able to meet demand at current prices due to slower growth in world grain harvests from 1990 onwards, according to Brown, food prices will rise for everyone—with especially harsh consequences for the 82 low-income, food-deficit countries.

Many agricultural economists and modelers disagreed with Brown's assertions. Reports published by major international institutions foresaw no problems. Published articles by some professionals were critical, or highly critical, of Brown's work. On the other hand, Japan's Overseas Economic Cooperation Fund (OECF) has reached conclusions somewhat similar to Brown's. And privately, some Chinese experts agreed with some of Brown's points. Furthermore, in just two years—from 1994 to 1996—China shifted from being a net exporter of 8 MMT of grain to being a net importer of 16 MMT, second only to Japan. (In 1997 and 1998, China returned to being a small net exporter.)

Understanding and consensus are urgently needed on China's future agricultural outlook. If the concerns being raised are valid, years of preparation by both food-exporting and food-importing countries are required. If the concerns are not justified, a careful analysis and interdisciplinary consensus is needed to put matters in perspective. In either event, the institutions involved need to come together to clarify their questions and obtain the best available data on which to base any analysis.

Several conferences and workshops were held on these issues,[12] but the principal authors of the projections did not come together to work as a group for the time needed to look deeply into their

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[9] United Nations. 1997.

[10] Brown's data comes form the USDA FAS PS&D Database, August 1998. USDA's ERS points out that China's State Statistical Bureau data gives a smaller figure for the losses, namely 667 ha/yr for the 1990–94 period.

[11] Brown. 1995. Page 103.

[12] For example, "Feeding China: Today and Into the 21st Century" held March 1996 at Harvard University, "Food and Agriculture in China: Perspectives and Policies" held 7–9 October 1996 in Beijing and hosted by the Chinese Ministry of Agriculture, and "The Keystone Center Workshop on Critical Variables and Long-Term Projections for

respective models to identify uncertainties and reduce their differences. The problem is made more difficult by the fact that Lester Brown does not use a formal model; as a result, his reasoning is not easy to track in detail. Agricultural economists, by contrast, use complex models that are difficult for anyone other than mathematical economists to understand.

Accordingly, professional representatives of key institutions involved in these issues joined together to create the Strategy and Action Project for Chinese and Global Food Security. The purpose was to clarify questions, obtain the best available current data, and recommend actions to reduce differences.

Process

The project was guided by a distinguished Convening Group[13] consisting of representatives of the U.S. Department of Agriculture's Economic Research Service (USDA/ERS), the International Food Policy Research Institute (IFPRI), the World Bank, the Millennium Institute, and the Worldwatch Institute. A representative from the Global Perspectives Unit of the U.N. Food and Agriculture Organization (FAO) also participated. The Millennium Institute,[14] which has no position on the issues, coordinated the project on behalf of the Convening Group. The Project was endorsed and supported by the Chinese Ministries of Agriculture and of Science and Technology and the Embassy of the People's Republic of China in Washington, D.C. The Chinese Research Center for Rural Economy played a major role.

Starting in the spring of 1997, the Convening Group, with support of the Millennium Institute:

- identified five areas of uncertainty—land, water, yields, livestock, and government policy
- obtained resource papers from 20 experts in both agricultural economics and natural resources from inside and outside of China
- selected and reviewed seven models of Chinese agriculture (in the case of Brown's analysis, Millennium Institute extracted from *Who Will Feed China* the "mental model" used by Brown and converted it into a computer model that Brown reviewed and approved)
- secured the sponsorship of Dr. Song Jian, former Chairman of the State Science and Technology Commission of China (SSTCC)
- translated the resource and model comparison papers (300 pages) into Chinese
- held a two-day working meeting of 48 Chinese and other world experts in Chinese agriculture in Washington, February 18–19, 1998
- wrote a consensus "Washington Report" of 70 pages, which was quickly translated into Chinese
- secured the commitment of Mr. Gan Shijun, Director General of the Department of Social

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Sustainable Global Food Security" held March 1997 at Airlie House in Virginia, and the Toronto meeting of the American Agricultural Economics Association.

[13] Katherine R. Smith, Director, Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture; Gerald O. Barney, President, Millennium Institute; Per Pinstrup-Andersen, Director General, International Food Policy Research Institute; Lester R. Brown, President, Worldwatch Institute; Alex F. McCalla, Director, Agriculture and Natural Resources Department, The World Bank.

[14] The Millennium Institute, founded in 1983, is an independent, technical, charitable, non-profit, and non-governmental organization. Its mission is to use sustainable development models and the turn of the millennium to catalyze a redirection of human civilization toward a peaceful, just, and sustainable future.

Development at SSTCC, and Mr. Ke Bingsheng, Director-General of the Research Center for Rural Economy (RCRE), to host a second working meeting in Beijing.

- developed a new six-region computer simulation model of Chinese agriculture—the "ChinaAg" model—and scenarios to go with it
- held the second working meeting of 40 of China's most knowledgeable agriculture and resource experts in Beijing, May 27–28, 1998, to discuss the ChinaAg model and the "Washington Report"
- developed a "reference" scenario suggested to modelers to facilitate future model comparisons (see Appendix I)
- collected and published the Chinese papers
- revised the "Washington Report" into this "Washington-Beijing" report.

Structure of the Report

The report begins with an overall summary. Next, the findings are presented in detail as they emerged from the Washington Workshop and with supplemental material drafted by the Chinese hosts at the Beijing Workshop for each section of the findings.[15] Finally, recommendations are made based on the two workshops and the suggestions of the Convening Group. A series of appendices provide additional information.

[15] The sections drafted by the Chinese hosts are entitled "Beijing Workshop Supplement:…" They have been edited only slightly for grammatical construction.

FINDINGS

The findings are based on the issues identified by the Convening Group, the resource papers, the discussions at the Washington and Beijing workshops, and the contributions of Chinese scholars. "Consensus opinions" are reported here, meaning that no formal vote was taken, but that an opinion or position expressed seemed, in the opinion of the authors, to reflect the consensus of the group. Consideration was given also to disciplinary backgrounds, so, for example, agronomists' views on yield potentials were given more weight than economists'. Final authority for the content of the report rests with the Convening Group in that the members all have the options of adding footnotes expressing any differences of opinion that they may have.

An effort has been made to focus the findings and recommendation on matters relating to reducing the uncertainties that make the projections so different. Inevitably, though, some findings and recommendations of a more general nature emerged.

The Models

Seven of the major models used to project supply and demand balances for China's future food security were analyzed by Dr. Weishuang Qu, Director of Modeling at the Millennium Institute.[16] The comparison was made by creating simplified versions of each of the models in a common modeling framework (see diskette, inside back cover).
The models analyzed are:

- the ERS's China Projection Model (Colby, Giordano, and Hjort, 1997), hereinafter referred to as the ERS China Projection Model
- the China Grain Model based on Lester Brown's *Who Will Feed China?* (1995), developed jointly by the Millennium Institute and Lester Brown, hereinafter referred to as the Brown model[17]
- the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) developed by IFPRI (Rosegrant, Agcaoili-Sombilla, and Perez, 1995; Fan and Sombilla, 1997), hereinafter referred to as the IMPACT model
- Jikun Huang's model (Huang, Rozelle, and Rosegrant, 1997), hereinafter referred to as the Huang model
- the Purdue University's Global Trade Analysis Project (GTAP) model chosen by Albert Nyberg (World Bank, 1997), hereinafter referred to as the Nyberg/GTAP model
- the World Bank model built by Don Mitchell and Merlinda Ingco (Mitchell and Ingco, 1993), hereinafter referred to as the Mitchell model
- the model used by the Overseas Economic Cooperation Fund of Japan (OECF, 1995), hereafter referred to as the OECF model.

All the models project that China cannot be completely self-sufficient and will need to import some grain. The projected amounts of imports, however, are very different. The Brown model projects China will want to import—and be capable of importing—258 MMT of grain by 2020. The Huang model, by contrast, projects only 24 MMT of imports. The difference of 234 MMT amounts to 117% of total annual world food trade in recent years, which is about 200 MMT.

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[16] Qu, 1997.
[17] Barney, Kura, Qu, Symalla, 1996.

Analysis of the seven models shows that there are differences in both supply and demand projections, but that the differences in projected supply are much greater than the differences in projected demand. Supply projections range from a high of 570 MMT to a low of 300 MMT; the supply difference of 270 MMT amounts to 67% of China's current production of 400 MMT. Demand projections range from a high of 727 MMT to a low of 490 MMT; the demand difference of 237 MMT amounts to 59% of China's current consumption of 400 MMT.
The huge range of projections from the seven models has its origins in differences of analytical methods, geographic aggregation, structural content, and scenario-specific assumptions.

Analytical Methods

The principal differences in analytical method relate to the linkage to international grain prices and to the representation of the complex food pricing and grain purchasing system in China.

Two models (ERS China Projection Model, IMPACT) have endogenous linkage to world grain prices; three (HUANG, Nyberg/GTAP, Mitchell) have exogenous connections to world prices; two (Brown and OECF) have no explicit linkage. Nyberg/GTAP and Mitchell do not disclose price assumptions. For the two models that do disclose endogenous world price projections, the trends are downward: -43% for ERS China Projection Model and -4% for IMPACT. While the Brown and OECF models do not explicitly link to world prices, they produce results that imply price increases.[18]

Although the agricultural market is partially operating in China, state pricing and purchasing decisions are still important in balancing supply and demand. None of the models adequately capture the complexities and dynamics of the Chinese pricing system. Domestic producer prices and consumer prices are model outputs. Ultimately it is these prices that directly influence the supply and demand behavior of the domestic market. However, only ERS provided access to their China Projection Model and its domestic price projections, and as a result the other models treatment of domestic and consumer prices is unknown and cannot be compared.

Four of the models use price elasticities to determine the relative mix of crops produced and the ratios amongst the factors of input. Only ERS provided access to their China Projection Model and showed their producer prices.

While the different price assumptions and analytical methods contribute to the range of projections, the methodologies for modeling price and the Chinese purchase system are not the only or even the most significant cause of differences among the projections.

Geographic Aggregation

The level of geographic aggregation varies among the models. Most models represent the country as a single region; only two represent the country as multiple regions. While additional geographic detail is appropriate as improved data become available for this large, diverse

[18] Authors' note: In the case of the Brown model, the report (*Who Will Feed China?*) explicitly states that price increases are expected and implies the need for a nonmarket means of food allocation. See Brown. 1995, p. 133.

country, the differences among the seven projections are not due primarily to differences of geographic aggregation.

Structural Content

Differences in structural content of the models are a key area of difference among the seven models. There are four major areas of structural difference.

- In most of the models analyzed, agricultural productivity is represented by the amount of gross cropped area times a crop yield factor. A few of the models (ERS China Projection Model, IMPACT, HUANG) are beginning to include irrigation as a yield enhancer and a smaller number (Brown, Nyberg/GTAP) also include water constraints on irrigation. The water limitation (especially in North China) is of great significance since about 50% of China's grain is irrigated. The treatment of the water constraint is a key factor in the differences among the models.
- Five models (ERS China Projection Model, Brown, IMPACT, Huang, Nyberg/GTAP) include livestock sectors in projecting grain demand. As the Chinese diet has shifted to increased meat consumption, the needs of the livestock sector for feed grains has become an increasingly important part of China's overall grain needs. The livestock sector is a critically important structural difference among the models.
- The ERS China Projection Model and the Brown model incorporate the multicropping index (MCI). The MCI is important because significant parts of China grow more than one crop per year, and the amount of land that is cropped more than once has been increasing. ERS and Brown make very different assumptions about the future of multicropping: In the ERS China Projection Model model, the MCI rises to 1.67 in 2020, whereas in the Brown model it falls to 1.38.[19] The key assumptions for future trends in the MCI need further study and justification.
- The models contain very different assumptions about future yields and the contribution of investment in agricultural research to increasing yields. Potential future yields are sometimes based on yields being achieved in other parts of the world when in fact the conditions in China (and the potential yields) are very different. A more accurate and appropriate approach is to base potential yields and yield limits on high-quality agronomic crop models that take into account the specific conditions of the growing areas in China.

Scenarios

Another key area of difference among the model's projections is that of the scenarios analyzed. By scenarios, we mean the collective sets of assumptions and data entered into the model.

All seven models explore many scenarios, and making comparisons is extremely difficult because the scenario-specific assumptions are not all documented. Nonetheless, it is clear that there are large differences among the assumptions on both the supply and demand sides, on price responsiveness, and on policy.

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[19] Authors' note: A question has arisen as to where this number came from. It emerged in consultation between Lester Brown and Weishuang Qu during the comparison of the Lester Brown computer model with the Lester Brown mental model. During these conversations, Brown indicated he expected China's MCI to fall to 1.31 by 2030. This drop would be in line with what happened in Taiwan, South Korea, and Japan. See Brown. 1995. P. 62.

- The supply projections are influenced significantly by documented and undocumented differences in assumptions for crop area, MCI, yields, water availability, fertilizer and other inputs, funding for and benefits of agricultural research, and even differences between the international and Chinese definitions of what constitutes "grain." The ERS China Projection Model projects an average yield of 5.42 ton per ha for 2020, while Brown's projection for 2020 is 4.41 tons/ha. A definition of "irrigation" and how it is represented in the models was not found in any of the documents except ERS.
- The demand projections are influenced significantly by documented and undocumented assumptions on GDP growth, population growth, feed grain conversion ratios, meat demand, and rural-urban ratios. The models are in close agreement about GDP at the starting time of the projections, but differ by almost 50% by 2020. All the models start at similar values of population, but the spread reaches more than 10% by 2010. The feed grain conversion ratio for pork ranged from 2.9 to 4.5. The ERS China Projection Model projects total meat demand of 243 MMT in 2020, while IMPACT's projection is 112 MMT (no milk and fish). For urban population, ERS assumed 40% in 2020, while Huang's assumed 50%.
- Both supply and demand projections are influenced significantly by documented and undocumented policy assumptions concerning degree of self-sufficiency, import choices (meat or food grains, or feed grains), state pricing and purchasing decisions processes, technological choices, and agriculture investment priorities.[20]

The ChinaAg Model

Dr. Qu Weishuang took all that was learned about needed structure, content, and data and summarized it in a paper for the Washington Workshop. The host of the Beijing workshop liked Dr. Qu's paper and proposed that a preliminary version of a model be developed and presented at the Beijing workshop. Dr. Qu then created a new six-region "ChinaAg" model based on data from the ERS China Projection Model (used with permission). The ChinaAg model is described in Appendix A.

Beijing Workshop Supplement: Models

The Beijing workshop (see Appendix E) was structured similarly to the Washington workshop, allowing a "Beijing Workshop Supplement" to be added to each section. These supplements were drafted in English by Dr. Ke Bingsheng at the Research Center for Rural Economy. They have been edited for grammar only, in order to preserve the Chinese viewpoints expressed. Where members of the Convening Group have comments or differing opinions, a footnote has been added.

Participants appreciated the efforts made by Dr. Weishuang Qu and Dr. Gerald O. Barney in improving the projection model. They agreed, in general, with the source of differences among the existing models and the five focal areas for further research suggested by the Washington Report. They felt that this consensus initiated in Washington and strengthened in Beijing could be a quite constructive result. It has set up a dialogue mechanism between scholars through which divergence will be lessened and discussion will be focused constructively.

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[20] Convening Group comment: While not disagreeing with the point, we note that there are questions as to how policies should be incorporated into models. USDA.

The Beijing Workshop acknowledged that the integration of government policies into the analytical model for China's future food projection by the Washington Report was an improvement. Participants noted that the changing policy variables in a transitional economy should play a leading role in determining the country's food prospect, and therefore should be made endogenously in the model.[21] The Washington Report was regarded as a good starting point in modeling this issue despite the imperfection of the technical design caused by incomplete information, which was to be enriched by the Beijing Workshop discussion. Participants encouraged the Millennium Institute to cooperate further with their Chinese counterparts to work out an improved model.

Areas of Uncertainty

The Convening Group members agreed on two broad areas of uncertainty—data and assumptions, and government policy. Resource experts were identified and papers commissioned for each area of uncertainty. The terms of reference of the resource papers list the questions the Convening Group members had in each area of uncertainty. Because many of these questions are still unanswered, the terms of reference are provided in Appendix F. The resource papers and workshop discussions are summarized below.

Data and Assumptions

Within the general area of data and assumptions, four specific areas of uncertainty were identified: land and soils, water and irrigation, yields and agricultural productivity, and livestock and other animal protein.

Land and Soils

Quantity of Land

How Much Land Is Cropped?

The official statistic is 95 million ha. This figure is incorrect due to underreporting by farmers and landholders and government officials.

The January 1997 agriculture census (soon to be released) by the State Statistical Bureau, will confirm that cultivated land has been underreported by approximately 38%.[22] After correction, the amount of arable land in 1995 was 132 million ha. It is estimated that cultivated land will decrease to 131 million ha in 2000 and to 125 million ha in 2030 (corrected figures).[23]

International comparisons of cultivated area are difficult to make based on even the corrected numbers, because a large fraction of what is called "arable" land in China is of such low quality and so steeply sloped that it would not be used in other countries.

