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Interim Report **IR-00-053**

Land Use Change at the National and Regional Level in China: A Scenario Analysis Based on Input-Output Modeling

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Abstract

Land availability is of crucial importance for China's development in the 21 century. Economic growth, urbanization, changes in life styles such as diet changes, and population growth will influence both the demand for and the supply of land. In this study, an input-output model expanded by a set of land categories is developed to synthesize various scenarios of changes in the economy and society, and to evaluate their impact on land-use changes in China. The scenario analysis is conducted at both the national and regional levels and for a time horizon of over 30-years. The analysis aims to show how different development paths will influence the available land base as well as the inter-regional and international trade flows of primary products for China in the coming decades. To do this a mixed model with supply-constraints for the major land-consuming sectors is used.

Given the moderate pace of technological progress, as commonly assumed in the literature, the resultant increases in final demands and sectoral outputs would drive the associated land requirements to exceed the then available land area. Scarcity of cultivated land, grassland, and forestland will be persistent. If the traditional policy of grain and food self-sufficiency were maintained intact, to keep the farmland requirement feasible, an annual growth rate of land-productivity of about 1.28 percent would be required, which is higher than what is usually expected for the next 30 years. In addition, faster technological advancement in the livestock sector will be necessary.

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About the Authors

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Laixiang Sun is a senior researcher, mathematician and economist engaged in developing the economic component of the IIASA-LUC model. He is also affiliated with the United Nations University (UNU), WIDER, in Helsinki, Finland, as a Project Director on property rights regimes, microeconomic incentives, and development, and with Guanghua School of Management of Peking University, in Beijing, China, as a Senior Research Fellow. Prior to these appointments, Dr. Sun was a consultant of UNU/WIDER and teaching assistant of two master degree courses at the Institute of Social Studies, The Hague. In the years between 1985 and 1991, Dr. Sun was a lecturer, and later also Associate Chairman of the Department of Economic Management, and Senior Researcher at the Research Center for Social Development of Contemporary China, both at Peking University in Beijing, China.

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I Introduction

Land availability, for the twenty-first century, is crucially important for China's food security and economic development. Although China has a total area of some 960 million hectares, which is the third largest in the world, only about 14.8 percent are cultivated with field crops and horticultural products. Lands unsuitable for agriculture such as mountains, deserts, or dry grasslands, cover a large fraction of the country. Primary farmland is located mainly in the same geographic areas where population and major economic activities have been concentrated. About one billion people (out of China's population of 1.3 billion) are concentrated in less than one third of the land area. The eastern region (Yangtze Delta), Sichuan, and the urban agglomerations along the eastern coast are the main population centers. These coastal areas are also the ones experiencing the highest growth rates in the economy. In several eastern provinces, settlement areas cover more than 10 percent of the total land and are further expanding. Cropland areas are shrinking due to both urban sprawl and growing land requirements of villages, rural industries, and infrastructure. On balance, China lost some 980,000 hectares of cultivated land to construction activities between 1988 and 1995 (Fischer *et al.* 1998). Urban infrastructure expansion is reducing cropland areas, grassland, and forestland; increasing urban (air) pollution and waste discharge are affecting soils and irrigation systems; and growing urban freshwater consumption is competing with agriculture for water supply.

China's food security is also threatened by losses of cultivated land due to disasters, water and wind erosion, as well as chemical and physical deterioration. Agricultural over-exploitation and industrial pollution exacerbate these degradation problems. Even though there are some controversial arguments about food demand and supply in China for the next 30 years (Brown 1995; Chen et al. 1996; Huang and Kalirajan 1997), there is agreement that arable land loss and land degradation are undermining China's food production capacity (e.g. Gardner 1996; Rozelle and Huang 1997). In the case of forestland and grassland over-exploitation and degradation might be even more severe (Fischer et al. 1996; Liu 1998; Richardson 1990).

Another trend in changing land use is agricultural restructuring such as the transformation of China's cropland into horticultural land and fishponds. This is due to changes in consumer demand as well as institutional and supply-side factors. It has become much more profitable for Chinese farmers to grow vegetables and fruits and sell these for market prices rather than to produce rice or wheat, which are still regulated by the state's procurement system. These changes in supply- and demand-side factors are reflected in changes in land use. From 1988 to 1995, 1.2 million hectares of land for crop production were converted to horticulture, which is equal to 25 percent of the total losses of cropland, and 0.23 million ha (4%) were converted to fishponds (Fischer et al., 1998). The conversion of cropland into fishponds and horticultural lands following the market-driven restructuring requirements of the agricultural sector might actually increase the food security.[1] The conversion of cropland into forest and grassland according to the requirement of conserving

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[1] This conversion has improved the trade balance of China as well. China has become the world's largest producer of fresh-water fish and crustaceans and China's fruits exports are earning about US$ 200 million (Smil, 1999).

soil resources and environment is also desirable from a long-term perspective. Between 1988 and 1995, such cropland conversions amounted to 2.97 million hectares (Fischer *et al.*, 1998).

These changes in China's land use pattern reflect changes in the country's institutional framework, economy, and society. China has been changing from a command economy to a market-based one, resulting in annual GDP growth rates of, on average, 9.8 percent between 1978 and 1998. Increase in income and migration from rural to urban areas have resulted in changes in lifestyles and consumption patterns. These changes in lifestyles are compounded by China's large population.