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[21] Convening Group comment: This has been known for some time, but nobody knows how to do it. USDA.
[22] Xian Zhude. 1998. National State Statistical Bureau. Statement at Beijing Workshop, 27-28 May, 1998.
[23] Mei, 1998, p. 1.

How is the Underreporting Distributed across the Country?

One study suggests the degree of underreporting rises the farther the land is from Beijing and Shanghai. Lands worked by poor people—as opposed to poor lands—are consistently underreported, but there is only a slight tendency for more underreporting of poor soil as compared with good soil. According to this study, assessments of overall land quality have not been influenced significantly by the underreporting.[24]

The opposite conclusion was reached from analysis of 1996–1997 household surveys in Zhejiang, Jiangsu, Fujian, and Yunan provinces. This analysis indicated that unreported lands are most often marginal, fragile, "corner," or newly reclaimed land and are usually "private plots" planted with vegetables and other minor crops for home consumption.[25] Adding in these unreported lands would reduce the average land quality.

Is Gross Cropped Area Increasing or Decreasing?

China's rates of land loss averaged 0.53% from 1957 to 1978, 0.31% from 1978 to 1990, and only 0.15% from 1990 to 1995.[26] In addition, 6.7 million ha of grassland have been lost due to degradation.[27] However, farmland protection is a growing policy priority of the government, and at least 20% of the high-yield lands are now protected.

Past trends and future projections are summarized in Table 1.

Table 1: Arable Land

	Arable Land (millions of ha)						
	1980	1985	1990	1995	1996	2000	2030
Uncorrected	99.3	96.8	95.7	95.0	95.5		
Corrected by 39%	138	135	133	132	133	131	125

Source: Ke Bingsheng, 1997, and Mei Fangquan, 1997.

Is Land Loss or Land Reclamation Larger?

The goal of Chinese land policy is to keep a "dynamic balance" between land lost to industrialization and land recovered through reclamation. For the future, land lost to urbanization will be largely offset by reclaimed land. The lost land, however, is in highly fertile areas.

Is the Share of Land Planted in Grain Increasing or Decreasing?

During the years 1978–1995, the area planted in grain has remained nearly constant at 110 million ha (corrected figure), and the policy goal is to keep the grain area stable at that level. Nonetheless, it will decline slightly to 107 million ha by 2030.[28]

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24 Lindert, 1997.

25 Huang and Rozelle, 1997, p. 24.

26 Chen and Pan, 1997, p. 3.

27 Ibid.

28 Mei, 1997.

This prospect will be influenced by the price ratio between grain and nongrain products, and by the cost of growing grain. Rising incomes and industrialization may create pressures to shift crops near urban areas away from grains, oils, and cotton.[29]

The proportion planted in grains consumed for food will decrease from 61% in 1993 to 55% in 2000.

How Is the Multicropping Index Changing?

The MCI rose from 1.47 in 1981 to 1.59 in 1996.[30] The current (1998) MCI is 1.56, and Chinese experts feel there is potential for increasing it to 1.60 or more by 2030.[31] By comparison, in *Who Will Feed China?* Brown used an MCI of 1.56 in 1995, and assumed a decrease to 1.38 in 2020. The ERS China Projection Model used an MCI of 1.58 in 1995, and an increase to 1.67 in 2020.

What Influences MCI?

Increases will be achieved through technology advances (especially mechanization) and the introduction of new rice varieties with shorter growing periods. Urbanization may increase the MCI, too, through increased mechanization and educating producers with better management skills. Urbanization can also reduce MCI, however, because multicropping is inherently labor-intensive, and urbanization offers off-farm income and creates incentives for labor to leave farms.[32]

Although it may be possible to shorten a crop's growing season and get, say, three crops a year instead of two, the yields would be lower because the growing capacity of the plant is determined by sunlight, temperature, and humidity, and it takes time for a plant to grow to the size where it can take maximum advantage of these factors.[33] (The area under the "growth productivity curve" remains the same no matter how many crops per year are planted.) It would be better to have a perennial crop, especially with regard to minimizing soil erosion. Growing three crops per year instead of two does not necessarily mean that the land will yield 50% more. The third crop may be grown during a less optimal part of the growing season. While the light may be available for achieving maximum yields, other factors such as water and fertilizers may be limiting.

The two main biophysical limits on yield are the amount of sunlight reaching the crop and the duration of the cropping season (often determined by temperature, with high temperatures speeding development and shortening the growing season). Water and nitrogen are also needed for crop growth.[34] Information about the amount and quality (depth, water, and nutrient capacities) and chemical composition of soils by region is needed in order to determine yield potentials and to best manage soils for increased agricultural productivity.

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[29] Lindert, 1997.
[30] Chen and Pan, 1997, Table 2.
[31] Mei, 1998, p. 5–6.
[32] Simpson, 1997, p. 18.
[33] Convening Group comment: The short season for each of the multiple crops may not increase total output one season, but over two to three year period, multiple cropping produced more output than just a single crop. USDA.
[34] Ibid.

Quality of Land

The data currently available on China's soils are incomplete but somewhat reassuring. The average quality of agricultural topsoil in China probably did not decline from the 1930s until 1980,[35] and while soils have deteriorated more rapidly since 1980, conditions to date have not seriously reduced crop yields overall.

The study "Assessment of Human-Induced Soil Degradation in South and Southeast Asia from 1994 to 1997," reports the following for all Chinese land:[36]

- Water erosion occurs mainly in the eastern provinces, especially in and near the Sichuan basin, where rainfall, population density, and land use intensity are all generally high. It is the dominant type of human-induced soil degradation, affecting 163 million ha. About three quarters of water erosion has negligible to light effect on productivity. However, there is a trend toward further deterioration for about 86% of all occurring water erosion.
- Wind erosion, both human-induced and natural, affects 122 million ha, of which 50% experiences significant loss of topsoil and 43% altered terrain.
- Chemical deterioration affects 70 million ha, of which 70% show a trend toward further degradation and 82%, fertility decline through loss of nutrients and organic matter.
- Physical deterioration (mainly in the northern part of the Great China Plain and in areas under high management levels) affects 30 million ha, of which 80% is aridification (light impact, currently, but intensifying). Waterlogging is negligible.
- Urbanization and industrialization causes loss of land to occur on another 2 million ha.[37]

A simulation by HUANG of future impacts of two forms of soil deterioration, erosion and salinity, found that annual growth in erosion and salinity of 0.2–0.4% reduced annual production by 7 MMT by 2020.[38] This is judged by the authors to be insignificant. On close examination of HUANG's model, however, it seems that the conclusion of "insignificance" is essentially inherent in the assumptions concerning erosion and soil salinization. These were each assumed to increase at the linear rate of 0.2% per year, which means that it would take 500 years to degrade a fertile soil to the point of being useless for farming.

In addition to the information reported here, the UN Environment Programme and the Institute of Soil Science in Nanjing are building a soils database that may be useful. Also, FAO has collected data on arid lands, permanent crops, and grasslands in China.

While these reports reduce the worst fears about overall soil quality, participants noted that the traditional measures of soil classification and soil chemistry noted above are not good agronomic indicators of soil quality. Soil structure and its capacity to hold both nutrients and water are also important, and these soil qualities vary widely in China and are influenced differently by various type of soil deterioration. Agronomist's fears will persist until a comprehensive picture is

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[35] Lindert, 1997.
[36] Van Lynden. 1997.
[37] Ibid.
[38] Huang and Rozelle, 1997, p. 22.

available of soil trends—including measures of nutrients and water retention capability—for China.

Beijing Workshop Supplement: Land and Soils

The participants agreed that the reported farmland is underestimated by 30–40% and that the yield for main farm products could be overestimated to some extent, leaving more potential for the country to raise its production. The participants warned, however, that one can not be too optimistic with the up-to-date figure because the country is losing its most fertile land and the land newly added is quite poor in quality. Whether or not the impact on yields of the decreased fertility of the land can be made up remains a technological and investment issue.

The participants agreed that the limited yet reducing cropland resource should be well protected for agricultural use through a series of policy measures against the increasingly competitive demand from the industrial and urban sectors.

Participants noted that future agricultural production will be influenced not only by the quantity and quality of the cropland but also by the institutional settings for farmland. A stable long-term farmland contract may provide farm households with the incentives to use resources efficiently as well as protect the land.

Xian Zude and Huang Xiaohu, based on a Xinhua News Agency report, stated that the farmland available is actually 130 million ha, indicating that China feeds 22% of the world population with less than 10% of the world farmland. They attributed the previous 37% underestimation of farmland in the official statistics either to a traditional surface unit "xiguan mu" being larger than the standard one used by farmers or to the field edges and some newly cultivated land on hills and mountains by individual farm households being neglected. Given the fact that these "black fields" are marginal land, the underestimation of crops and overestimation of yields may be large. Consequently there may be only very limited potential for a sudden increase in production.

Zhang Wenbao and others argued that the soil fertility and MCI for the recently reclaimed farmland, mainly in the northeast and northwest, is too low to offset the yield loss due to the reduction of crop fields in the southeast caused by the rapid industrialization and urbanization process. The southeast has experienced a sharp rice production decline in 1993/94. Zhang showed that from 1986 to 1995 there was a net reduction of cropland in China of 1.93 million ha with the reclaimed cropland of 4.93 million ha balancing only part of the lost cropland of 6.86 million ha. He further pointed out that even for the newly reclaimed land competition from nonfarm sources claimed about 50% of the land. Participants emphasized that one should be cautious with the updated land data; the apparent increase in cultivated land does not provide information about the relative quality of the "new" land.

The experts noted that the amount of potentially reclaimable land in China is big enough to offset the farmland to be lost in the coming years, and still leave some 13 million to 33 million ha for further examination.

Another area for possible production rise is the MCI. Scholars agree that future increases in the MCI are quite uncertain, however, especially when the existing level should be perhaps adjusted according to the forthcoming revised farmland data.

Even though we assume the potential for land reclamation and an increase in multicropping is technically possible, it would require a huge investment, a constraint that is seemingly neglected in the research output available currently.

Participants agreed that effective policies could play an important role in the protection of both farmland quantity and quality. A permanent cropland protection system will maintain the minimum cropland area for food security strategy, and a long-term land contract will stabilize farmers' investment expectation in improving soil quality.

Water and Irrigation

Water Needed

Water is a limiting resource in many parts of China, especially in the north. Annual average precipitation is only 630 millimeters, and per capita water resources are about one fourth of the world average. The proper management of this resource is critical for the improvement of yields.

The total amount of water needed for grain production can be estimated from projections of grain production, assuming that the amount of water needed to grow a ton of grain is between 1,000 and 1,500 tons (see Table 2).[39]

Table 2: Water Needed for Growing Grain

	Total water needed for growing grain (billion tons)				
	1995	2000	2010	2020	2030
Grain produced (MMT/yr)	465	490-500	540-560	575-620	620-690
Water needed if 1,000 tons of water per ton of grain	465	490-500	540-560	575-620	620-690
Water needed if 1,500 tons of water per ton of grain	698	735-750	810-840	862-930	930-1035

Source: Mei Fangquan

Currently 70% of China's grain harvest comes from irrigated land. China's irrigated land has expanded from 17 million ha in 1950 to roughly 50 million ha in 1993, but has not increased much—if at all—since 1993. Irrigated area per person peaked in 1978 at 0.047 ha and has declined to 0.041 ha in 1995, a drop of 11%. Existing irrigation systems are performing badly. Many water projects have deteriorated due to waterlogging, salinization, and mining of groundwater aquifers. Agricultural productivity growth in irrigated areas has slowed.[40]

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[39] Brown estimates 1,000 tons, Nickum estimates 1,150 tons, and FAO estimates 1,500 tons.

[40] Huang and Rozelle, 1997, p. 24

Estimates of needed irrigated area are presented in Tables 3 and 4 using two methods. Method A is based on projections of both arable area and the share irrigated; it is unclear if the projections of the share irrigated are based on projections of water availability for irrigation or are merely extrapolations of trends. Method B is based on recommended amounts of arable land to be irrigated in 2000, 2010, and 2030, not on an analysis of the water that will be available.

Table 3: Needed Irrigated Area (Method A)

	1950s	1957-early 1970s	1976-1989	1990	1995	2000	2010	2020	2030
Arable land				133	132	131			125
Share irrigated					54%	56%	62%	67%	80%
Irrigated area (M ha)					71	73			100

Source: 1950s–90 from Nickum, 1997; 1995–2030 from Mei, 1997 and Ke, 1997

Table 4: Needed Irrigated Area (Method B)

	1950s	1957-early 1970s	1976-1989	1990	1995	2000	2010	2020	2030
Irrigation area (M ha)	21–27	40–44	44–45	47	49.4	53.3	56.7		73.0

Source: 1950s–90 from Nickum, 1997; 1995–2030 from Mei, 1997

Water Available

No projections of water available for grain production were found either for China as a whole or for specific regions.

The rates of pumping and the status of water tables are of particular concern. By one report, water tables are falling almost everywhere the land is flat.[41] In 1995 the Yellow River ran dry for an extended period, reducing irrigation water and cutting grain production in Shandong Province by 2.7 MMT. The rate of overextraction (extraction less recharge) of groundwater is estimated to be 8 billion m^3/yr. Current data on the distance from the land surface down to the water table and the volume of the aquifer are dated and fragmentary. Fortunately, a report on groundwater extraction rates is due to be published by the end of 1998.[42]

A systematic assessment of data and integration of the inflows and outflows for China’s major watersheds was performed by Dennis Engi of Sandia National Laboratory. The model and details of the analysis are available on the Sandia website.[43]

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[41] Joint Sino-Japanese Working Group Report (via personal communication from Lester Brown).
[42] Wang Hao, personal communication.
[43] Engi. 1997

In addition to declining water tables, factors influencing water availability include salinity and precipitation variability. As a result, irrigation water availability will vary from year to year and, during dry periods, even day to day.

Crop yield potentials are very dependent on humidity levels, and yields in northern China are limited as much or more by low humidity as by lack of irrigation water. The south-north water transfer project cannot alter the humidity of the arid north. If agronomic models were used to assess the costs and benefits of the south-north project, it might prove to be more beneficial to invest the funds not in the project but in water conservation measures in the north and general agricultural development in the south, where the natural humidity helps plants use water and nutrients efficiently.[44]

Arable land in southern China has eight times the amount of water per ha as northern China, and the government has undertaken the design of a large project to transfer water from the wet south to the drier north. The project design has been completed, and the five-year construction project will begin by 2000. When complete in 2005 or later, the project will deliver up to 20 billion tons of water/yr to northern China.[45] If all of the transferred water were to be used for irrigation, it would be sufficient to produce 20 MMT/year of grain; however, very little of it is likely to be used for irrigation.

In the future, the amount of water available for irrigation will depend increasingly on competition from other uses, especially industrial and urban domestic uses. The competition will be increasingly difficult for irrigation use because the economic benefit of water used for industry is about 70 times higher than for agriculture. In times of water shortage, the political value of water for urban domestic use is vastly higher than of water for irrigation. As a consequence, water from the south-north transfer project is likely to go to Beijing and Tianjin rather than to farmers' fields.

Table 5 summarizes China's water use by sector in 1995 and estimates for 2020.

Table 5: China's Current and Future Water Use by Sector

	1993			2020	
	$10^8 m^3$	Share of Total	Change	$10^8 m^3$	Share of Total
Urban Domestic	183	3%	270%	678	9%
Rural Domestic	245	5%	61%	395	5%
Industrial	761	14%	145%	1868	26%
Irrigation	3910	74%	2%	4001	56%
Forestry, husbandry, fishery	201	4%	30%	262	4%
Total	5300	100%	36%	7204	100%

Source: Wang and Shen, 1997.

[44] Sinclair, 1997, and personal communication.
[45] Ke, personal communication.

The shift is clearly toward industry and urban uses and away from irrigation.
The China Institute of Water Resources and Hydropower Research has made water demand projections for nine different river basins and areas by sector (urban domestic and rural domestic; industry; irrigation; and forestry, husbandry, and fisheries).[46] The projections are summarized in Table 6.

Table 6: Current and Projected Water Demand*

	1997	2050
Share of pop. that is urban	30%	60%
Urban domestic water use	177 liters pc	285 liters pc
Rural domestic water use	89 liters pc	154 liters pc
Industrial water reuse	50%	75%
Industrial water use quota	159 m^3	7 m^3
Water use per mu: Rice field Irrigated dryland	 800 m^3 400 m^3	 700 m^3 347 m^3
Ag. water use efficiency	45%	60%
Food output per m^3	0.84 kg	1.25 kg
Per capita forestry, Husbandry, fishery water Demand quota	14 – 17 m^3	14 – 17 m^3
Demand by sector: Agriculture Industry Domestic	(in 1993) 74% 17% 9%	 54% 30% 16%
Per capita water demand	445 m^3	525 m^3
Total water demand	ca. 534 billion m^3	ca. 814 billion m^3

*Key assumptions: Population growth stops at 1.55 billion in 2050. Urbanization increases smoothly from 30% in 1997 to 60% in 2050. Food consumption is flat at 400 kg per capita (grain equivalent) through 2050. Two thirds of staple foods and 90% of cash crops are produced in irrigated areas, which are expected to increase with population growth, and then be stable near 2050. Fraction of water used for irrigation gradually declines from current 60%. Industrial water demand reaches zero increase by 2050. Urban domestic water quota is stable by 2050; rural and urban domestic water use quotas are equal (and close to the current urban quota) by 2050. The water demand quota of forestry, husbandry, and fishery are stable by 2050. (From Wang and Shen, 1997.)

While these projections are useful, they do not answer the question of how much water will be available for irrigation in the different regions of China. Because of the growing competition for water, the answer to this question will depend in part on the type of economic development that occurs.

The problems with water are fourfold: supply, shortage, wastage, and quality. Correcting the latter two can go a long way toward fixing supply and shortage.

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[46] Wang and Shen, 1997.

China can greatly reduce wastage by using plastic pipes rather than sheet flow or trenches. This change, in one example, reduced water use from 9,000 to 6,000 cubic meters per ha.[47] Drip irrigation can greatly improve actual use application efficiency (the amount of water that arrives at each individual plant). One study reports that with drip irrigation both grain output and overall agricultural output value were continuing to increase in the suburbs of Beijing even after water was being diverted to the urban core and the overall irrigated area had declined. A shift to high-value crops and increased efficiency in the use of water made up for loss of water, land, and skilled labor.[48]

Much water is also wasted through pollution. Industries should be fined heavily for discharging toxic chemicals and heavy metals in their waste water, and industrial waste water should be kept separate from domestic urban waste water so that the nontoxic urban waste water can be treated and reused for irrigation.

The amount of irrigated land is expected to increase, in part due to the adoption of the use of plastic pipe and spray irrigation technology, leading to decreased water use and greater water availability for other lands.[49]

Beijing Workshop Supplement: Water and Irrigation

The Beijing Workshop reached a consensus that water scarcity in China may become the most critical constraint on its food production potential. It was noted that the per capita farmland size in China is only one third of the world average while the water possessed is even less: one fourth of the global mean. With the growing importance of commodity grain production in the arid and semiarid north, where 65% of the total farmland shares only 20% of the country's water resource, the rising demand for irrigation water for increasing food production will leave an enlarging water deficit in this region to be settled. Meanwhile, the competitive use of water in the industrial and residential sectors is producing more and more pressure on agriculture.

Beyond the general agreement that the water problems are serious, participants held different opinions concerning the impact of water problems on agriculture.

Lester Brown concluded that water scarcity is the most underestimated issue concerning China's food security. He noted that overpumping of irrigated water from the aquifer in North China has led to the decline of water tables and the drying up of the Yellow River before it reaches the sea, which in turn has produced water shortages that have constrained yield increases in this increasingly important grain-producing area. For instance, production of wheat in Shangdong Province decreased by a large margin in 1995. The overuse of water may in a few years turn the Yellow River into an inland river, as has happened with the Colorado River in the United States, creating more environmental problems for agriculture and farmers in this region. He also mentioned that South China, though adequate in aggregate water volume, is now seriously troubled with an aggravated pollution of the Yangtze River, which has negatively influenced the

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47 Mei, personal communication.

48 Nickum, 1997, p. 13.

49 Mei, personal communication.

irrigation and farmland in the area.[50] Meanwhile, the increasing demand of water use from residential and industrial sectors will vie with agriculture for the limited resource, leaving less water available for irrigation, as industry has a great advantage in the competition by producing an output of as much as 70 times in value that of agriculture from the same amount of water. This competitive advantage of industry over agriculture for water may make China resort to a food-import strategy based on a principle of economic efficiency: the import of one ton of wheat equals that of 1,000 tons of water. But there are also alternatives, such as enhancing the efficiency of water use in both agriculture and industry through technology innovation, changing the crop and livestock pattern from the water-consuming rice-pork structure to the relatively water-saving wheat-poultry structure, and substituting wind electricity for hydropower in energy production in areas where possible, etc.[51,52]

Zhang Yue and Ren Guangzhao used a series of historic data to argue that Brown overestimated the water scarcity problem in China while underestimating the water-saving prospect. During the past five decades, China's grain production, irrigated water used, and irrigated area available have grown up to 505 MMT, 400 billion cubic meters, and 51 million ha respectively by 1996, an increase of 3.46 times, 3 times, and 2.2 times over the figures in 1950. In the first three decades, the above three increased simultaneously, while in the second two decades starting from 1980, grain production grew by 57% while the irrigated water used decreased by 8%, which in fact was, to greater or lesser extent, attributed to the extension of water-saving technology. Based on this scenario, they suggest that the water supply is sufficient to support future grain production increase. Zhang predicted that in the next five decades, China's population will reach 1.6 billion with a grain demand of 640 MMT, of which at least 500 MMT or 78% will be produced in the irrigated area with the remaining 140 MMT or 22% produced in the nonirrigated area. Ren estimated that the irrigated land available may ultimately reach 64 million ha, more than enough to support the grain increment of 140 MMT. They, together with Yang Xiaoliu, argued that Brown was incautious in drawing some misleading conclusions by induction from partial fact or fragmentary data. For instance, the cause for the drying up of the Yellow River could be very complicated, the decrease of wheat production Brown reports in Shandong Province could not be found in Chinese production statistics, and the water table decline at an average of 1.5 meters per annum in North China Plain could perhaps be the case at some points but apparently is not the whole picture.

Du Ying and other participants noted that water pricing and investment are important in water conservancy and water-saving programs. Zhang and Ren backed up this point by reporting that the central government has put US$200 million since 1996 into supporting 300 counties in developing water-saving programs that will save 33 billion cubic meters of water per year. They pointed out the trend is encouraging. For example, spray irrigation has covered nearly 170 thousand ha of farmland in Jilin Province only in two years. The widespread use of sprinkling and dripping systems in the coming years will raise the water use efficiency considerably and increase the grain yield, as did plastic sheets 10 years ago. Thus the water scarcity problem

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[50] See, for example, Welcomme. 1998 and FAO. 1995.

[51] Lester Brown has reviewed this paragraph and confirmed that it correctly reports what he said.

[52] Brown and Halweil. 1998

limiting the further production rise in North China can be settled through extension of the water-saving technology.

The participants are quite divided in their opinions on the water issue with regard to its current status and prospect. Further study is needed to provide convincing results.

Yields and Agricultural Productivity

The Error in Historic Yield Data

China's yields for wheat and rice appear to be at world-class levels. While maize yields are 20% lower than in the United States,[53] this may be due in large part to the fact that in many areas, the highest quality lands are used for paddy rice and what is left is used for corn, wheat, and other crops.[54] So, on the basis of international comparisons, one might conclude that there is little possibility for yield increases in China.

This assessment is wrong for two reasons. First, the yield statistics available from China's State Statistical Bureau are overestimated due to the underreporting of grain land.[55] The reported and adjusted figures are presented in Table 7.

Table 7: Reported and Adjusted Yields in China, by Crop

Crop	Production	Reported Yield	Adjusted yield for 37% greater land area
	(t y^{-1})	(t ha^{-1} y^{-1})	(t ha^{-1} y^{-1})
Rice (milled)	125 x 10^6	4.1	3.0
Maize	105 x 10^6	4.7	3.4
Wheat	99 x 10^6	3.4	2.5
Soybean	11 x 10^6	1.4	1.0

Source: after Sinclair, 1997.

Second, international comparisons do not provide a sound basis for estimating achievable yields. Sound assessments of achievable yield increases in China require the use of agronomic models to calculate the yield ceilings imposed by biophysical and resource limitations for each crop in each of China's agro-ecological zones.[56] The recent slowing of crop-yield increases in industrial countries appears to be associated with reaching the biophysical limits of crop yields; in the United States and Japan, for example, actual farm field yields are about 70% of the maximum yields obtainable. It is impossible to know if yields in China are near such ceilings without analysis with agronomic models.

Agronomic models require inputs from several disciplines. These include intensity and duration of sunlight, temperature, humidity, capacity of soil to retain nutrients and water, and depth and chemical composition of soils. Statistics on "irrigated area" are insufficient and need to be

53 Rozelle, personal communication.
54 Ke, personal communication.
55 Huang and Rozelle, 1997, p. 24.
56 Ibid., p. 7.

supplemented with information on how much water is applied with what frequency and how it is applied. Data on "effectively irrigated areas" and "use application rate" are also useful.

In the absence of agronomic analysis of yield potentials in China, it can be noted that the use of inorganic fertilizer is expected to increase from 35.95 MMT in 1995 to 43.10 MMT in 2010 and then to 47 MMT by 2020. This is a 34% increase over 25 years. China has increased yields in part using labor-intensive methods, and the cost of labor in China is expected to increase. The advancing age of the current agricultural labor force will also affect the price of labor in the future.

Illiteracy is a critical factor in bringing new technology into production. Most laborers who remain in the agricultural sector are elderly or unskilled farmers.[57] Of the 140 million surplus rural laborers, 22% are illiterate or semiliterate. Ninety-five percent of the Chinese who are illiterate and more than 15 years old live in rural areas.[58]

Land Tenure

Although China's land tenure policies have changed to favor farmer's long-term use of land (which encourages improved husbandry), it is not clear how effectively these policies are being implemented at the local level, nor what impact increased tenure has on yield improvements.

Technology Advances and Related Trends

Technology advances are occurring in many areas, and China is increasingly able to take advantage of technologies developed elsewhere.

Past biotechnological improvements in crops have come about through alteration of a single gene. Increasing yields, however, requires changing many genes because yields are determined by many genes, not one. Major attempts to convert the metabolism of a crop from the so-called C3 cycle (which must capture carbon dioxide when the sun is shining and plants are stressed) to the more efficient C4 cycle (which also captures carbon dioxide at night, when water losses are minimized) have not succeeded. Efforts to reduce the water demand of fruits have failed; they require water no matter what genetic changes are made. Decades of effort to improve the efficiency of chlorophyll have also failed; it appears to be absolutely perfect in its capacity to harvest sunlight. Consequently, biotechnology will probably not achieve any "breakthrough" improvements in yields.[59]

It is likely that technology will help in other respects. For example, grain losses from diseases, pests, weeds, and rats are currently estimated at 10–15% per year.[60] Improved storage and handling technologies, along with the use of new pesticides and herbicides, could help reduce losses.

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[57] Ibid., p. 24.

[58] Chen and Pan, 1998.

[59] Sinclair. 1998.

[60] Chen and Pan, 1997, note to Table 4.

As noted earlier, the MCI is increasing and will continue to do so, in particular because the rural labor surplus will provide people to plant crops and because new technologies, such as plastic films, will increase the growing season in northern China.[61]

Beijing Workshop Supplement: Yields and Agricultural Productivity

Given the fact that farmland acreage is limited and shrinking, the potential for increases of agricultural production will depend primarily on yield growth. This topic caused a twofold debate among the participants: Have the current yield levels reached a biotechnological plateau and hence left China little potential for breakthrough? And, if not, what are the major constraints leading to the existing flattening of yield growth worldwide?

Brown noted that the world yield growth has slowed down since 1990 to an average annual rate of only 1% compared with 2.1% between 1950 and 1990. He attributed the slowdown to the physiological limits in yields of main crops having been almost reached, whereas new technology for breakthrough yield increases will not be available in the foreseeable future.[62,63]

Based on comparative research, Brown believes that China's grain yield prospect is not that promising. He discussed the prospects for wheat, rice, and corn.

For wheat, the yields vary enormously from one country to another. The yield of France, 7 tons per ha, for instance, is more than 10 times that of Kazakhstan. It would be highly misleading, however, to use such disparities as evidence of potential for improvement in lower-yielding countries. In fact, the prospect for raising yields further may be better in France than in Kazakhstan, where rainfall is marginal for agriculture and wind erosion of soil is devastating to cropland fertility. Now that developing countries are collectively using fertilizer, high-yielding varieties, and other advanced technologies, the ranking of countries on the yield chart is determined largely by environmental factors such as rainfall, daylength, and solar intensity.[64] In almost every place in the world where wheat is produced, the historic rise in yields is slowing. In France as well as in other major wheat-producing countries, it took less than five years to go from 5 to 6 tons per ha, but more than a decade to go from 6 to 7 tons per ha. The United States and Mexico have not seen any improvement in wheat yields during the past 13 years. While China was able to roughly quadruple its yields over the past half-century, environmental constraints will make raising wheat yields in China more difficult as aquifers are depleted, as response to additional fertilizer diminishes, and as the country's explosively growing cities pull irrigation water away from agriculture.

For rice, the full yield potential is not only dependent on large quantities of water but also is affected by latitude (with yields rising as distance from the equator increases) and by solar intensity (with yields rising as the amount of sunlight in the growing season increases). This is why rice yields in Japan are one-third lower than in California. Although Japan has a latitudinal

[61] Pan, personal communication.
[62] Lester Brown has reviewed this paragraph and confirmed that it correctly reports what he said.
[63] Convening Group comment: Some members of the Convening Group questions Brown's assertion in this paragraph.
[64] Convening Group comment: Management should also be on this list. USDA.

advantage and makes full use of irrigation to give it the highest yields in Asia, California has an abundance of sunshine, while in Asia rice is grown during the summer monsoon season, when extensive cloud cover reduces the amount of sunlight reaching rice fields. Japan plateaued its rice productivity in 1984. This example may suggest that China has probably approached its rice productivity ceiling due to its relatively disadvantageous geographic and climatic features.

For corn, the prospect for raising yields is better. China, as a relative newcomer to modern corn production, has seen its yields rise rapidly to about 5 tons per ha. And while they will rise further, they are not likely to reach the U.S. levels of 8 tons per ha because China does not reserve its best cropland for corn. Indeed, no other major corn-producing country has a region of deep, well-drained soils and near-ideal growing conditions comparable to the U.S. Midwest. In general, China may still have potential to increase grain yields. However, the questions of "how much" and "how rapidly" could not be answered optimistically due to current biological and technological limits.[65,66]

Zhu Xigang also noted that the yield growth rate has slowed. He pointed out that although technology advance may have a positive effect on yield-raising, factors that will reduce the yields should not be neglected:

- Yield-raising in China formerly relied mainly on increased inputs, including irrigation, fertilizer, and plastic sheet, which in turn may raise the marginal cost of the production and make the commodity output not competitive from the viewpoint of international trade.
- Technological promotion in China used to focus on yield-raising but neglect quality-raising; the latter is an important factor as incomes rise and has already begun to push production in a possibly downward direction.
- Water scarcity in the North will limit the country's yield-raising capacity.
- Increase of MCI will be more and more difficult with the continuous climbing-up of labor costs in rural areas.

Lin Yifu and Wang Hongguang disagreed with Brown's thoughts about agricultural productivity. Lin noticed that Brown's published conclusions were drawn from two sources of evidence: China's yield levels are close to the world top, and the world's top yields have leveled off since the late 1980s. Lin further pointed out that Brown's seemingly plausible evidence is not solid enough to support his conclusions. First, China's farmland area is underestimated by at least 25%, leaving the country much more leeway to raise grain yields. One cannot, however, count on this too much because increases in land and yields caused by underreporting will be far from enough to satisfy a growing demand by 50% due to the population growth of 30% and income growth of eight times in the coming 30 years. Over the next three decades the increase of food supply to cover the rising demand will come mainly from new yield-raising technologies.[67]

Second, and more important, the leveling off of world yields is caused by economic factors rather than technological factors. The twentieth century has witnessed a time of production surplus, with real grain prices dropping by 2% per annum. Governments in industrial countries have

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[65] Lester Brown has reviewed the previous three paragraphs and confirmed that they correctly report what he said.
[66] Brown. 1997.
[67] Convening Group comment: The "at least 25%" seems low.

maintained a subsidized price higher than the market price. As a result, more investment in agricultural science and technology to raise yields now means still larger grain surpluses and larger government costs for subsidies. A rational government will not prefer the double burden of "invest more, lose more."[68]

Lin and Wang suggested that the prospect of yield-raising is largely dependent on agricultural science input. Their research findings showed that even under the existing biological circumstances the yields of crops can be raised by 150–200% provided that the technological requirements in the fields of the most-productive farmers are met in the fields of all farmers. They stressed that the growth rate of yields is a policy issue rather than a technological issue, depending on the type of food security measures adopted. Biological breakthroughs of varieties are foreseeable if the investment is big enough.[69] A policy to be completely self-sufficient and an import-substitution policy may have different implications for investment in agricultural science and hence result in different rates of yield increase.[70]

Livestock and Other Animal Protein

Meat Consumption and Production

The amount of meat included in a nation's diet is important in determining its grain requirements because up to seven kilograms of grain must be fed to animals to produce a kilogram of meat.[71]

As shown in Table 8, total meat production in China has been growing.