In order to assess how changes in the economy and society affect future land use, it is necessary to combine biophysical, economic, and societal data. A consistent theoretical framework is crucial for such investigations. In this paper, we employ a structural economics framework in which scenarios about possible future stages of society and economy are embedded. The core of our framework is an input-output model. Input-output modeling deals with structural changes via analyzing discrete and explicit changes from one state of the economy to another. These changes in structures are derived from scenarios, which are developed around each question to be explored. Socioeconomic changes are linked to different types of land via an explicit representation of land requirement coefficients associated with specific economic activities. In this way, land is treated as explicit factor input. Both the direct and indirect land-use requirements are captured by the representation of the sectoral interdependence of the input-output model. For our interest, we deal with only the land requirement of each economic sector rather than value compensation for land use.

In many studies dealing with similar questions, the focus has been either on a small region of China or on the aggregate national level. The small-region models might deliver excellent results for the region concerned, but they are unable to deal with the inter-play across regions and do not allow any predictions for the national level. Studies focussing on the national level usually lack the capability to tackle regional differences and the interaction among regions. Typically, population densities, soil and climate conditions, and economic development are significantly different across regions in a large developing country like China. China can be perceived as a group of co-evolving, dissimilar economies rather than a homogenous entity. On one hand, China has fast-developing urban growth centers in the coastal areas and, on the other hand, backward rural areas with distinct income, lifestyle and expenditure patterns. Differing regional growth paths in the past might also have considerable effects in the future and influence the future flow of regional migration due to labor demand of growth centers.

In this paper, we build our model from the ground up and develop seven regional models and then a national one for China. We specify various development paths for different regions and use data and information available at both the regional and national level. The combination of and communication between regional and national models enable us to investigate how the constraints of (immobile) land availability in each region might affect the inter-regional trade flow of land-based products. This further allows us to evaluate the degrees of land scarcity at both regional and national levels and the magnitude of the necessary land-productivity improvement that is required under different sets of assumptions for keeping the land requirement feasible in the future. As far as we know, our modeling is among the very first to set up inter-related regional input-output models for China with strong biophysical linkages explicitly focussing on land-use change.

The strong biophysical linkages are mainly manifested in the derivation of regional differences of the land requirement coefficients and the typical I-O technical coefficients. In other words, while we can stylize certain technological development trends at the national level based on a literature survey, their regionalization is not straightforward; we create these regionalized linkages based on the Agro-Ecological Zone (AEZ) assessment within a Geographical Information System (GIS). In addition, the AEZ assessment is also used to derive the future land suitability in each region.

The report proceeds as follows. Section 2 explains the structural framework of our modeling and the way to use it for scenario analysis. Section 3 describes the available data sets of the economy, population, and biophysical characteristics at the regional level. Section 4 analyzes and quantifies the major driving forces of land-use change and develops scenarios for them. The major driving forces include per capita income growth driven by the comprehensive economic growth, lifestyle changes, urbanization, and technological progress in general and land productivity improvement in particular. Section 5 discusses the results of the scenario-analysis. First, a national model is presented (in Section 5.1) to show the national aggregate scarcity of land in 2025 and to estimate the magnitude of necessary land productivity improvements in order to meet the growing demand for land in the future undere the assumed scenarios for the driving forces. Then it proceeds to the regional level (in Section 5.2) and investigates how constraints of the (immobile) land availability in each region might affect the inter-regional trade flow of land-based products in China. Finally Section 6 concludes the report and discusses policy implications of the results as well as advantages and disadvantages of the approach.

2 The Modeling Framework for Scenario Analysis

Scenario analysis investigates interactions among selected possible trajectories of major driving forces and shows the development of and interaction among the relevant systems. It supports decision making and policy development and serves as a tool to foster creativity and to stimulate and guide discussion on the points of interest (Clark and Munn 1986; Prieler et al. 1998; Toth et al. 1989). A well-established theoretical framework is a key for such investigations. In this paper we employ a structural economics framework in which scenarios about possible future stages can be analyzed. The focus of structural economics is to describe the state or structure of an economic system and its quantitative and qualitative changes that take place over time (Duchin 1998, p. 10). “Scenario” in such a setting means the change of the structure of the economy as represented by production and consumption patterns and their associated material, energy, and monetary flows.

The core of our approach is a recursive input-output model expanded by a set of different land categories. The basic purpose of an input-output model is to predict levels of output, value added, and employment given a certain increase in final demand (representing various socio-economic scenarios). Input-output modeling deals with structural changes via analyzing discrete and explicit changes from one state of the economy to another. Structural changes include the technology used in different sectors, the changes in relative size of different sectors, changes in the composition and magnitude of the different final demand sectors, and the availability and quality of different environmental resources. A central piece of information is technical literature and expert knowledge to provide information on current and potential future production processes, population and other social trends, and the environment. These changes in structures are derived from scenarios, which are developed around each question to be explored. For instance, uncertainty about technological developments can be made explicit by introducing a range of scenarios based on different sets of assumptions. Dealing with structural changes in this way constitutes the most distinguished feature of input-output modeling. This feature makes it powerful in the evaluation of alternative scenarios about future paths of the economy. Through the evaluation of scenarios that reflect current thinking, scenario analysis based on input-output modeling is capable of stimulating new insights into the search for promising development patterns for the future (Duchin 1998).

The rationale for extending the standard input-output framework to estimate land-use change can be summarized as follows. In order for the final demand of a given sector to expand, the output of other sectors must expand as well, corresponding to the input requirements of the given sector. As all economic activities consume space, in the long-run, in order to achieve significant increases in output, there must be increases or changes in land use or land productivity. The mathematics of the I-O model allows accounting for indirect effects or round-by-round effects of final demand, which are created by the inter-industrial linkages of production. For example, even though some industrial or service sectors need only small amounts of food and other fibers per unit of their output, the overall effect on land use from these sectors in the future can be substantial considering their very high growth rates.

In this section we first establish the desired linkage between the basic I-O model and land-use changes. Then we develop a supply-constrained I-O model that is capable of accommodating to the restrictions imposed by land availability, and of capturing the gap between the exogenous demand and the constrained (endogenous) final deliveries in the major land-use sectors. Finally, we present a brief introduction of the Agro-Ecological Zones (AEZ) assessment modeling, which has served as a basic tool in our derivation of regional specific land requirement coefficients, in the dis-aggregation of the agricultural sector into six sub-sectors for each regional I-O table, and in the calculation of potential output in major land-use sectors.

2.1 Linking the Basic Input-Output Model with Land-use Change

Equation (1) describes the relationship between the endogenous total output vector, x, and the corresponding final demand vector, y; the technology of an economy is represented by a matrix of technological coefficients, A:

(1) $(I - A)\, x = y.$

In the standard version, changes in the exogenously given vector of final demand (Δy) are driving the economy via a matrix of output multipliers, the Leontief inverse, $(I - A)^{-1}$ resulting in changes in sectoral output (Δx):

(2) $(I - A)^{-1}\, \Delta y = \Delta x.$

In order to link land-use changes in economic sectors to those in land categories (such as cultivated land, grassland, forestland, etc.), the vector representing changes in output (Δx) is pre-multiplied by a diagonal land requirement coefficient matrix ($\hat{C}$) and a land distribution matrix (R).

(3) $\Delta L = R\hat{C}\Delta x$.

The land distribution matrix R gives the mapping relationship between land uses in economic sectors and the natural categories of land, and the elements in R are the shares of the former in the latter. Section 3.2.1 will present the technical details for establishing R in the study. The vector of land requirement coefficients (c_j) is defined as the ratio of total land use in each sector (L_j) over total sectoral output (x_j).

(3a) $c_j = \frac{L_j}{x_j}$.

The land requirement coefficient vector (c_j) represents land use in hectares per one million Yuan of output of sector j. This is equivalent to the inverse of sectoral land productivity (p_j), which represents the output in Yuan produced on one hectare of land:

(3b) $p_j = \frac{x_j}{L_j}$.

Future land use (L^{2025}) is the sum of present land uses (L^{1992}) and the changes in land use (ΔL) triggered by the changes in output (Δx) based on the scenarios:

(4) $L^{2025} = L^{1992} + \Delta L$.

In the short term, producers might be able to expand their output without significant needs for further land, especially in the case of industrial and service sectors. The link between output and land use is therefore best perceived as a long-run relationship (Xu et al. 1994, p. 162).

2.2 The Supply-Constraint Input-Output Model

Input-output models usually assume that the economy instantaneously (that is, within the observed time period, usually a year) adjusts to shifts in spending patterns. All production activities are assumed to be endogenous and demand-driven, that is the model assumes excess capacity throughout the economy. Supply is assumed to be perfectly elastic in all sectors, and an increase in demand is sufficient to stimulate increases in output and incomes. Firms are, in reality, unable to adjust immediately to such changes, due to constraints in capacity, skilled labor, or other input factors. In the standard model, it is assumed that land-use changes across all sectors will result from a change in final demand. However, clearly some sectors will not automatically expand or shrink their land requirements in direct proportion to output changes and are not able to do so because of zoning regulations or other restrictions of land availability. If this is indeed the case, then the model derived above will provide multiplier estimates that are unrealistically large due to expectations regarding supply response. A more reasonable assumption is that the availability of land may restrict economic sectors and the production of goods and services. Therefore, the standard input-output model needs to be modified to incorporate supply constraints on certain production activities, thus permitting a more realistic evaluation of multiplier effects of injections into the economy. To account for restrictions in supply a number of authors developed models with supply assumed to be completely inelastic in some of the sectors (Lewis and Thorbecke 1992; Miller and Blair 1985; Parikh and Thorbecke 1996; Subramanian and Sadoulet 1990).