Table 8: Livestock Production, 1985–96 (MMT)

	1985	1996	Annual Growth Rate
Pork	16.6	40.4	8.5 %
Beef	0.5	4.9	23.9 %
Mutton	0.6	2.4	13.6 %
Poultry meat	1.6	10.7	18.9 %
Eggs	5.3	19.5	12.5 %

Source: Zhang, et al., 1998

Preliminary results from the First Chinese Agricultural Census announced in late February 1998 indicate that livestock inventories in national statistics are overestimated, meaning livestock production and consumption have been overestimated and actual meat consumption is somewhat lower than estimated from meat production figures. (Also see Beijing Workshop Supplement below.) An overestimate of meat output is likely, with implications for figures on production

68 Convening Group comment: This is probably true for the big five exporters (USA, Canada, EU, Australia, Argentina), but China has its prices quite high already. Millennium Institute.

69 Convening Group comment: The asserting that the growth rate of yields is a policy issue is highly debatable. Until they are achieved, "breakthroughs" are not foreseeable, and the investments required to achieve them are not knowable. USDA.

70 Convening Group comment: There is also a question of self-sufficiency vs. cost, and analysts in China would serve policymakers well by imagining alternative uses of grain lands and calculating the relative costs and benefits of alternative uses and alternative degrees of grain self-sufficiency. USDA.

71 While fish and seafood are not specifically addressed in this study, they are important sources of protein in the Chinese diet and their cultivation is contributing to grain demand.

rates per animal.[72] Resolution of this discrepancy will help greatly to reduce the differences among projections of China's future feed grain import needs.[73]

Although there are uncertainties in the basic data, there is no question that a significant shift in the Chinese production and diet has taken place.[74]

The Chinese Demand for Meat in the Decades Ahead

Model simulations show a much more modest change for the next 30 years:

Table 9: Per Capita Meat Demand (in kilograms)

	1995	2025	Change, 1995–2025
Beef		3.2	
Pork		35.3	
Poultry		18.2	
Total meat	43.8	58.1	33%
Eggs	13.9	12.6	-9%

Source: Simpson, 1997, p. 14-15

Large increases are expected in Chinese stocks of livestock by 2025. The increases in beef cattle and chickens are particularly large.[75]

Table 10: Increase in Cattle, Pigs, and Chickens Under Two Economic Scenarios

	Increase 1990–2025
Beef Cattle	
Sluggish economy[76]	85%
Robust economy	60%
Pigs	
Sluggish economy	17%
Robust economy	25%
Chicken	
Sluggish economy	100%
Robust economy	100%

Source: Simpson, 1997, p. 14-15

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[72] Alexandratos, personal communication. Tuan, personal communication.

[73] Fuller. 1998.

[74] Convening Group comment: This shift in diet not only increases the demand for gain but also contributes to increased heart disease and diabetes. See, for example, Project HOPE health education program for China, rburaste@projhope.org. Millennium Institute.

[75] Convening Group comment: For further information on this topic, see ERS. 1998. "China's Livestock Economy" China Rept. USDA.

[76] Convening Group comment: Several members of the Convening Group questioned the 85% figure for the sluggish economy. The response from the author: "What I wrote is correct. When the economy is robust it is true that beef consumption will increase faster than in a sluggish economy. But, structural changes in beef production will be great. For example, mechanization will take place quickly, and cattle now used for draft will be replaced by cattle aimed only at beef production. In addition, rapid transportation improvement will lead to China's vast grasslands being shifted to production of calves (and lambs) which will be shipped for growing out to slaughter weight in crop areas. These structural changes will lead to much greater productivity increases than in pigs or poultry."

Four of the models have meat demand: ERS China Projection Model has prices and elasticities; IMPACT has prices, but not elasticities; HUANG has consumption prices and elasticities; Nyberg/GTAP has prices but not elasticities. Based on the information available, the models generally assume large elasticities on productivity, which makes production rise with relatively small changes in price.

No one provided precise information on the share of livestock that are fed grain, but Simpson indicated that he had an estimate in his model.[77]

Zhang and Xu state that a "basic balance between demand and supply or a periodical status of supply exceeding demand" now exists in China.[78]

Conversion Ratios of Feed to Meat

Three main production systems (traditional backyard, specialized households, and enterprise systems) are used in China to produce meat for consumption. While "specialized household" systems are increasing in number, along with even larger "enterprise" or "commercialized" systems, the traditional backyard operation still predominates in many parts of China. Each system has different production characteristics and feed consumption efficiencies. Other factors that affect the feed conversion ratio include the livestock species and breed, the nutritive value of the feed, animal health, weather, and husbandry (farm management).
Calculating livestock feed requirements is complicated by the fact that many crops have multiple uses and provide multiple products. For example, barley is used for human food, animal feed, and beer, and spent grains from brewing can be fed to animals. The challenge is to determine the proportion fed, particularly the amount treated chemically to improve digestibility and protein content.[79]

In addition, nonconventional feed resources account for a significant proportion of total animal feedstuffs consumed in livestock operations. In 1990, about 35% of all energy availabilities for which data could be obtained or for which calculations could be made were from such nonconventional resources. Treated straw and other low-quality forages also hold great potential to expand feed resources significantly.[80]

Calculation of feedstock requirements also depends on the mix of species in the livestock population, and major changes in China's livestock industry are in progress. The population of chickens, an animal with a low feed conversion ratio, is growing rapidly (19% per year), as is that of beef cattle, an animal able to digest grass and grow on a minimum of grain.

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[77] Simpson, 1997.
[78] Convening Group comment: Periodic imbalances of supply and demand are well known and costly economic phenomena. Dynamic models of policy, price, stocks, production, and consumption are available to analyze commodity production cycles and management options. See for example, Meadows. 1970. Millennium Institute.
[79] Simpson, 1997, p. 16.
[80] Ibid., p. 10.

While the structure of China's livestock industry is shifting toward more commercial and management-intensive production systems, there is still great variation in feed grain conversion ratios by management system and by species. For example, Simpson found that beef production conversion ratios can range from 7:1 to 3:1, and that pork production conversion ratios can range from 4:1 to 2.5:1.[81] As a result, applying a "standard" feed conversion coefficient or using maize for carbohydrate and soybeans for protein does not capture the complexity of the situation in China.

With these complexities in mind, Fang Cheng and colleagues at the Chinese Research Centre for Rural Economy (RCRE) in China and the Department of Agricultural Economics at the University of Arkansas conducted a livestock survey in seven representative provinces in China in 1997.[82] From this summary, Fang and his colleagues have been able to calculate the Feed Conversion Ratio (FCR), the Concentration Feed Conversion Ratio (CFCR), and the Feed Grain Conversion Ratio (FGCR) in China by livestock class and production system (see Table 11).

Table 11: Conversion Ratios for Feed and Grain

Livestock Class	Feed Conversion Ratio[1]		Ration of Concentrates to Meat/Eggs Output[2]			Ratio of Feed Grain to Meat/Eggs Output[3]		
	B[4]	S[4]	B[4]	S[4]	E[4]	B[4]	S[4]	E[4]
Pork	4.66	3.69	3.47	3.24	3.30-3.80	2.08	2.06	2.00-2.28
Beef	9.03	4.94	4.01	2.70	N/A	3.34	1.97	N/A[5]
Mutton	N/A	4.72	N/A	1.13	N/A	N/A[5]	0.80	N/A[5]
Chicken	N/A	22.36	N/A	2.35	N/A	N/A[5]	1.64	N/A[5]
Eggs	N/A	2.96	N/A	2.96	N/A	N/A[5]	1.96	N/A[5]

[1]Ratio of total feed consumption (concentrates and roughage) to net output of meat or eggs (kg of feed per kg of net liveweight gain of meat or eggs).
[2]Ratio of concentrates fed (feedgrains, oil meal, fishmeal, bran, and concentrate mixes) to net liveweight (kg) gain of meat or eggs.
[3]Ratio of grains (corn, sorghum, wheat, rice, barley, corn, and potatoes (grain equivalent)) to liveweight (kg) gain of meat or eggs.
[4]B stands for backyard production households; S stands for specialized production households, E stands for large-scale enterprises.
[5]N/A; not available.

The feed grain conversion ratios reported here are quite low (efficient) by comparison with many other countries and probably reflect the feeding of various crop residues and noncommercial feeds.

Reducing livestock mortality rates could improve the efficiency of livestock production systems. Current livestock mortality rates in China are 10–12% for pigs, 20–30% for chickens, and 5% each for cattle, sheep, and goats.[83] Shortages of both raw materials for feed manufacture and feed additives, as well as imbalances between the supply and the nutritional requirements of animals, may also be constraining livestock production.[84]

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[81] Ibid., p. 12.
[82] Zhang et al., 1998.
[83] Zhang and Xu, 1998, p. 3.
[84] Ibid., 1998, p. 7.

Beijing Workshop Supplement: Livestock and Other Animal Protein

Participants noted that feed grain consumption has become a larger fraction of total grain consumption as the rising affluence enlarges demand for meat. As long as income continues to grow, this trend will continue, but perhaps not at the same rate.

Significant as this matter is, there are no data available in official statistics to show how much of the total grain is consumed as feed per annum. Estimates vary from 20% to 35% of the total grain, with a gap of about 75 MMT in recent years. Several other uncertainties, including the feed-meat conversion ratio, the total meat output, and per capita meat consumption, make the estimation of feed grain consumption quite uncertain.

Zhang Cungen explained the causes for the variances from a methodological point of view. He found that there are two methods calculating feed grain consumption. The first is deduction of food grain, seed grain, industrial grain, and loss from the total; this method is simple but not reliable because the disaggregated data are also based on estimation rather than on accurate statistics. The other method, the feed-meat conversion ratio model, is methodologically more scientific but technically more difficult. Zhang C. together with He Xiurong stated that the first difficulty comes from the calculation of the feed-meat conversion ratio, which should take into account conversion variances by animal species, feed varieties, ecological regions, production systems, and other factors. Some participants noted that in the backyard livestock production system, pigs are usually fed with "a lot of green feed," which could explain what appears to be an extremely low (efficient) feed grain conversion ratio in China—that is, the rapid increase in meat production without big increases in feed grain supply. The backyard production system, however, is in decline because the rise of labor costs, the specialized farm household system, and the enterprise system are becoming increasingly important in livestock production. The question is, When will the latter systems dominate livestock production? When they do, it will mean a big increase in demand for feed grain.

Some other participants pointed out that grassland potential should not be neglected when discussing the livestock production. Huang Xiaohu noted that, contrary to the trends for cropland, grassland in the country between 1990 and 1996 increased by about 10 million ha. Luo Yousheng further pointed out that the grassland reclaimable in the country totaled about 320 million ha, which when reclaimed can contribute greatly to the meat supply. Luo made a productivity comparison between the southern provinces, where 13 million ha of grassland produced 1.65 MMT meat, and New Zealand, where the same amount of grassland produced over 4 MMT of meat. He then concluded that had the grassland productivity in these provinces reached that of New Zealand, it would have meant an equivalent increase of 20 MMT feed grain. Luo also noted that if the current grain loss of over 15% had been cut to 5% of the total output (FAO standard), it would have meant an additional 50 MMT grain for both food and feed consumption.[85]

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[85] Convening Group comment: Perhaps, but the investment to make such a large cut in grain losses would be prohibitively large. USDA.

The second difficulty Zhang C. and He referred to comes from the official statistical discrepancies between total meat output data and per capita meat consumption data, making the real meat production unknown to everybody. The discrepancy between the production and consumption suggested by some scholars could be as large as about 60%. The possibility of an overestimation of meat output is strongly suggested by the fact that consumption surveys show a level on meat intake that is much lower than the one derived from output figures. The output reports may highly overestimate actual meat production. The household consumption surveys, on the other hand, may moderately underestimate the real consumption level due to not counting the out-of-household consumption and consumption of the floating population. It is suggested by some scholars, based on their research findings, that the actual meat output is between 67% and 53% of the official output—that is, one third to one half lower than the officially proclaimed achievements. Obviously, this could be fatal to feed grain estimation.[86]

Participants noted there is a lot to be done in the livestock sector. Particular importance is attached to the parameter of feed-meat conversion ratio and the data of actual meat output. They encouraged the Research Center for Rural Economy (RCRE) to continue its analysis of the longitudinal data of the farm households from its National Rural Surveillance Network and thereby to work out a more reliable feed-meat conversion ratio. They also expected the State Statistical Bureau (SSB) to disseminate the meat output data from the Agricultural Census as soon as possible.

Policy

Agricultural policy in every country is inseparably linked to trade policy, rural-urban balance, population policy, transportation, and investment. China is no different in this regard, and agriculture policy in China needs to be integrated into the overall national strategy for politically, economically, socially, and environmentally sustainable development.[87]

Agricultural Self-Sufficiency

The government of China considers a high level of food self-sufficiency, avoiding supply shocks, and stabilizing consumer prices as matters of national security and stability. In fact, food self-sufficiency has been and will continue to be the central goal of China's agricultural policy.[88]

The State Commission has noted that: "Only when the Chinese people are free from food availability and stability of food supply worries can they concentrate on and support the current reform, thus ensuring a sustained, rapid, and healthy development of the economy."[89]

"Food self-sufficiency" has been defined by China as 95% sufficient, meaning that, on average, the net import of grain is to be kept under 5% of domestic consumption. Year-to-year variations might range from 4% to 8%. A 5% import translates to roughly 25 MMT at current total domestic consumption of about 500 MMT. An 8% import would amount to about 40 MMT.

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86 Convening Group comment: Consumption and disappearance data generally are different, even in the United States. USDA.

87 Gan, personal communication.

88 Ibid., p. 28.

89 Ibid., p. 1–2.

Another way of looking at Chinese food security is to note that 25 MMT to 40 MMT of imports are between 10% and 20% of the current world food trade of 200 MMT. It is impossible for China to feel secure importing 50–75% of its grain, as some North African and Middle Eastern countries do. Even 40% of domestic consumption would equal the current total world grain trade. And in emergencies, China would probably be reluctant to import more that 25% of the grain traded internationally, which currently would set an upper bound of 50 MMT.

To plan its food policies, China will need good information on how much grain the world can produce sustainably in the long-term and how much grain other countries will be needing. In *Who Will Feed China?*, Brown estimates that the world's grain exporters can increase their output by less than another doubling before their agricultural carrying capacity is reached. How much additional food other countries will want will depend on population and agriculture policies around the world. If world population levels off at 11 billion and if world per capita grain consumption does not increase, the additional demand by 2050 would be about 50%.

There are costs of demanding 95% self-sufficiency. Domestic grain prices are already higher than international prices, and to encourage production, domestic producer prices may need to go even higher. If the 95% self-sufficiency policy were relaxed, there would probably be increases in economic efficiency.

Chinese government officials manage domestic producer prices and international purchases in a way to balance supply and demand at minimum cost. Stocks (a State secret) are compared with desired stocks. If stocks are low relative to targets, producer prices are increased; if high relative to targets, producer prices are reduced. International purchases are influence by need and, to the extent possible, timed to coincide with low international prices.[90]

Agricultural policy in China is complicated by the fact that currently 140 million Chinese in rural areas are considered surplus labor. The preliminary report of China's first agriculture census shows the country having 561 million in its rural workforce—25% more than the official figure of 453 million. Of the 561 million, three quarters are engaged in agriculture and one quarter in rural industry. Agriculture accounts for one fourth of economic output, but three fourths of the labor force.[91] The growing gap between agricultural wages and opportunities in rural areas versus those in urban areas is drawing people out of agriculture in spite of government efforts to limit rural-urban migration. If the scale and efficiency of production are increased, there is risk of a high level of rural unemployment and political unrest.[92]

Food security for China's poorest is linked somewhat to China's overall food security problem. The U.N. World Food Programme provides 100,000 tons of grain per year for food security of China's poorest. Since people eat about 300 kg/year of grain, this is enough to feed about 330,000 people, or 0.03% of China's total population.

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[90] Authors' note: While none of the models dealt with the dynamics of stocks and prices, the basic structure for such a model has been developed. See Meadows. 1970.
[91] UN Food and Agriculture Organization. 1998.
[92] Pan, personal communication.

In the future, China will definitely need to import some food grains or feed grains or meat. If China chooses to import feed grains, its rural surplus labor can add value through livestock operations.[93]

Given the policy background above, the following are specific strategies that might be useful for achieving 92–96% self-sufficiency.