The basic input-output relationship of an *n*-sector economy as shown in equation (1) is here repeated as a set of equations. The sectors have been arranged in a way such that the first *k* sectors indicate the endogenous elements and the last (*n* - *k*) sectors are the exogenous sectors:

$$(5) \qquad \begin{aligned} &(1-a_{11})x_1 - a_{12}x_2 - \ldots - a_{1n}x_n = y_1 \\ &\qquad\qquad\vdots \\ &-a_{k1}x_1 \ldots + (1-a_{kk})x_k \ldots - a_{kn}x_n = y_2 \\ &\qquad\qquad\vdots \\ &-a_{n1}x_1 \ldots - a_{nk}x_k \ldots + (1-a_{nn})x_n = y_n . \end{aligned}$$

We rearrange this to have the exogenous variables on the right-hand side and the endogenous variables on the left, where the exogenous variables are indicated by using an overbar:

$$(6) \qquad \begin{bmatrix} P & 0 \\ R & -I \end{bmatrix} \begin{bmatrix} X_{no} \\ Y_{co} \end{bmatrix} = \begin{bmatrix} I & Q \\ 0 & S \end{bmatrix} \begin{bmatrix} \overline{Y}_{no} \\ \overline{X}_{co} \end{bmatrix},$$

where the sub-matrices are as follows:

P	the $k \times k$ matrix containing the elements from the first *k* rows and the first *k* columns in (*I* - *A*)*;* *P* is a matrix representing average expenditure propensities of sectors that are not supply-constrained;
R	the $(n - k) \times k$ matrix containing elements from the last (*n* - *k*) rows and the first *k* columns of (*I* - *A*); *R* is a matrix representing average expenditure propensities of non-constrained sectors on supply-constrained sector output;
X_{no}	the *k*-element column vector with elements x_1 through x_{k};, representing endogenous total output of sectors that are not supply-constraint;
Y_{co}	the (*n* - *k*)-element column vector with elements y_{k+1} through y_n, representing endogenous final demand of supply-constrained sectors;
Q	the $k \times (n - k)$ matrix of elements from the last (*n* - *k*) rows and first *k* columns of -(*I*-*A*); the matrix *Q* represents supply-constrained sector expenditure propensities on output of sectors that are not supply-constrained;
S	the $(n - k) \times (n - k)$ matrix of elements from the last (*n* - *k*) rows and columns of -(*I*-*A*); *S* represents here a matrix of average expenditure propensities among supply-constrained sectors;
$\overline{Y}_{no}$	the *k*-element column vector of elements y_1 through y_k , representing exogenous final demand for sectors that are not supply-constrained;
$\overline{X}_{co}$	the (*n* - *k*)-element column vector of elements x_{k+1} through x_n, representing exogenous total output for supply-constrained sectors.

To solve for the endogenous variables, we bring the first matrix from the left-hand side to the right:

$$(7)\begin{bmatrix} X_{no} \\ Y_{co} \end{bmatrix} = \begin{bmatrix} P & 0 \\ R & -I \end{bmatrix}^{-1} \begin{bmatrix} I & Q \\ 0 & S \end{bmatrix} \begin{bmatrix} \overline{Y}_{no} \\ \overline{X}_{co} \end{bmatrix}$$

In multiplying the two terms on the right hand side, we obtain the mixed multiplier matrix *(M_m),* which is post-multiplied by a vector of exogenous final demand and exogenous output. In the modified model, changes in exogenous final demand in the unconstrained sector or changes in exogenous supply in the constrained sectors are met by changes in output in the unconstrained sectors and by changes in imports and exports of the constrained sectors.

The derived net exports of the supply-constrained sectors (T) are the difference between the exogenous final demand and the endogenous final delivery in the corresponding sectors:

$$(8) \qquad T = \overline{Y}_{co} - Y_{co}$$

Exogenously generated potential output (x_f) is calculated by dividing the then available land per land-use category ($\overline{L}_f$), which includes agricultural land, grassland, and forestland, by the respective future land requirement coefficient (c_f):

$$(9) \qquad x_f = \overline{L}_f / c_f$$

2.3 Set-up of the Biophysical Linkage: The AEZ Model

The AEZ assessment model is used to derive regional differences for the land requirement and land productivity coefficients (Equations 3a, 3b), for the disaggregation of the agricultural sectors into six sub-sectors in each regional I-O model, and for the calculation of exogenously generated potential output (Equation 9).

The AEZ method was originally developed by IIASA and FAO in the early 1980s (FAO 1995; FAO/IIASA/UNFPA 1983) and was then repeatedly used and subsequently improved in several global and national studies (FAO/IIASA 1993, Fischer *et al.* 2000). The AEZ algorithm assesses the potential suitability and productivity of a particular land area for agricultural uses, depending on its soil, terrain and climate conditions and at given input and management levels.

A detailed presentation of all functions of AEZ modeling is beyond the scope of this paper.[2] To understand the basic principles of the AEZ approach let us consider an illustrative example. A farmer faces the task to evaluate the suitability of a particular land unit for crop production. He would take into consideration a whole range of factors, including the quality of the soil, the local climate conditions, and the possibilities of using different types of inputs such as fertilizers, pesticides, machinery, etc. The farmer would also consider various mixes of crops that are possible under the specific conditions of this plot, including multiple sequential cropping. The AEZ algorithm proceeds in a similar way and incorporates well-established scientific information. To put it in more details, the AEZ method allows the calculation of attainable yields of each land unit of the given digital maps through suitability

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[2] For the technical details, see Fischer and Makowski 2000; for a description of a global-scale AEZ application, see Fischer *et al.* (2000) or consult http://www.iiasa.ac.at/Research/LUC/GAEZ.

assessment. An Agro-Ecological Zone is a polygon obtained by overlaying maps of the climatic resources inventory (i.e., map of climatic belt, thermal zone, length of growing period), with maps of soil resources inventory and terrene condition. Every AEZ land unit has a homogeneous climate, soil association, and topographic characteristics. Each AEZ land unit is then assessed in terms of all feasible agricultural land-use options of interest. At a given level of input, the productivity assessment records expected production of relevant agro-ecologically feasible cropping and grazing activities.

The strength of the AEZ method is manifested in its ability to match land quality with the ecological requirements of the respective plants for soils, climates, etc., under explicit recognition of the socio-economic setting. The application of this method allows us to quantify regional differences that are basically determined by natural factors. We apply the results of the AEZ assessment for the sectors of grains, other crops, and pasture livestock production. Due to the fact that land suitability changes along with changes of different land utilization types prescribed by certain social and economic conditions, three production scenarios for low, medium, and high input levels are developed (see e.g., Xie and Jia 1994). Variations in input levels are represented by the differences in multi-cropping indexes, scale and intensity of land management, factor-intensity of labor, capital, and energy utilization, and operational technologies employed.

3 China and the Regions: Representation of the Economy and its Land Base

In this section we use the framework outlined above to establish the representations of both the regional and national economies in terms of extended input-output models. The reference year is 1992 and the year for scenario analysis is 2025. In Section 3.1, we describe the structure of the economy in 1992, how the regional tables are derived, and how changes in the structure of the economy are modeled. In Section 3.2, we present the current land-use structure and discuss regional land productivity differences in China for the base year. To calibrate the scenarios for land availability in 2025, in addition to the usual land development consideration, we use a GIS technique to estimate the possible land conversion from other categories to the built-up category. To derive regional differences in land productivity, we use the results from the AEZ assessment for China.

3.1 China's Economy in an Input-Output Framework

3.1.1 Establishment of Regional Input-Output Tables with Disaggregated Agricultural Sectors

In our I-O model, China is divided into 8 regions based on their unique geographic, agro-climatic, demographic, and economic development levels, and consolidated with provincial level administrative boundaries for the sake of data availability and consistency. These eight regions are presented in Table 1 and Figure 1.

Seven out of the eight regions form the geographic building blocks in the LUC economic model. The Plateau region is currently not considered in the analysis because of a lack of input-output data. Although the Plateau region holds strategic importance in terms of geography and politics, its economic shares in the national economy are minor in comparison to the main input-output indicators of the other regions.

Figure 1: Map of China showing Provincial Boundaries and the Eight Economic Regions

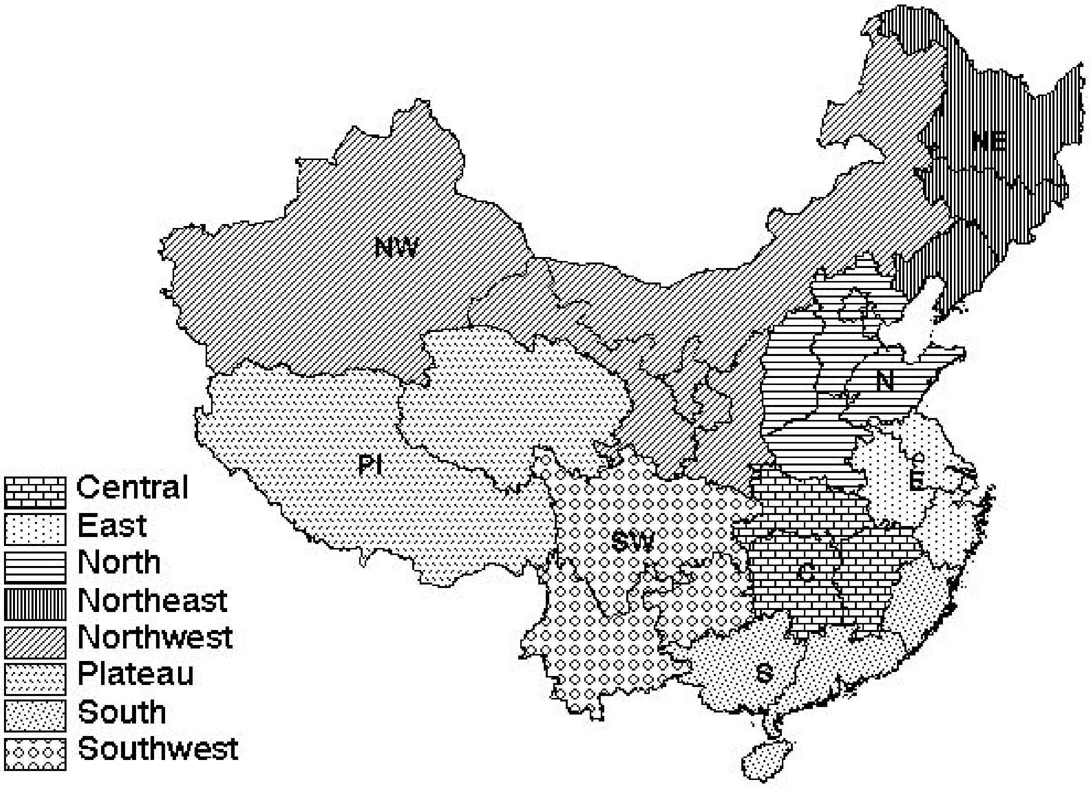

Table 1. Eight Economic Regions of the China Land-use Change (LUC) Model

R1 – North	Beijing, Tianjin, Hebei, Shandong, Shanxi, Henan
R2 – Northeast	Liaoning, Jilin, Heilongjiang
R3 – East	Jiangsu, Shanghai, Zhejiang, Anhui
R4 – Central	Hubei, Hunan, Jiangxi
R5 – South	Fujian, Guangdong, Guangxi, Hainan,
R6 – Southwest	Sichuan, Guizhou, Yunnan
R7 – Northwest	Shaanxi, Inner Mongolia, Ningxia, Gansu, Xinjiang
R8 – Plateau	Qinghai, Xizang