Increasing Investment in Agriculture

Increasing production will require increasing investment. China may be reluctant to borrow for investment in agriculture, so generating investments from within the sector would be helpful. The performance of the sector can be helped by reducing the state tax burden placed on the farm sector, by enhancing market and trade policies, by separating policy controls from market functions, and by removing opportunities for local officials to distort or destroy economic incentives and undermine higher-level policies.[94] Despite two decades of strong economic growth, the farm sector is still heavily taxed, and large income gaps between urban and rural populations still exist.[95]

Most investment is targeted at supply-oriented irrigation projects.[96] If water assessments are correct, diminishing returns on water supply investments are probably already being experienced, and there could be advantages in shifting investments to demand-side management and water-efficient technologies.

Applying Advanced Technologies

Growth in investment in agriculture research and development is critical for increasing future grain production. China's 1993 Agricultural Law says that the government's expenditure in agriculture should be increased at a higher rate than the growth of government revenue in the same period.[97] Also, agricultural research priorities should be based on careful evaluation with agronomic crop models focused on regional conditions in China, not on international yield comparisons for dissimilar regions.

There is a danger that research capabilities could be destroyed by institutional reform. Efficiency gains through institutional reform are often limited. Currently the technology extension system is deteriorating.

It must be kept in mind that China's ability to import high-yield technology will be influenced by China's policy on intellectual property rights.[98]

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93 Rozelle, personal communication.
94 Ibid.
95 Paarlberg, personal communication.
96 Huang and Rozelle, 1997, p. 21.
97 Ke, 1998, p. 20.
98 Rozelle, personal communication.

Opening Transportation Bottlenecks

Food security is also limited by internal transportation and grain handling capabilities. Rail transport, the primary freight mode, is efficient but insufficient to avoid peak-period congestion, especially on north/south trunk lines.[99] Shipping grain from northeastern to southern China is more expensive than importing it into the south from abroad. The volume of grain stored in deficit areas is greater than would be necessary under improved transport conditions and cannot be reliably expanded during periods of short-term need. When farmers cannot ship large crops to market (as in 1996–97), their incentive to produce falls.[100]

The capacity of ports is limited. There is insufficient bulk grain handling capability. Refrigeration capacity is critically important for shipping meat and is currently very limited. Also, opening the transportation bottleneck involves competition for infrastructure capital.

Changing Water Policy

Chinese water policy seems focused on increasing supply. Supply and demand management (efficiency) seem not to be a priority. To begin with, however, farmers will inevitably face competition for irrigation water supplies from urban and industrial users, and efficiency considerations must be considered increasingly in Chinese planning.

The south-north water transfer project is expected to provide what seems like a large amount of water—up to 20,000 MMT annually. However, since grain requires approximately 1,000 tons of water per ton of grain, the transfer will produce only 20 MMT of grain if the water is all used for irrigation, and most of it will go to urban and industrial uses.[101]

Beijing Workshop Supplement: Policy

The Beijing participants provided additional information useful for shaping the policy analytical framework, but the conversion of policy variables into model parameters remains difficult due to both the lack of quantitative policy information and to the rapid changes in China's economy.

Du Ying pointed out that the government policy could be examined through three issues: production potential, economic rationality, and political rationality. Models should focus less on sufficiency of food production and more on policy alternatives influencing the level of economically efficient and politically secure food production. The premise of a highly self-sufficient policy or a moderately import-dependent policy will have different impacts on grain supply and enlarge the variances between projections.

Tang Renjian supported the above statements and noted that China's self-sufficiency-oriented grain strategy was unlikely to change. Based on this assumption, six policies will be of key significance in constructing the policy parameters:

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[99] Ibid., note in Table 1, shown by Rozelle during his presentation.

[100] Huang and Rozelle, 1997, p. 25.

[101] Authors' note: some members of the Convening Group have observed that the figure of 1,000 tons is correct for total water needs, but that since some comes from rainfall, the requirement for irrigation is more on the order of 500 tons of water. In this case 20,000 MMT of water might produce as much as 40 MMT of grain.

- resource utilization and protection policy, of which farmland and water resource policy in a sustainable development perspective will be the core;
- land tenure policy, where safety of land availability for rural households will have direct impacts on farm investment and income;
- grain purchase and sales policy, for which the ongoing reforms will make the marketing process more transparent;
- technology promotion policy, which will determine to what extent agricultural productivity and resource utilization efficiency will be raised;
- government investment policy, through which agricultural infrastructure improvement will be influenced; and
- trade policy, in which substitution effect will work based on the comparative advantages.

Ma Xiaohe expressed similar thoughts in slightly different terms. The orientation of Chinese government agricultural policy is framed by the interaction of factors of economics, politics, and international trade environment. The political factor is particularly important; its aim is to find a way to balance supply-demand using cost-benefit and comparative advantage principles in a manner that creates enormous employment opportunities from agriculture for the huge rural labor force. This point was also emphasized by Tang and others. Ma listed the following seven policy variables to be considered for future food projection under the context of highly self-sufficient strategy: technology promotion, investment, price incentive, structural change, resource-saving, land tenure, and internal and international trade.

Chen Fan described the objectives of the government's agricultural policy as being to raise food production, enhance farm income, and protect the natural environment. The production objective has been given top priority through a series of measures, including the existing marketing institution and pricing mechanism. As incomes rise, however, there will be increased attention to environment objectives. The development of capital market will be critical to balance the three objectives and provide the funds needed by programs of soil, water, technology, and infrastructure improvement, all of which are constraints to production enhancement.

Liu Zhicheng and others described the national food consumption guideline underlying Chinese agricultural policy: a mixed diet primarily of grains and vegetables supplemented by meats, a diet rooted in traditional Oriental culture and in line with modern health science.[102]

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[102] Convening Group comment: The Beijing Supplement on policy is striking for its limited discussion of pricing policy.

RECOMMENDATIONS

The recommendations are drawn from the resource papers and from the Washington and Beijing Workshops. Most of them focus on action designed to reduce the uncertainty and improve the base of knowledge from which the projections are made. They are addressed to the research community, funders, modelers, and Chinese policymakers. They are organized into three major categories: Models, Data and Assumptions, and Policy.

The Models

A Model for the Future

To be useful, models must be a simplification of reality. Different disciplines tend to simplify in different ways. The natural resource disciplines tend to simplify price and substitution; economic disciplines tend to simplify water, agronomic constraints on yields, and the effects on grain demand of increased livestock production. The interdisciplinary assessment of this project is that a realistic and reliable analysis of China's future food security will require an integration of the disciplinary perspectives of both the economic and natural resources. To meet these requirements, changes are needed in all of the models reviewed in this study.

More specifically, the model of the future should include the following:

<u>Supply side</u>

- Yield
  - Yield projections on yield potentials derived from agronomic models, not on international comparisons
  - Ag investment on research and irrigation
  - Producer prices (output prices)
  - Energy, fertilizer, and labor prices (input prices)
  - Water availability
  - Soil quality
  - Elasticity of yield on all the above factors
- Harvested area
  - Agriculture land and its changes
  - Percentage of agricultural land for growing grains and its changes
  - Multicropping index and its changes

<u>Demand side</u>

- GDP and per capita income growth
- Consumer prices
- Income and price elasticities of food demand
- Population growth for rural and urban
- Per capita meat demand
- Feed grain demand (conversion ratios)
- Per capita food demand
- Seed, loss, and draught animal demands
- Cross price elasticities[103]

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[103] Convening Group comment: There is a question of benefit versus cost here. The rice and wheat cross price

Policy issues

Land tenure
Grain self-sufficiency rate
Meat self-sufficiency rate
Consumer prices
Producer prices
Government investment in research and infrastructure
Trade environment (WTO membership)
Grain procurement and distribution system

Analytical Methods

All the analytical methods used are adequate to address the question of Chinese food security. The primary recommendation here is for better documentation of the methods used.

Geographic Aggregation

Even treating China as a single aggregate is sufficient to address broad questions of food security, but as data quality improves, regional disaggregation to perhaps a half-dozen regions is recommended.

Structural Content

To meet these requirements, structural changes are needed in all the models reviewed in this study.

- The IMPACT, Nyberg/GTAP, OECF, and Mitchell models need to add a livestock/meat/feed grains sector.
- The ERS China Projection Model, Huang, Nyberg/GTAP, OECF, and Mitchell models need to add water constraints or at least diminishing returns to investment in irrigation.[104]
- The work of Worldwatch Institute would be stronger and more understandable if it were based on computer models rather than just mental models.

Future models need to:

- improve the representation of the Chinese markets and the state pricing/import decision system (both prices and stocks), giving particular attention to representing the actual policy instruments;
- make policy variables endogenous because in China's transitional economy they will play a leading role in determining the country's food prospect;
- include maximum potential yields calculated with agronomic models of specific crops in specific environments in order to assess realistically the maximum potential yields and the percentage of peak international yields that can be achieved in specific areas;

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elasticities are big, but all the rest are small. There may be an alternative approach that is more effective. USDA.

[104] Authors' note: The Convening Group members agree with this point for North China, but not all are persuaded for South China. Nonetheless, while water is generally much less of a problem in the south than in the north, there are reports that even the Yangtze River may soon run dry in some stretches for part of the year because of the adverse impact of deforestation on aquifer recharging. The flooding is exacerbated by the deforestation, and when the runoff is fast (during floods) the recharge is reduced. See, for example, Welcomme, 1995 and FAO, 1995.

- separate out roots and tubers from crops defined internationally as “grain”;
- include fish production[105];
- incorporate the three main livestock production systems (backyard, specialized household, and enterprise) in the feed grain/livestock sector and address the trend toward large-scale systems;
- include both international and domestic prices;
- document clearly and publicly the structure, assumptions, and data used;
- include an overall indicator of Chinese food security including weather variability; and
- include irrigation in enough detail to address water actually delivered in the field and to assess the cost and benefits of a wide variety of water conservation technologies.

Future applications of models need to:
- improve the presentation of results to policymakers: short-term levers need to be related to the long-term problems; countries have long-term problems, but only short-term policy levers; in presenting the results of model analysis, attention is needed to recommendations for addressing long-term problems with short-term policy levers; recommendations derived from the models need to be explained clearly and related to available policy actions;
- use sensitivity analysis to identify which of the assumptions most strongly influence the model results;
- include the costs of assumed changes—increases of yields, MCI, irrigation, south-north water transfer, etc.—and comparisons with alternative uses of capital;
- analyze scenarios the include the historical variations of weather;
- explore the consequences of the climate change scenarios of the Intergovernmental Panel on Climate Change (IPPC), which suggest northern China may become even drier than it currently is, with even more erratic precipitation, and South China may experience more floods and hurricanes[106];
- analyze transport costs to account for price differentials of imported products in different regions of China so that projections can be made about how much will be grown (and invested) locally versus imported; and
- calculate the annual costs to China of maintaining domestic prices above international prices and limiting access to international grain markets.

Modelers should:
- develop a list of the structural changes that Chinese policymakers might make in the agricultural sector and analyze them in scenarios;
- publish projections based on the S&A reference scenario (see Appendix I) to make the comparison of models easier;
- make clear and justify assumptions for future trends in the MCI;
- make the price elasticities from their models transparent and accessible;
- represent better the complex food pricing and grain purchasing system in China, since the state pricing and purchasing decisions are still important in balancing supply and demand;

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[105] Nickum, personal communication.
[106] Watson, Zinyowera, and Moss. 1997.

- use without hesitation the best estimates available for data and assumptions even if they are quite uncertain, but document them clearly so that policymakers have a clear understanding of what is being assumed and what uncertainties need to be resolved;
- analyze cost trade-offs for alternative uses of land and water; and
- quantify and specify the contributions of investment in agricultural research to increasing yields and the lags between investment and increased yield in the field.

Model development plans (also see Appendix H):
- IFPRI: strengthen water and natural resource representation in IMPACT.
- World Bank: no immediate plans for further work with GTAP.
- ERS: improve livestock component of China Projection Model.
- Worldwatch Institute: would like to see a simple model used to assess production potential for both exporters and importers.
- Millennium Institute: seeks collaborators to refine and apply the ChinaAg model.
- RCRE: wants to develop a China model.

Data and Assumptions

The recommendations on data and assumptions cover four areas: land and soils, water and irrigation, yields and agricultural productivity, and livestock and other animal protein.

Land and Soils

Data and assumptions on China's land and soil are discussed under two topics, soil quantity and soil quality.

<u>Soil Quantity</u>

Recent surveys by the State Land Administration Bureau represent a major leap forward in the quality of information on how much land is being cropped. Nonetheless, still better information is critically important for managing China's land and water resources.

- The State Statistical Bureau of China must quickly rationalize Chinese land and yield statistics, correcting the 39% underreporting of cropped area and revising yields downward accordingly. Until the bureau corrects and adjusts the national land and yield statistics, decisionmakers and policy analysts in China will be operating with seriously misleading information on matters of extreme importance to the food security and welfare of China.
- The work of the Institute of Soil Science in Nanjing, FAO, and the International Soil Reference and Information Centre in the Netherlands should be supported, as well as that of the State Land Administration Bureau.
- The Ministry of Agriculture, other relevant ministries, the Chinese State Statistical Bureau, Chinese Academy of Sciences, and Chinese Land Management Bureau should:
    - consider further GIS data applications, including hydrological inventories, stream flows, climate change, weather variability, precipitation, crop yields, and livestock inventories and consumption rates.;
    - compile statistics on the rate, sources, and causes of land loss and land reclamation,

    and then combine these to provide information on the increase or decrease of land planted in grain by region;
    - collect information about the mechanisms by which the multicropping index may be increased or decreased, including influences of water availability, labor availability, prices, investments, GDP growth, and the investment of funds and the time lags to achieve specific increases in MCI;
    - collect data on and develop models of the impact of urbanization and income growth on agriculture; and
    - analyze and report the expected amount of increase in the area of water catchments needed to store more water in North China and the amount of land expected to be taken from agricultural production.

Soil Quality

Information about soil quality and trends was inconclusive. The challenge is to integrate the data and produce a solid time series.

- The government, funders, and assistance agencies need to provide resources to build a comprehensive inventory of China's land and soil quality as soon as possible. A careful inventory of land and soil quality is needed. Information on soil classification, soil chemistry, and soil physics is not sufficient; information is needed on soil depth and structure, soil erosion, the type of erosion, and water- and nutrient-holding capacity.
- Researchers and relevant ministries in China should:
    - compile and publish data on how atmospheric conditions (such as acid rain) and land use practices affect not just soil chemistry, but also the quality of soils in China—the structure of the soil and the biology of the flora and fauna;
    - analyze and report the impact of soil changes on agricultural yields; and
    - compile better data on the areas affected by soil salinization, drought, and urban water shortages by region; crop and economic loss estimates would also be useful.

Water and Irrigation

Reducing the range of opinions on China's future food security requires more definitive data on water usage, current supply, supply potential and the state of irrigation systems, and the timing of anticipated increases or decreases in demand and supply.

Further region-specific water analysis is needed to provide a basis for more definitive assessment of the impact of water constraints.

- China's State Statistical Bureau and Water Conservation Ministry must examine irrigated area data to determine if a similar problem of underreporting exists in these statistics as well as in the harvested area statistics.

Demand for Water

- The Ministries of Science and Technology, Agriculture, and Water Conservation, together with the State Statistical Bureau, need to separate out by region information on how much water is needed for growing grains and other crops over the next three decades.

- Relevant ministries should compile information on price elasticities of demand for irrigation water by region, sector, and crop.
- Relevant ministries and researchers should collect data on the range of in-field water response functions for different regions and crops.

Water Supply

- Relevant ministries should study carefully and extend the ground water assessment work of Dennis Engi (see http://www.igaia.sandia.gove/igaia/china/chinamodel.html). Perhaps more detailed, region-specific information is available from the China Institute of Water Resources and Hydropower Research, and perhaps Chinese information can be integrated into the Engi water model for China.[107]
- Relevant ministries, possibly in collaboration with international agencies, should establish a standard for collecting and organizing irrigation and water data (including effectively irrigated area, use application rates, water wasted, water polluted, water table levels, pumping rates, and sustainable pumping rates) by, for example, river basins, provinces, or agricultural regions or by agrohydrological regions, using the Shin Li Bu (Ministry of Water Resources) survey of the 1980s; this work needs appropriate funding.
- The State Statistical Bureau should apply comprehensive reporting systems to irrigation systems.[108]
- Relevant ministries should release more detail on China's water infrastructure plans, including information on the quantity and timing of planned water transfers, where water will be used, and for what purposes.
- Wang and Shen should extend their data and analysis for China's planned water allocation programs with information about when the allocated water is expected to be available and details about how much water is being transferred to where and for what uses via the South-to-North Water Transfer Project.
- The Chinese government should clarify what rules govern farmers' decisions about the use of water. Information is needed on the workings of the current pricing and market allocation mechanisms, and on the criteria that will allow farmers to make decisions about their use of water. How, for example, will competition for water between the agricultural sector and Town and Village Enterprises be resolved?
- Relevant ministries and researchers should consider the following questions on water and irrigation raised by several Washington and Beijing Workshop participants:
    - If the actual cropland area in China is understated by some 40%, is the irrigated area similarly understated?
    - How deep are the aquifers in China, particularly those that are being depleted under the North China Plain and elsewhere?
    - What is a reasonable rate of pumping that might be sustained?
    - What share of China's irrigation is based on the unsustainable use of water?
    - To what extent is aquifer depletion irreversibly impairing the capacity of aquifers to

[107] Engi. 1997.
[108] Nickum, personal communication.

store and transport water?