The economy of China and its regions are represented by the 1992 input-output tables (see Appendix, Table 23). These existing tables were constructed by the Department of National Economic Accounting within the State Statistical Bureau of China (SSB) (1996; 1997). The national table includes 118 sectors, 6 of these are in agriculture, 84 in industry, 1 in construction, 6 in transport and communication, and 21 in service sectors. However, the regional tables exist only in a more aggregate form, distinguishing only one agricultural sector. The "value-added" categories at both the national and regional level include the following: capital depreciation, labor compensation, taxes, and profits. "Final use" at the national level comprises of six categories: peasant, non-peasant, and government consumption, fixed investment, inventory changes, and net exports. The regional table gives only three final use categories: total consumption, total investment, and net exports.

For the purpose of analyzing land-use changes at the regional level, we disaggregate the aggregate agricultural sector into six sub-sectors, divide total consumption into peasant, non-peasant, and government consumption, and separate fixed investment from changes in inventory (see Table 2). We further assume that peasant consumption is similar to rural consumption and non-peasant consumption resembles the consumption pattern of urban people. Unfortunately, there are obvious inconsistencies in the SSB-classification system for urban, rural, and city population, because the system mixes territorial and functional definitions. The definitions have also been changed over time and non-recorded migration from rural to urban areas further distorts the actual residency (Heilig 1999).

Table 2: Scheme of the Regional Input-Output Table and the Available Data for 1992

	Grains	Other Crops	Forestry	Livestock	Handicraft	Fishery	Industry	Construction	Transport	Trade	Services	Peasant	Non-Peasant	Government	Investment	Inventory	Net-Exports	Sum
1. Grains	Σ						Σ	Σ	Σ	Σ	Σ	Σ			Σ		Σ	x
2. Other Crops																		x
3. Forestry																		x
4. Livestock																		x
5. Handicraft																		x
6. Fishery																		x
7. Industry	Σ						x	x	x	x	x	Σ			Σ		x	x
8. Construction	Σ						x	x	x	x	x						x	x
9. Transport	Σ						x	x	x	x	x						x	x
10.Trade	Σ						x	x	x	x	x						x	x
11. Services	Σ						x	x	x	x	x						x	x
Capital	Σ						x	x	x	x	x							
Labor	Σ						x	x	x	x	x							
Taxes	Σ						x	x	x	x	x							
Profits	Σ						x	x	x	x	x							
Sum	x	x	x	x	x	x	x	x	x	x	x							

Notes: *X* indicates information available from the published national and regional input-output tables and from other statistical sources. Σ indicates that only aggregate information for a group of cells is available.

Sources: *Statistical Yearbook of Rural China* (State Statistical Bureau 1993, pp. 59), and *Statistical Yearbook of China* (State Statistical Bureau 1993, pp. 47 and 49).

Nevertheless, it is impossible to establish the required input-output tables by using only the information above and to solve the balancing conditions of a typical input-output table since there would be too many unknowns and too few equations. In order to estimate the required additional information, we apply a procedure based on adjustment of national coefficients using the techniques of *location quotients* (LQs) adjustments. Then, we minimize the sum of squares of the percentage difference between the unknown cell figures and those obtained from the LQs procedure for each regional table, subject to the typical I-O balancing condition and other summing-up requirements (for more detail see Sun 2000).

3.1.2 Projections of Future Technology

The impact of changes in economy and society on land-use will depend on patterns of consumption as well as production. Extent and patterns of consumption are discussed in the form of various scenarios in Section 4. The patterns of production are represented in the technology matrix or A-matrix (see Equation 1). Their immediate effects on land-use are represented in the land-requirement coefficients or C-matrix (see Equation 3a). In order to project the future production functions of the respective sectors and the related effect on land-use, we use a mixed approach of applying case studies and the RAS method. We use the case studies for projecting key cells of the future production functions of certain sectors, as indicated by "B" in Table 3. Then we calculate the remaining cells based on information indicated in Table 2 and by using the RAS method, a mathematical optimization tool presented below.

The case study methodology was suggested and applied by Duchin and Lange (Duchin et al. 1993; 1994). The purpose of this approach is to develop a number of scenarios about the future regarding certain key economic sectors in terms of growth and technologies and to construct a corresponding database that contains the quantification of these parameters (Idenburg 1993). The development of such case studies requires assembling information from many sources, such as technical publications and databases, and expert opinions. Due to time and budget constraints, it was impossible to conduct such selected case studies with great technical detail. As a sound compromise, we have selected variables with relatively reliable information available. These include partial or full information of land inputs, the intermediate purchases and deliveries, value added, final demand, and total sectoral outputs. The remaining missing data are estimated by the RAS procedure.