- How will loss of irrigation water affect fertilizer use and the potential for raising land productivity?
- What is the economically feasible potential for increasing irrigation efficiency?

Yields and Agricultural Productivity

Yields and agricultural productivity depend on many inputs. Participants focused on land quality, water available to plants, new technologies, new management practices, prices, and incentives that encourage investments in improving land.

- No assessment of future crop yields can be made until there is an accounting of present individual crop yields by individual regions. The development of this inventory is thus a high priority for China.[109]
- Assessments of future yields cannot be based on international comparisons, but must be based on yield potentials calculated with crop-specific agronomic models. China needs to review the literature on plant models created by agronomists and apply the models.[110] A good starting point for China's own analysis may be available from the FAO and the International Institute of Applied Systems Analysis (IIASA). FAO and IIASA have collaborated to produce a database and report on 20 agroecological zones in China and maximum yields of various crops that may be achieved in these zones.[111]
- Separate analyses of potential yield increases and the time and cost to achieve them are needed. Agronomic crop models (now well developed and reliable) should be used to assess maximum potential yields for the various regions of China.
- Relevant ministries and researchers should determine yield potentials by crop species and region. Climatic differences across China and yield capability differences among crops make it necessary to develop a fairly refined description of current cropping status; several approaches are possible: intensive field surveys, satellite observations combined with simple crop models, or a combination of the two.[112]

Soil Degradation

Yields are affected by the amount of land under cultivation and by soil's capacity for growing a particular crop—its fertility or ability to deliver water and nutrients to growing plants. As noted earlier, better data on the quality and quantity of cropland in China are needed.

- Relevant ministries and researchers are encouraged to compile data on water and soil erosion in the grasslands of the "underdeveloped western area," especially that caused by overgrazing and overuse of soils.

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[109] Ibid.

[110] See the papers by Amir and Sinclair (1991), Park and Sinclair (1993), Sinclair (1984), and Sinclair (1994) and others.

[111] Alexandratos, personal communication.

[112] Ibid

Water Supply and Grain Yields

Participants emphasized that yield potentials are affected not only by the water delivered to the roots of plants, but also by the weather, insulation, length of day, temperature profile, and humidity.

- Relevant ministries and researchers should develop a comprehensive in-field water response function by crop land by level of fertilizer application.[113]
- Relevant ministries should establish a network of weather stations and collect basic weather data including at least daily minimum and maximum temperatures, precipitation, humidity, and solar radiation.[114]
- Researchers and farmers should work to increase the efficiency of water use once the water reaches the field.[115]

Investments in Agricultural Research and Irrigation

- Since return on investment in water varies greatly with area-specific conditions (humidity, soil properties, length of day, temperature and insulation profiles, etc.), relevant ministries, researchers, and farmers should establish priorities for irrigation based on these conditions.[116]
- Relevant ministries, researchers, and farmers should work together to investigate alternative irrigation technologies to reduce water use and deliver more water to the soil under crops.[117]
- Relevant ministries, researchers, and farmers should collaborate to investigate the problems associated with sustained irrigation. Issues to be addressed include fertilization, pest management in humid climates, balancing variable rainfall with irrigation, waterlogging, salinity, and wastewater disposal.[118]
- Researchers should collect data on the impact of irrigation on yields.[119]

Price of Fertilizer and Labor, and Producer Prices

Relevant ministries, researchers, and farmers should collaborate to determine the effect of the quantity of different types of fertilizer used (by crop), labor, and producer prices on yields by crop and region.

Land Tenure

While further study of the influence of land tenure policies on yields may produce further useful insights, enough is known already that the policy of longer-term extension should be strictly implemented as a base for sustained and sustainable agricultural growth.

[113] Convening Group comment: State Statistical Bureau may have this data already. USDA.
[114] Alexandratos.
[115] Ibid.
[116] Sinclair.
[117] Ibid.
[118] Ibid.
[119] Ibid.

Technology Advances and Related Trends

Many of the technology advances expected are in the area of improved crop cultivars, irrigation systems, and management practices. Labor, education, and urbanization trends will all affect what happens in the agriculture sector.

- Researchers should compile data on the extent to which the application of integrated prevention and control techniques (such as integrated pest management) would help reduce grain loss as well as environmental damage from agriculture.[120]
- Researchers should consider how investments in education and literacy programs affect labor productivity, especially in agriculture.
- Researchers should develop a method to anticipate the impact on yields of greater investment in agricultural research and irrigation.

Livestock and Other Animal Protein

Although recent work has allowed a more sophisticated analysis of the livestock sector, a great deal remains to be done in order to understand its complexities and how production systems and efficiencies may change in the future as demand for meat increases and new technologies are used.

Demand for Meat

- Researchers should compile data on how diets change as per capita income rises as well as price elasticities of demand, by type of meat and by region. Particular attention should be given to the leveling off of meat demand at high income levels.

Conversion Ratios of Feed to Meat

The feed conversion ratios from a survey of seven provinces in the paper by Zhang et al. provides a basis for incorporating present feed conversion rates into models.[121]

- A separate, regional-specific model is needed to determine future conversion rates.[122] The model should include feed conversion technologies in sufficient detail to capture the effects of new technologies, some of which may be large.[123] Nonconventional feed resources should be included to account for crops that have multiple outputs—some used for livestock, some for humans.
- Researchers and relevant ministries should continue to compile additional data on feed conversion ratios by region, type of production system, and animal type.[124]

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120 Chen and Pan, 19997, note to Table 4.
121 Zhang et al., 1998.
122 Simpson, 1997, p. 30.
123 Fuller, personal communication.
124 Ibid., p. 31.

Feeding Grain to Livestock

- The Research Centre for Rural Economy should conduct annual surveys of livestock production systems, expanding and sharpening the questions based on the results of their first survey.[125]
- Researchers should determine livestock mortality rates. If they are high, measures should be taken to lower the rates, and these should be incorporated into livestock models.[126]
- Relevant ministries and researchers should determine the extent of shortages of raw materials for feed manufacture and of feed additives (such as meals and nutritional/mineral additives), as well as any imbalances between the supply and the nutritional requirements of animals. If these are more than minor, they may restrict any possible improvements in feed conversion ratios and livestock production, and should be included in the models.[127]
- Relevant ministries and researchers should compile data on production along with estimates of the number of operations in each type of livestock production system (backyard, specialized, and large-scale), the grain inputs of each type of livestock production system, the quantity of production, and the speed at which technological and management changes are taking place.[128]

Other

- Relevant ministries and the State Statistical Bureau should standardize the definitions used (for "grain," for example) in their statistics collection and reporting.
- Researchers should determine the environmental impacts of manure removal and disposal from the more concentrated livestock production systems.[129]
- Where possible, ministries and researchers should conduct their research based on surveys rather than the old comprehensive reporting system census because the survey is much more cost-effective.

Policy

The aim of the Strategy and Action Project was to identify recommendations for action that would, in a relatively short period of time, reduce the differences among projections by modelers about the future of China's food security, or to be more specific, about China's future food import needs.

Most if not all of the resource papers and the discussions at both the Washington and Beijing Workshops offered policy recommendations that join other works on the subject.[130] Reduced to their essence, most of the policy recommendations are for policymakers to answer (or to change their answer for) the following difficult questions:

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[125] Fred Crook, personal communication.
[126] Ibid.
[127] Zhang and Xu, 1998.
[128] Simpson, 1997, p. 31.
[129] Ibid.
[130] See, for example, Cheng, Findlay, and Watson, 1997.

- What level of food and feed grain self-sufficiency will be sought?
- What level of meat self-sufficiency will be sought?
- How will producer and consumer prices be set and how will they change?
- What will be the level and allocation of government agricultural investment?
- What will be the land tenure policy for the next 30 years?
- What will be the tax burden on the rural and farm sector?
- W hat about China's entry into the World Trade Organization (WTO)?
- To what degree will there be separation of policy tasks from market functions?[131]

There are a variety of other policy issues that have an impact on Chinese food security. These include:

- China's population control policy, which has had significant effects on food demand[132];
- financial, legal, and other institutional frameworks that are needed for the market to work effectively[133];
- controls on the import, marketing, and price of fertilizer, which are currently excessive[134];
- efficient and sustainable use of natural resources and environmental protection, which is essential for China's long-term food security (the reclamation of lands, leaving little habitat for endangered species, and the intensive use of fertilizers and pesticides, which has widespread ecological consequences and even impacts on the development of the human fetus,[135] are just two of many environmental issues that require attention);
- the shift in China's diet toward higher meat consumption, which has adverse health effects; and
- post-harvest losses, which are high in China and should receive the attention of analysts and policymakers.

[131] Ibid.
[132] Ke, personal communication.
[133] Ibid., p. 25.
[134] Ibid.
[135] Colburn, 1996.

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Appendices

Appendix A. The ChinaAg Model

The objective of the ChinaAg model is to provide a relatively understandable, convenient, and useful policy tool for use by Chinese and other policymakers and researchers in assessing the future of Chinese food security in the face of many uncertainties.

The ChinaAg model is a "draft" model. It is hoped that once Chinese researchers have learned to use this tool and evaluated its components (structure), relationships (equations), and assumptions (data), it can be refined and updated to become a participatory and consensus-building tool to facilitate Chinese national and regional decisionmaking.

The ChinaAg model has the following features:

1. It is transparent. All its components, equations, and assumptions are quickly available to users for verification and communication purposes.

2. It is tested. The simulation starts from 1980, and the results from the model during 1980–98 are compared with actual data during the same period for model adjustment and verification. After the historical results from the model fit reasonably well with actual data, the model continues to simulate the future from 1998 to 2020. The simulation is not a simple extrapolation, but a complex, dynamic simulation of interaction of all of the variables.

3. Prices are exogenous. The pricing, purchasing, and marketing systems of China are changing, and if prices were endogenous, adjusting the model for the historical period of 1980–98 to match real supply, demand, and prices would be more effort than could be managed under this project.

4. It is flexible. Additional regions, crops, meats, and even and endogenous pricing/stock system can be added relatively easily.

5. It is region-specific. The ChinaAg model covers six geographic regions: Northeast (Heilongjiang, Liaoning, Jilin); North (Shandong, Hebei, Beijing, Tianjin, Henan, Shanxi); Northwest (Shaanxi, Gansu, Nei Monggol, Ningxia, Xinjiang, Qinghai); East (Zhejiang, Jiansu, Shanghai, Anhui); Central (Hubei, Sichuan, Hunan, Jiangxi); and South (Guangdong, Guizhou, Yunnan, Xizang Guangxi, Fujian, Hainan).

6. It is crop- and meat-specific. The ChinaAg model has four grains and seven meats.

Further information on the model is provided in Qu, Weishuang and Barney, Gerald O. 1998. "Projecting China's Grain Supply and Demand Using a New Computer Simulation Model." Millennium Institute Professional Paper #15.

Appendix B: List of Participants and Observers for the Washington Workshop

Participants

Nikos Alexandratos, Chief, Global Perspectives Studies Unit, Economic and Social Department, UN Food and Agriculture Organization; Rome, Italy

Gerald O. Barney, President, The Millennium Institute; Arlington, VA; USA

Philip Bogdonoff, Vice President, The Millennium Institute; Arlington, VA: USA

Lester R. Brown, President, Worldwatch Institute; Washington, DC; USA

Cheryl Christensen, Deputy Director, International Programs, Market & Trade Economics Division, Economic Research Service, US Department of Agriculture; Washington, DC; USA

Hunter Colby, Economist, Economic Research Service, U.S. Department of Agriculture; Washington, DC; USA

Frederick W. Crook, Agricultural Economist, Economic Research Service, U.S. Department of Agriculture; Washington, DC; USA

Shenggen Fan, Research Fellow, International Food Policy Research Institute, Washington, DC; USA

Cheng Fang, Research Associate, Agricultural Economics & Rural Sociology, University of Arkansas; Fayetteville, AR; USA

Gan Shijun, Professor, Chinese Society for Sustainable Development; Beijing; P.R. CHINA

Ke Bingsheng, Director-General, Research Center for Rural Economy, Ministry of Agriculture;Beijing; P.R. CHINA

Peter H. Lindert, Agricultural History Center, University of California, Davis; Davis, CA; USA

Liu Zhaodong, Minister-Counsellor, Science and Technology, Embassy of the PRC; Washington, DC; USA

Alex F. McCalla, Director, Agriculture & Natural Resources, World Bank; Washington, DC; USA

Mei Fangquan, Director General, Scien-Tech Documentation & Information Centre, Chinese Academy of Agricultural Sciences; Beijing; P.R. CHINA

James Nickum, Dept. of Social and International Relations, Graduate School of Arts and Sciences, University of Tokyo; Tokyo, JAPAN

Albert Nyberg, Senior Agricultural Economist, Rural and Social Development, The World Bank; Washington, DC; USA

Robert Paarlberg, Professor, Department of Political Science, Wellesley College; MA; USA

Pan Xiaoming, Inst. Systems Science, Academia Sinica, International Input-Output Assoc., Member, Zhong Guan Cun; Beijing; P.R. CHINA

Per Pinstrup-Andersen, Director General, International Food Policy Research Institute; Washington, DC; USA

Weishuang Qu, Director of Information Systems, The Millennium Institute; Arlington, VA; USA

Mark Rosegrant, Research Fellow, Environment, Production & Technology, IFPRI; Washington, DC; USA

Scott D. Rozelle, Associate Professor, Economics, Stanford University; Stanford, CA; USA

James Simpson, Professor, Ryukoku University; JAPAN

Thomas Sinclair, Plant Physiologist, Agricultural Research Service, US Department of Agriculture; Gainesville, FL; USA

Francis Tuan, Agricultural Economist and Leader of the China Project, Economic Reserach Service, U.S. Department of Agriculture; Washington, DC; USA
Wang Hao, Professor, Department of Water Resources; Beijing, P.R. CHINA
Zhang Jichen, Admin. Centre for China's Agenda 21; Beijing, P.R. CHINA

Observers

Changuang Bian, Correspondent, Washington Bureau/Science & Tech. Daily, Alexandria, VA; USA
Susan Bradley, Director of Development, Millennium Institute; Arlington, VA; USA
Brian Brandenburg, Senior Livestock Specialist, The World Bank, China – East Asia Region, Washington, DC; USA
Frank Fuller, FAPRI / CARD, Iowa State University; Ames, IA; USA
Michael Gilbert, Modeling Intern, Millennium Institute; Arlington, VA; USA
Liyuan Gu, Correspondent, Xinhua News Agency; Arlington, VA; USA
Brian Halweil, Staff Researcher, Worldwatch Institute; Washington, DC; USA
Jean Harrison, Special Assistant, Millennium Institute; Arlington, VA; USA
Erland Heginbotham, Chief, China Agriculture Project, Institute for Global Chinese Affairs, University of Maryland; College Park, MD; USA
Hideki Hongo, Chief Representative, Agriculture & Livestock Industries Corporation, Cherry Creek Plaza 1, Suite 640; Denver, CO; USA
Hsin-Hui Hsu, Agricultural Economist, Economic Research Service, U.S. Department of Agriculture; Washington, DC; USA
Dingjin Hu, Second Secretary, Science & Technology, Embassy of the PRC; Washington, DC; USA
Jing Huang, Cambridge, MA; USA
Reah Janise Kauffman, VP for Special Activities, Worldwatch Institute; Washington, DC; USA
Walter E. Parham, Honorary Professor at South China Ag. Univ., Vienna, VA; USA
Josef Schmidhuber, O.E.C.D. - O.C.D.E.; Paris, FRANCE
T.C. Tso, Chair of the Board, Institute of International Development & Education in Agriculture & Life Sciences (IDEALS); Beltsville, MD; USA
Bernard Wasow, Program Officer, Community & Resources, Ford Foundation; New York, NY; USA
Changhua Wu, World Resources Institute, Washington, DC; USA
Xiao Zhang, Dept. of Civil Engineering, University of Virginia; Charlottesville, VA; USA

Appendix C: Participants in the Beijing Workshop

Gerald O. Barney, President, Millennium Institute; Arlington, VA USA
Ke Bingsheng, Director-General, Research Center for Rural Economy, Ministry of Agriculture; PR China
Lester R. Brown, President, Worldwatch Institute; Washington, DC, USA
Fang Cai, Deputy Director-General, Research Institute for Population, Chinese Academy of Social Sciences; PR China
Liqun Cao, Division Director, Research Center for Rural Economy, PR China
Fan Chen, Deputy Director, Foreign Capital Project Management, State Leading Group Office for Poverty Alleviation; PR China
Jiyuan Chen, Director-General, Research Institute for Rural Development, Chinese Academy of Social Sciences; PR China
Kun Chen, Deputy Director, Chinese Society for Sustainable Development; PR China
Xiwen Chen, Senior Research Staff, Development Research Center of State Council; PR China
Guoqiang Cheng, Senior Research Fellow, Research Institute of Agricultural Economy, Chinese Academy of Agricultural Sciences; PR China
Yin Du, Director-General, Department of Policy Reform and Law, Ministry of Agriculture; PR China
Shijun Gan, Director-General and Prof., Dept. of Science and Technology for Social Development, Ministry of Science & Technology; PR China
Jianjua Guo, Research Staff, Research Center for Rural Economy; PR China
Jun Han, Deputy Director-General, Research Institute for Rural Development, Chinese Academy of Social Sciences; PR China
James Harkness, Representative, Ford Foundation; USA
Gehua He, Deputy Division Director, Department of Rural Science and Technology, Ministry of Science & Technology; PR China
Huiwei He, Research Staff, Research Center for Rural Economy; PR China
Xiurong He, Dean and Professor, College of Economics and Management, China Agricultural University; PR China
Yupeng He, Deputy Division Director, Research Center for Rural Economy; PR China
Hsin-Hui Hsu, Agricultural Economist, Economic Research Service, US Department of Agriculture; USA
Jikun Huang, Director, Agricultural Policy Research Center of Agricultural Economy, Chinese Academy of Agricultural Sciences; PR China
Xiaohu Huang, Senior Research Fellow, Chinese Institute for Land Surveying and Planning, State Land Administration; PR China
Zhongyi Jiang, Senior Research Fellow, Research Center for Rural Economy, Ministry of Agriculture; PR China
Reah-Janise Kauffman, Vice President, Worldwatch Institute; USA
Else Larsen, Representative, World Food Program; PR China
Kerstin Leitner, Resident Representative, United Nations Development Program; PR China
Justin Lin, Director and Professor, China Center for Economic Research, Peking University; PR China
Zhicheng Liu, President, Chinese Association of Agricultural Economists; PR China
Zhiren Liu, Senior Research Fellow, Research Center for Rural Economy, Ministry of Agriculture; PR China

Shaoqing Lu, Deputy Division Director, Research Center for Rural Economy; PR China
Yousheng Luo, Former Director-General, Department of Policy Reform and Law, Ministry of Agriculture; PR China
Xiaohe Ma, Deputy Director-General, Economic Research Institute, State Development Planning; PR China
Fangquan Mei, Director-General, Science-Technology Documentation and Information Center, Chinese Academy of Agricultural Sciences; PR China
Jianping Miao, Former Director-General, Research Center for Rural Economy, Ministry of Agriculture; PR China
James Nickum, Visiting Professor, University of Tokyo; Japan
Roufeng Niu, Senior Research Staff, Research Institute of Rural Economy, Chinese Academy of Agricultural Sciences; PR China
Weishuang Qu, Director of Information Systems, Millennium Institute; USA
Guangzhao Ren, Deputy Director-General, Department of Water Administration and Water Resources, Ministry of Water Resource; PR China
Hongyuan Song, Division Director, Research Center for Rural Economy; PR China
Tsutomu Tanaka, Professor, Chuo University; Tokyo, Japan
Renjian Tang, Deputy Director-General, Department of Policy Reform and Law, Ministry of Agriculture; PR China
Liang Tong, Director, International Training Center for Sustainable Development; PR China
Dewen Wang, Research Staff, Research Center for Rural Economy; PR China
Hao Wang, Senior Research Fellow, China Institute of Water Resources and Hydropower Research, Ministry of Water Resources; PR China
Hongguang Wang, Professor, China Agricultural University; PR China
Weizhong Wang, Dept Director-General and Professor, Dept. of Science and technology for Social Development, Ministry of Science & Technology; PR China
Xiaoming Wang, Deputy Division Director, Research Center for Rural Economy; PR China
Ying Wang, Division Director, National Feed Industry Office, Ministry of Agriculture; PR China
Wei Wei, Division Director, Research Center for Rural Economy; PR China
Simei Wen, Dean and Professor, College of Economics and Trade, South China Agricultural University; PR China
Tiejun Wen, Division Director, Research Center for Rural Economy; PR China
Zhude Xian, Deputy Director-General, General Organization of Rural Social Economic Survey, State Statistical Bureau; PR China
Tingkai Yang, Deputy Director-General, Office for National Feed Industry, Ministry of Agriculture; PR China
Xiaoliu Yang, Director, China Institute of Water Resources and Hydropower Research, Ministry of Water Resources; PR China
Cungen Zhang, Senior Research Fellow, Research Institute of Agricultural Economy, Chinese Academy of Agricultural Sciences; PR China
Jiayuan Zhang, Deputy Director-General, Administrative Center for China's Agenda 21; PR China
Jichen Zhang, Administrative Center for China's Agenda 21 (ACCA21); PR China
Lingxiu Zhang, Deputy Director, Agricultural Policy Research Center, Research Institute of Rural Economy, Chinese Academy of Agricultural Sciences; PR China

Wenbao Zhang, Deputy Director-General, Research Center for Rural Economy, Ministry of Agriculture; PR China
Yue Zhang, Senior Research Fellow, Department of Rural Water Resources, Ministry of Water Resources; PR China
Xiaohui Zhang, Deputy Division Director, Research Center for Rural Economy; PR China
Xigang Zhu, Director-General, Research Institute of Agricultural Economy, Chinese Academy of Agricultural Sciences; PR China

Appendix D. Program for the Washington Workshop

The Strategy and Action Project for Chinese and Global Food Security
Working Meeting, February 17-19, 1998

<u>Program</u>

Note: to the fullest extent possible this working meeting will have no papers presented. Papers will be prepared and distributed in advance, and participants are encouraged to read them before the working meeting begins. In reality, some brief introduction to the papers is needed, but the meeting time will be used primarily for discussion and consensus building on the draft report.

<u>Tuesday, Feb. 17</u>

6:30pm - 10:00pm	**Welcoming dinner at the Cosmos Club** 2121 Massachusetts Avenue, N.W., Washington, DC 20008, Tel: 202 387-7783
6:30pm	Wine & Cheese
7:30pm	Dinner
8:30pm	Guest speaker: **Per Pinstrup-Andersen, IFPRI**, "Emerging Issues Related to the World Food Situation"

<u>Wednesday, Feb. 18</u>

The working meeting is being hosted by the International Food Policy Research Institute (IFPRI) in the **second floor conference room** of their offices at:

Location: 1200 17th Street, N.W.
Washington, DC 20036,
Tel: 202 862-5600

8:30am

Welcome & Introductions: Per Pinstrup-Andersen, IFPRI
Cheryl Christensen, USDA/ERS

Goals of the working meeting: Jerry Barney, Millennium Institute

- Achieve consensus on specific actions needed to reduce the uncertainties in projections of China's future agricultural supply and demand.
- A report of the consensus with specific recommendations.

Rapporteur for the working meeting: Philip Bogdonoff. As each area is covered, the key points, agreements, and differences will be summarized.

9:00am

> ***Key sources of the projections:***
> Comparison of the key models and similarities and differences among them.
> Presenter: **Weishuang Qu, MI, 15 min.**
>
> **Responses by modelers:**
> Lead respondents: **Shenggen Fan** and **Nikos Alexandratos, 5 min. each.**
>
> **Discussion, 35 minutes**
>
> Moderator: **Jerry Barney**

10:00am *COFFEE BREAK*

10:15am

Discussion of Issue Papers, based on papers distributed in advance, of critical resource and environmental factors which models must include.

Format:

- Presentation by Issue Paper author, up to 15 minutes
- Two discussants, up to 7 minutes each
- Open discussion

Moderator for all Issue Paper discussions: Jerry Barney

Land:

- Presenter 1: **Peter Lindert**
- Presenter 2: **Godert van Lynden**'s paper (presented by Fred Crook)
- Presenter 3: **Mei Fangquan**
- Lead respondents: **Fred Crook** and **Ke Bingsheng**

12:15pm *LUNCH*

1:30pm

Water and Irrigation:

- Presenter 1: **Jim Nickum**
- Presenter 2: **Wang Hao**
- Lead respondents: **Lester Brown** and **Mark Rosegrant**

3:00pm *COFFEE BREAK*

3:30pm

Yields & Agricultural Productivity:

- Presenter 1: **Thomas Sinclair**
- Presenter 2: **Pan Xiaoming**
- Lead respondents: **Mei Fangquan** and **Al Nyberg**

5:00pm DAY'S SUMMARY by Rapporteur.

5:30pm *Break for DINNER*

<u>**Thursday, Feb. 19**</u>

8:00am RECAP, AGENDA REVIEW

8:30am

Livestock:

Presenter 1: **James Simpson**
Presenter 2: **Zhang Jichen**
Lead respondents: **Francis Tuan** and **Fang Cheng**

10:00am *COFFEE BREAK*

10:15am

Government Policies:

Presenter 1: **Scott Rozelle**
Presenter 2: **Ke Bingsheng**
Presenter 3: **Gan Shijun**
Lead respondent: **Robert Paarlberg**

11:30am

Discussion of Model Development Programs and the incorporation of new data and knowledge in the areas discussed yesterday, including suggestions of how environmental and resource factors are best included.

Questions:

1. What were your plans before today?
2. How will you modify what you'll do based on what you've heard so far?
3. What comments do you have about the other models?
4. What weaknesses do you see in your own models? e.g., what data do you see you now need?

- IFPRI -- **Mark Rosegrant**
- World Bank -- **Al Nyberg**
- USDA/ERS -- **Hunter Colby**
- Worldwatch -- **Lester Brown**
- FAO -- **Nikos Alexandratos**

Moderator: **Jerry Barney**

12:30pm *LUNCH*

1:30pm

Summarize Preliminary Conclusions and Implications: What have we learned and what do we need to do next? Our plans are to identify the key issues that have emerged from the meeting, and then—on the fly—pick someone to make opening comments. We are thinking of three areas:

1) areas of convergence,
2) areas of divergence, and
3) unknowns.

Respondent 1: Fred Crook
Respondent 2: Thomas Sinclair
Respondent 3: Francis Tuan

Moderator: **Jerry Barney**

2:15pm

Outline Overall Agenda and Research Requirements for the next five years, with recommendations for home institutions, Chinese institutions, and funding institutions on:

- model improvements: Weishuang Qu
- data development needed: Mark Rosegrant
- further research needed: Philip Bogdonoff
- new topics to be addressed: Gerald Barney

Moderator: **Lester Brown**

3:15pm *COFFEE BREAK*

3:45pm

Conclude with:

- next steps
- commitments

Led by: **Jerry Barney** and **Cheryl Christensen**

4:45pm ACKNOWLEDGEMENTS

5:00pm ADJOURN, WINE & CHEESE RECEPTION

* * *

Appendix E. Program for the Beijing Workshop

The Workshop on China's Future Agricultural Supply and Demand

Notice for Delegates

Meeting Program

May 27	7:30 a.m.	--	8:00 a.m.	Breakfast
	10:00 a.m.	--	12:30 p.m.	Session 1
	12:40 p.m.	--	14:00 p.m.	Lunch
	14:00 p.m.	--	17:30 p.m.	Session 2
	18:00 p.m.	--	19:30 p.m.	Reception
May 28	7:30 a.m.	--	8:00 a.m.	Breakfast
	8:30 a.m.	--	12:00 p.m.	Session 3
	12:10 p.m.	--	13:30 p.m.	Lunch
	13:30 p.m.	--	16:30 p.m.	Session 4
	18:00 p.m.	--	19:00 p.m.	Dinner

To Be Noticed

1. The cafeteria for delegates is at Asia Dining Hall on the 1st floor of the West Wing, Beijing Continental Grand Hotel.
2. The sessions are held in Meeting Room 4 on the 3rd floor, Beijing International Convention Center.
3. The earphone for simultaneous interpretation is used with the deposit of a valid ID of the delegate.
4. The meeting policy requires wearing of a delegate card during the conference period.
5. The liaison office of the meeting in Room 1034 is at the delegate's service during the conference period.
6. The laundry and long-distance calls are not covered by this meeting.

The Workshop on China's Future Agricultural Supply and Demand

Workshop Program

27 May	9:00 -- 10:00	"Registration, Tea and Cookies"	
	10:00 -- 11:00	Moderator:	Gan Shijun
		Greetings:	Gan Shijun
		Summary of Washington Report:	Jerry Barney
		Lead Respondents:	Liu Zhicheng
	11:00 -- 12:30	**Washington Report:**	**Policy**
		Reporter:	U.S. Participant
		Lead Respondents:	Tang Renjian
			Chen Fan
			Ma Xiaohe
	14:00 -- 15:30	**Washington Report:**	**Water**
		Moderator:	Miao Jianping
		Reporter:	Lester Brown
		Lead Respondents:	Zhang Yue
			Ren Guangzhao
			Yang Xiaoliu
	15:30 -- 16:00	**Tea Break**	
	16:00 -- 17:30	**Washington Report:**	**Land**
		Moderator:	Liu Zhicheng
		Lead Respondents:	U.S. Participant
			Zhang Wenbao
			Xian Zude
			Huang Xiaohu
	18:00 -- 19:30	**Dinner**	

28 May	8:30 -- 10:00	**Washington Report:**	**Yield and Productivity**
		Moderator:	Wen Simei
		Reporter:	Lester Brown
		Lead Respondents:	Zhu Xigang
			Justin YifuLin
			Wang Hongguang
	10:00 -- 10:30	**Tea Break**	
	10:30 -- 12:00	**Washington Report:**	**Livestock**
		Moderator:	Luo Yousheng
		Reporter:	Hsinhui Hsu
		Lead Respondents:	Zhang Cungen
			Wang Ying
			He Xiurong
	13:00 -- 15:00	**Washington Report:**	**Model**
		Moderator:	Mei Fangquan
		Reporter:	Qu Weishuang
		Lead Respondents:	Huang Jikun
			Wen Simei
	15:00 -- 15:30	**Tea Break**	
	15:30 -- 16:30	**Concluding and Syntheses**	
		Moderator:	Ke Bingsheng
		Speakers:	Gan Shijun
			Liu Zhicheng
			Jerry Barney
			Lester Brown
			Other Participants

Appendix F. Terms of Reference for Issue Papers

The Convening Group agreed that Issue Papers would be commissioned on five key issue areas: land, water, yields, livestock, and policy. The terms of reference for the resource papers are provided here because many of the questions are very important but still unanswered. A list of the resource persons and the titles of their papers follows at the end of the terms of reference, and persons seeking additional information on specific topics may contact the authors directly.

* * *

General Points:

The resource persons are to prepare Issue Papers describing the best available information in the area assigned, and specific recommendations of what needs to be done to improve the quality and timeliness of important information. The resource persons will participate in the February 18–19, 1998 workshop in Washington, DC.

The Issue Papers will go directly into the draft Report, which will consist of a Technical Report of perhaps 150 pages, and an Executive Summary of perhaps 30 pages.

The first draft of the Issue Papers will be distributed three weeks in advance of the February 18–19, 1998 workshop, and therefore must be received by the Millennium Institute two days prior to that date.

The Issue Papers are to consist of two parts: (1) a detailed, technical survey paper of up to 30 pages, for the Technical Report, laying out the issues and making specific recommendations for factors that need to be included in projection models relating to China's future production and consumption of food (grains); and (2) a 4-page summary to go in the Executive Summary.

* * *

The five issues are presented on the following pages as Terms of Reference (statement of work to be done) for the resource persons.

a) Key Issue: Land

Prepare a synthesis paper that reviews the following issues in a manner helpful to agricultural economists modeling the future of the food (especially grain) import/export balance in China for the next 30 years.

- Review the different estimates of the current stock of agricultural land (for example, SSB, UNDP, et al.).
- Assess the total land available to agricultural production currently (and in the future), its use (by crop), and productivity (yield).
- Shifts of land from or to grain production to oilseed and fiber production, and shifts to higher value food items like fruits and vegetables.

- The future rates of urbanization.
- The future losses of agricultural land to be expected as a result of urbanization and industrialization.
- Economic growth and impact on composition of diet, including beer consumption.
- Soil quality change over time (e.g., soil losses, degradation, reclamation; effects of pollution) and differences among regions.
- Future non-food and non-feed uses of grain (e.g., alcohol production).
- Cost estimates related to land and energy.
- Important data sources, studies, models, researchers.
- Anything else you feel agricultural economists modeling the future of the Chinese food (grain) import/export balance for the next 30 years should know in this issue area.
- Specific recommendations to researchers and funders for improving the quality, availability, etc. of information needed to help China make decisions about its agricultural future.

b) Key Issue: Water

Prepare a synthesis paper that reviews the major factors related to water and irrigation that may affect long-term food (grain) balance in China. Where possible, address the following issues, and any others you deem relevant, in a manner that would be helpful to agricultural economists modeling the future of the Chinese food (grain) import/export balance for the next 30 years. All issues to be addressed for three regions: North, Central, and South China.