Table 3. Scheme of Input-Output Table of China in 2025

	Grains	Other Crops	Forestry	Livestock	Handicraft	Fishery	Industry	Construction	Transport	Trade	Services	Int. Deliveries	Final Demand	Total Output
1. Grains				**B**			**B**					**U**	**FD**	**X**
2. Other Crops												**U**	**FD**	**X**
3. Forestry												**U**	**FD**	**X**
4. Livestock												**U**	**FD**	**X**
5. Handicraft												**U**	**FD**	**X**
6. Fishery												**U**	**FD**	**X**
7. Industry				**B**								**U**	**FD**	**X**
8. Construction												**U**	**FD**	**X**
9. Transport												**U**	**FD**	**X**
10. Trade												**U**	**FD**	**X**
11. Services												**U**	**FD**	**X**
Intermediate Purchases	**V**	**V**	**V**	**V**	**V**	**V**	**V**	**V**	**V**	**V**	**V**			
Value added	**X - V**													
Total Output	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Land in Yuan/ha	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**			

Notes: *L*'*s* are derived from literature and the AEZ model. *U*'*s, V*'*s,* and *X*'*s* are derived for the major economic sectoral groups of agriculture, industry, and services from World Bank estimates and by comparison to structural changes in industrialized countries over a longer time period. Sub-sectoral shares within the agricultural sector are derived from an AEZ-based scenario assessment. *U*'*s* for the agricultural sectors are reduced by 15 percent considering the increasing substitution of industrial raw materials for agricultural products in intermediate uses. Handicraft is treated in the same way as used for the service sectors. *B*'s are subject to respective lower-bounds in the optimization procedure so as to guarantee a sufficiently high figure in the corresponding cell, which would partly reflect the increasing share of feeding mode in livestock production.

The RAS approach is a mathematical procedure,[3] in which a new coefficient matrix is generated by solving an optimization problem subject to given row and column margins, represented by the totals of intermediate output (U_{2025}) and intermediate purchases (V_{2025}). The underlying logic is that, given limited information, it is assumed that the A-matrices for

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[3] The term RAS refers to a mathematical procedure for adjusting, iteratively, rows and columns of a given input-output coefficient matrix, $A(0)$, in order to generate an estimate of a matrix, $A(1)$, for a new time point, when only the new structural information of sectoral output, $X(1)$, intermediate deliveries, $U(1)$, and intermediate purchases, $V(1)$, are assumed known. Once the procedure converges, the final outcome is usually denoted as $A(1) = RA(0)S$, in which R is a diagonal matrix that is the product of a series of diagonal matrices, and so is S.

the year 1992 (A_{1992}) and for the year 2025 (A_{2025}) be sufficiently close to each other subject to the constraints representing the new information set (i.e., the vectors of row margin U_{2025} and column margin V_{2025}). Given the additional information concerning some specific cells, and regarding the relative size of the various sectors and the value-added components of the Chinese economy in 2025, we can minimize the difference between A_{1992} and A_{2025} (Budavari 1981, p. 404):

$$(10) \qquad D[\,A_{1992} : A_{2025}\,] = \sum_i \sum_j \left\{ a_{ij}(\,2025\,) \left[ln\left(\frac{a_{ij}(\,2025\,)}{a_{ij}(\,1992\,)} \right) - 1 \right] \right\}$$

This minimization of the RAS objective function generates the least "surprising" representation of A_{2025} because it fully incorporates both the historical information A_{1992} and the new structural information X_{2025}, U_{2025}, V_{2025}, and B’s.

3.2 Land Use in China

The input-output model is extended to incorporate land use. The land-use data is derived from the IIASA-LUC database. A number of fairly large and detailed geographical databases on China including biophysical attributes of land and statistical data at the county level, have been implemented in the LUC geographical information system. These data sets permit estimation of the land area and type used in each of the economic sectors.

Table 4 presents the land-use pattern in the early 1990s. Except for calculating the share of sown areas for grains in the total sown areas from the *Statistical Yearbook of Rural China* (State Statistical Bureau 1993, p. 87), all other calculations are based on the detailed nationwide survey of land use, which was conducted, county by county and step by step, by the State Land Administration during the 1980s. Table 4 shows that only about 141 million hectares or 14.8 percent of the approximate 960 million hectares of China’s total territory are currently being cultivated (field crops and horticulture). Lands unsuitable for agriculture, such as mountains, deserts, or dry grasslands, cover a large fraction of the country.

According to a recent assessment of land production potential in China (Fischer 1999) about 159 million hectares have cultivation potential for grain, of which 132 million hectares are currently used. As Heilig (1999) argues, "the bottleneck is not land, but the availability of investment capital, agricultural know-how, and infrastructure in remote areas." Under the requirement of land suitable for high input-agriculture, meaning mechanization and intensive fertilizer use, China has only some 118 million hectares that are potentially suitable. According to agro-climatic conditions, China can be divided into eight multi-cropping zones ranging from simple cropping to three crops per year (Albersen *et al.* 2000).

In the Chinese land-use database, horticultural land is distinguished from cropping land. With regard to the distinction between land use for grain and for other crops, it serves for the analytic purpose only because in practice, land uses for grain and for non-grain crops are typically inter-cropped in a given cropping rotation. Following this analytical distinction, about 28 million hectares or 3 percent of China's total land area is used for horticulture and other crops. The most important sub-groups in the other crop sector include oil seeds, cotton, sugar cane, tobacco, orchards, tea plantations, mulberry fields, and tropical crops (Fischer *et al.* 1996).