- Total water resources and regional and seasonal distribution (identify whether there are good water supply, demand, and allocation models for China).
- Demand of water from urban and industrial sectors, and expected growth in demand.
- Surface and subsurface water availability, risk of exhaustion.
- Pollution (including salt) levels and effects.
- The current water use efficiency in agriculture (including irrigation) and its potential improvement in the future.
- Price elasticities and cost estimates related to irrigation water.
- Future allocation of water among sectors, and the expected availability for agricultural production.
- Important data sources, studies, models, researchers.
- Water recycling potential.
- Local management of water -- how the system operates (water use associations or other institutions) and what influences they respond to
- Anything else you feel agricultural economists modeling the future of the Chinese food (grain) import/export balance of the next 30 years should know in this issue area.
- Specific recommendations to researchers and funders for improving the quality, availability, etc. of information needed to help China make decisions about its agricultural future.

c) Key Issue: Yields and Agricultural Productivity

Prepare a synthesis paper that reviews major factors related to food production and grain yields that may affect the long-term food (grain) balance in China. Address the following issues (but not limited to) in a manner that would be helpful to agricultural economists modeling the future of the Chinese food (grain) import/export balance for the next 30 years. The following to be addressed by crop type.

- Estimate the actual yields in China (underreporting land may mean over-reporting yields), their regional differences, and the yield gap between China and other countries. Sown area by crop and yields achieved. Reasons for the gaps and prospects for narrowing them.
- Future yield increases, biological yield potentials, and especially, farmers' field yield potentials. Assess the impact of agricultural research (including new varieties, more efficient use of fertilizer, pest management, etc.) on yield growth. What are the research needs for raising yield ceilings?
- Alternative technology.
- Research funding required, and expected future funding.
- Environmental impacts of fertilizers and pesticides.
- Impact of climate change (IPPC scenarios) depleted ozone layer.
- Price elasticities and cost estimates of fertilizers and pesticides.
- Important data sources, studies, models, researchers.
- Status of Chinese agricultural research (e.g., like the case of hybrid rice; also "sustainable capacity").
- Anything else you feel agricultural economist modeling the future of the Chinese food (grain) import/export balance for the next 30 years should know is this issue area.
- Specific recommendations to researchers and funders for improving the quality, availability, etc. of information needed to help China make decisions about its agricultural future.

d) Key Issue: Livestock / Animal Protein

Prepare a synthesis paper that reviews major factors related to the livestock (and other animal protein) sector that may affect long-term food (grain) balance in China. Address the following issues in a manner that would be helpful to agricultural economists modeling the future of the Chinese food (grain) import/export balance for the next 30 years. The following to be addressed in terms of types of animals (beef, pork, chicken, fish, eggs):

- Address data issues. Production may be overestimated and consumption may be over- or underestimated.
- Growth in demand for livestock products (meat, dairy, etc.); rural and urban.
- Grain-meat conversion efficiencies.
- Feed grain demand
- Oilseed meal demand.
- Trade-offs: meat vs. feed grains vs. food grains; grow vs. import?
- Assess future imports or exports of livestock products.
- Environmental impacts of meat and poultry operations (e.g., runoff)

- Price elasticities and cost estimates.
- Evaluate the effects of technological and structural change in the livestock sector (feed conversion improvement from research, shift from backyard to commercial production) on future feed demand.
- Important data sources, studies, models, researchers.
- Anything else you feel agricultural economist modeling the future of the Chinese food (grain) import/export balance of the next 30 years should know in this issue area.
- Specific recommendations to researchers and funders for improving the quality, availability, etc. of information needed to help China make decisions about its agricultural future.

e) Key Issue: Policy

Prepare a synthesis paper that reviews major government policies that may affect the long-term food (grain) balance in China. Address the following issues in a manner that would be helpful to agricultural economists modeling the future of the Chinese food (grain) import/export balance for the next 30 years.

- Investment policy.
- Research funding.
- International policy: e.g., what should China trade for food? Also, what are China's options in agriculture if it were to join the WTO?
- Import policy (self-sufficiency, infrastructure, et al.)
- Macro policy: e.g., how should production be allocated?
- Social policy: e.g., how and whether to meet rising expectations?
- Food and agricultural policy.
- Infrastructure capacity for food (grain) imports and exports, inland transport, bulk handling.
- Carryover stocks, especially rural household stocks.
- Land tenure and property rights.
- Domestic market liberalization.
- Energy supply.
- Land ownership change.
- Potential sources of imports.
- Honoring of grain trade contract.
- Willingness to allow domestic prices to exceed international prices.
- Important data sources, studies, models, researchers.
- Policy strategy.
- Anything else you feel agricultural economists modeling the future of the Chinese food (grain) import/export balance of the next 30 years should know in this issue area.
- Specific recommendations to researchers and funders for improving the quality, availability, etc. of information needed to help China make decisions about its agricultural future.

Resource People

Jikun Huang
Center for Chinese Agricultural Policy
30, Baishiqiao Road
Beijing 10081, China
Tel: 86-10-6217-6604
Fax: 86-10-6218-7545
Email: ccap@public3.bta.net.cn
Paper Title: *Agricultural Policy, Development, and Food Security in China* (with Scott Rozelle)

Peter H. Lindert
Agricultural History Center
University of California - Davis
Davis, CA 95616
Tel: 916-752-1983
Fax: 916-752-5611
Email: phlindert@ucdavis.edu
Paper Title: *The Quality and Quantity of China's Farmland Since the 1930s*

James Nickum
Dept. of Social & International Relations
Graduate School of Arts & Sciences
University of Tokyo
Komaba 3-8-1, Meguro-ku,
Tokyo 153, Japan
Tel: 81-3-5454-6449
Fax: 81-3-5454-4339
Email: nickum@waka.c.u_tokyo.ac.jp
Paper Title: *Issue Paper on Water and Irrigation*

Scott Rozelle
Associate Professor
Stanford University
Stanford, CT 94305
Tel: 415-723-9303
Fax: 616-261-3493
Email: rozelle@leland.stanford.edu
Paper Title: *Agricultural Policy, Development, and Food Security in China (with Jikun Huang)*

James R. Simpson
Faculty of International Communication
Ryukoku University, Bldg. 4, Room 332
1-5 Yokotani Oe-cho, Out-shi, Seta,
Shiga 520-21 JAPAN
Tel: 81-77-543-7882
Fax: 81-77-543-7882
Email: simpson@rnoc.fks.ryukoku.ac.jp
Paper Title: *Livestock Animal Protein*

Thomas Sinclair
Agronomy Physiology Laboratory
IFAS, Building #350, SW 23rd Street
Univ. of Florida, P.O. Box 110965
Gainesville, FL 32611-0965
Tel: 352-392-6180
Fax: 352-392-6139
Email: trsincl@nervm.nerdc.ufl.edu
Paper Title: *Crop Yield and Productivity in China*

Godert W. J. Van Lynden
International Soil Center (ISRIC)
P.O. Box 353
Wageningen 6700 AJ
Netherlands
Tel: 31-317-471-711
Fax: 31-317-471-700
Email: vanlynden@isric.nl
Paper Title: *Assessment of the Status of Human-Induced Soil Degradation in China*

Andrew Watson
Chinese Economies Research Center
University of Adelaide
Adelaide, Australia 5005
Tel: 61-8-8303-5791
Fax: 61-8-8303-4388
Email: awatson@arts.adelaide.edu.au
Paper Title: n/a

Appendix G: Priority Factors for Model Input

The following factors are recommended as a reference for all groups modeling Chinese agriculture. If each such group would include the analysis of the factors, model comparisons would be much easier and understandable. Of course, there are no limitations on other factors that can be analyzed or any suggestion that the reference is not correct. It is mainly a point of reference for model comparisons.

* * * *

I. Population

II. Land

- A. Quality
  1. Is soil quality degrading? If so, how fast and where is it happening?
- B. Quantity
  1. How much land is cropped (total ha)?
  2. Is gross cropped area (not only total ha) increasing or decreasing? Is land loss or land reclamation larger?
  3. Is the fraction of land planted in grain increasing or decreasing?
  4. How is the multiple cropping index (MCI) changing? How is MCI influenced by water availability, prices, investments, and GDP growth?

II. Water

- A. Demand: how much water is needed for grain production in different regions of China?
- B. Supply: how much water is available on a sustainable basis for grain production in different regions of China?

III. Yields:

What is the influence of the following factors on agricultural yields?

- A. Soil degradation
- B. Water supply (in different regions of China)
- C. Investments (in agricultural research and irrigation)
- D. Price of fertilizer and price of labor
- E. Grain producer price (for farmers, not consumers)
- F. Land tenure
- G. Technology advancements and related trends

IV. Livestock

A. Per capita meat demand:

1. How much is demanded currently?
2. What is the influence of income on meat demand?
3. What is the influence of meat prices on meat demand?
4. What is the human population likely to be, year by year, to 2030?
5. What will be the change in total meat demand?

B. What are the conversion ratios of feed to meat for various livestock?

C. What fraction of livestock are fed grain?

D. What is the GDP growth trend?

V. Policy

A. Is investment in agriculture perceived as important for projecting future grain production? How will agriculture investment compare with and compete with investment in other sectors?

B. What funds will be available for investment in agricultural research and irrigation systems, and how will these investments change yields?

C. What factors and priorities influence policy on fertilizer and labor prices, grain producer prices, and grain consumer prices?

D. In what ways and roughly when might policy on land tenure change? How does different land tenure influence agricultural production?

E. What is the desired degree of agricultural self-sufficiency for China? What is the priority for feed grain or meat self-sufficiency if both can not be achieved? In other words, should China import feed grain or meat?

F. What is the infrastructure required for handling grain and meat imports? What is the current port capacity for bagged grain and bulk grain?

Appendix H: Model Development Plans

Members of the Convening Group and others who have used or plan to use models in their work gave brief reports about their future plans for their models.

Mark Rosegrant of International Food Policy Research Institute plans to incorporate the allocation of water into IFPRI's IMPACT model, and also to incorporate natural resources into the model more explicitly through the use of production functions. He will do so by developing a fish sector, linking global food projections and local biophysical models, and developing a Geographic Information System database. The GIS will have global information for rainfall, net evapotranspiration, and the water supply in major river basins. He will mesh the global information with country-level information about crop areas, divided into irrigated and rainfed areas.

Al Nyberg, World Bank, reported that the model he used, the Global Trade Analysis Project, is maintained at Purdue University. It is a general equilibrium model that looks at world trade in agriculture. The China data are built on a 1993 input-output study. Although this is an aggregate model, it can be disaggregated. GTAP is a large trade policy model that requires about six hours to run. It was a major effort to disaggregate China and put in the necessary variables and data. He does not plan to use GTAP in the near future, however, as his work is moving toward rural development and away from food security. He will be looking at poverty and employment, town and village enterprises, and other issues of rural development.

Hunter Colby of the Economic Research Service at USDA remarked that the China Projection Model's purpose is to forecast trade, but much of China's trade is set by leaders, not by economics. Nonetheless, for the next two years, the ERS team (including Fred Crook and Francis Tuan) will use Fang Cheng et al.'s data to make revisions to the livestock production component of the model. They will also build on Frank Fuller's work on reconciling meat production and consumption figures. The process they use is to think about policy the way they expect Chinese policymakers will think and then to make forecasts and adjust as deemed necessary for reasonable results. They will strive to make the policy assumptions as explicit as possible.

Lester Brown, President of Worldwatch Institute, acknowledged that he does have a "mental model" that has now been expressed as a computer model. He said that his projections about China's grain production may be reversed. Today he would modify downward the population numbers he used and would increase the cultivated area to reflect underreporting. He feels a simple model would be useful in assessing food production potential for both exporters and importers based on existing information on cropland area, future availability of water for irrigation, and potential contribution to grain production of existing agricultural technologies, especially in light of Tom Sinclair's comments about yield ceilings. He has published an article with Brian Halweil on China and water and expects to have a book on world water and agriculture out in 1999.

Nikos Alexandratos of FAO indicated that this U.N. agency is involved in many activities. In his own projection work in the Global Perspectives Studies Unit, China is one of 140 countries being studied. FAO has to consider not only grains, livestock, and seeds oil, but also such commodities as sugar, cocoa, and rubber. FAO has a database (with IIASA) on agro-ecological zones, but until recently this did not cover China. It also has plant (agronomy) models like the ones mentioned by Tom Sinclair.

Josef Schmidhuber, Organisation for Economic Co-operation and Development (OECD), reported that OECD is building a modeling framework similar to IFPRI's IMPACT model, with less emphasis on country detail and commodity coverage and more emphasis on policy, especially trade policy. One shortcoming is that it has very aggregate coverage of non-OECD areas. They plan to represent China separately using the ERS China Projection Model. They are looking forward to working with other groups.

Pan Xiaoming of the Institute of Systems Science, Chinese Academy of Sciences, reports that the Academy has models of GDP and inflation trends. They want to extend these to an input-output model disaggregated to the subregions of China, with agricultural commodities separated out.

Qu Weishuang, Millennium Institute, has now developed a model of the kind he proposed based on data from the ERS China Projection Model and including both livestock and water constraints.

Ke Bingsheng, Research Centre for Rural Economy, Ministry of Agriculture, says the RCRE does not have a long-term model. His intention is to implement the model proposed by Dr. Qu Weishuang. He notes that previously many top Chinese policymakers were not interested in models, but as they see foreigners doing interesting things with models, they are becoming more interested. So RCRE would like to work with colleagues at this meeting on models so as not to be "outsiders" to this profession. He also wants to help improve the data needed for models and decision making.

Appendix I: The Strategy and Action Project Reference Scenario (S&A Scenario) of Major Assumptions and Results

During the Washington and Beijing workshops, it was noted that model comparisons are difficult because of the wide range of assumptions used by modelers. To reduce this difficulty, it was recommended that the Convening Group develop a reference set of major assumptions for analyzing China's agriculture, and invite all modeling groups, when next they are making projections, to analyze this set of assumptions among others. While the reference assumptions are not "right," model projections based on them would be easier to compare than are projections based on dissimilar assumptions.

It is also recommended that modelers publish their assumptions in at least these specific areas. To do so will to increase the model's transparency, thereby increasing its credibility.

The following set of assumptions was developed by the Millennium Institute staff based on information obtained during the Strategy and Action Project. Although the Convening Group has reviewed these assumptions and suggested some changes, the assumptions are not consensus values from the Convening Group.

	circa 2000	**circa 2020**
Demand side:		
food demand		
population	1.2 B	1.4 B
urban population ratio	31%	40%
real GDP (income) in E12 (Trillion) Yuan90	5	21
real GDP growth	0.09	0.04
income elasticities of per capita grain demand	-0.12 to +0.15, depending on income level and rural or urban	Change with income level
grain consumer prices (Yuan90/ton)	1400 to 1600	1200 to 2000
price elasticities of per capita grain demand	-0.5 to -0.05	Same as present
intercrop elasticities	Please specify	Please specify
feed demand		
income elasticities of meat demand	0.1 to 1.2, depending on income level, and rural or urban	Change with income level
meat consumer prices (Yuan90/ton)	5500 to 9500	7500 to 15000
egg consumer price (Yuan90/ton)	4000	4500
fish consumer price (Yuan90/ton)	Please specify	Please specify
price elasticities of meat demand	-0.18 to -0.06	Same as present
intermeat elasticities	Please specify	Please specify
conversion ratios (for all meat)	0.36 to 2.8	same as present
fraction fed (for all animals)	0.2 to 1	same as present
meat imports	0 to 10%	same as present

other demand		
industry	Please specify	Please specify
brewery	Please specify	Please specify
Supply side:		
cropped land		
total cropped area in Mha	132	128
multicropping index (national average)	1.5	1.6
grain planted area in Mha	89.3	88.2
fraction of cropped land for grain	59.4 %	57.3%
producer price elasticities of land use	0.25	Same as present
Yields		
grain producer prices in Yuan90/ton	600 to 1200	600 to 1100
producer price elasticities of yield	0.1	0.1
ag research stock in M Yuan90	1400	1750
elasticity of ag research stock	0.12 to 1.54	Same as present
water availability	1	0.95
elasticity of water availability	1	1
soil degradation	Please specify	Please specify
elasticity of soil degradation	Please specify	Please specify
fertilizer prices in Yuan90/ton	1087	1090
elasticity of fertilizer prices	-0.14 to -0.08	same as present
irrigation stock in M Yuan90	92,000	170,000
elasticity of irrigation stock	0.1	0.1
technology contribution	0.001/year	0.001/year

Suggested Results for Baseline Comparison*

	circa 2000	**circa 2020**
Demand side:		
per capita grain food demand in kg/year		
grain consumer prices		
per capita meat demand in kg/year		
meat consumer prices		
Supply side:		
grain planted area in Mha		
yields (national average) in ton/ha		
grain producer prices		
meat producer prices		

* Prices should appear as results if they are calculated endogenously.