Table 4: Land-Use Pattern in China in the early 1990s

Economic Sectors	**Land Use** (in 1000 hectares)	**Percent of Total Land**
Grain	112,205	11.73
Other Crops	28,438	2.98
Forestry	205,546	21.49
Livestock	303,912	31.78
Fishery	34,640	3.62
Industry and Services	1,737	0.18
Transportation	7,136	0.75
Urban Residents	2,124	0.22
Rural Residents	14,023	1.47
Unused (incl. error)	246,573	25.78
Total	956,334	100.00

Sources: IIASA-LUC database based on annual land surveys conducted in the 1980s at the county level, (State Statistical Bureau 1993).

Notes: Land use for Other Crops includes horticulture. The Land Survey Data includes the categories of cultivated land (both irrigated and rain-fed) and horticulture. We use the statistics on sown area for grains and other crops provided in the *Statistical Yearbook for Rural China* (State Statistical Bureau 1993) to derive land figures in the category of Other Crops before the horticultural land is added in.

The largest land-use category in China is grassland with some 304 million hectares or 31.8% of total land. Some 6.1 million hectares are improved or sown grassland and the rest is natural grassland (Chen and Fischer 1998, p. 17). Pastureland in China is either steppe, mainly distributed in the arid and semi-arid zones of Northern China, or grass on mountains and sloped land located in the agricultural regions. Some 91% of the steppe land and about 59% of the grass slopes are used for livestock production (Fischer *et al.* 1996, p. 56). Only some 10 percent of the total grasslands can be considered as high-yield grasslands with an annual dry-matter production of more than 2000 kg/ha. Almost 60 percent of the best pasture productivity class are scattered in the Northeast (Chen and Fischer 1998, pp. 17).

The total water area for fish farming, including fishponds, paddy land, coastal waters, and wastelands (some of which is waterlogged) amounts to some 34.6 million hectares, which is 3.6% of total land in China. About half of the total fish production is from fish farms; the remainder is from ocean or freshwater fishing. Fishing on paddy land provides about 1 percent of total fish production (State Statistical Bureau 1993, p. 146).

Built-up land is used for residences, transportation, industrial production, handicraft, mining, and services. It amounts to some 25.8 million hectares and accounts for about 2.6 percent of the total land. In several eastern provinces, settlement areas cover already more than 10% of the total land and are increasing. In the future, it is widely recognized that the increasing demand for additional built-up land will further take away cropland areas around the cities. Cropland areas will not only shrink because of urban sprawl, but also due to the growing land requirements of villages and rural infrastructure.

The category "Other Lands" comprises areas unsuitable for habitation and biomass production such as deserts, glaciers and permanent snow, bare land and rocks, sandy and saline land. This category accounts for one quarter of total land in China.

These data, together with the data provided by the input-output tables, permit to calculate land requirement coefficients (and land productivity coefficients) for the base year as presented in Table 5.

Table 5. Land Requirement Coefficients for China's Regions in 1992

(Hectares per million Yuan)

Economic Regions	**Grains**	**Other Crops**	**Forestry**	**Livestock**
R1 – North	363.8	145.0	510.7	330.2
R2 – Northeast	513.3	169.5	8,663.3	1,132.4
R3 – East	236.8	103.1	730.7	39.9
R4 – Central	231.9	105.1	1,438.8	434.7
R5 – South	326.6	76.4	1,112.0	443.9
R6 – Southwest	450.1	149.8	2,599.3	2,303.0
R7 – Northwest	786.5	233.7	5,387.5	24,608.5
China	391.3	130.9	2,088.9	2,928.0

The 1992 land requirement coefficients shown in Table 5 represent the reciprocals of the average productivity of the total acreage in a given land use category. The use of these coefficients in scenario analysis would give us the land requirement at present-day efficiency. Generally speaking, the higher the number in each cell the less productive is the land to produce the respective output. However, it should be kept in mind that because the data do not permit to distinguish undisturbed primeval forests from used forests, and because unused primeval forests concentrate in Northeast and Southwest, the high figures in the forestry column for Northeast and Southwest mean only a low economic utilization of the total forest resources in these two regions.[4] With regard to the livestock production, the huge variability of coefficients is partly due to the varying shares of pasture versus farm-based livestock production across regions, and partly due to the different environmental factors such as soil, temperature, and precipitation, which greatly influence grassland productivity.

3.2.1 Land Availability in 2025

Land availability forms a binding constraint to land-use requirements in general and for agricultural land uses in particular. Without additional available land, the only choice left

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[4] Whether China should exploit these primeval forests for economic purpose or not has been hotly debated, which is beyond the scope and interest of this report.

for an economy is to increase land use intensity (i.e. land productivity) or to increase imports. For given the foreseen scenarios of land productivity improvement and land availability, the balancing of the I-O model estimates the required net import of land-based sectors so as to meet the additional final demand created by changes in the economy and society. Stated differently, given limited land, there is a clear-cut trade-off between land productivity improvement and net import requirement. This sub-section discusses our estimation of the land availability in the major land-use sectors for the year 2025.

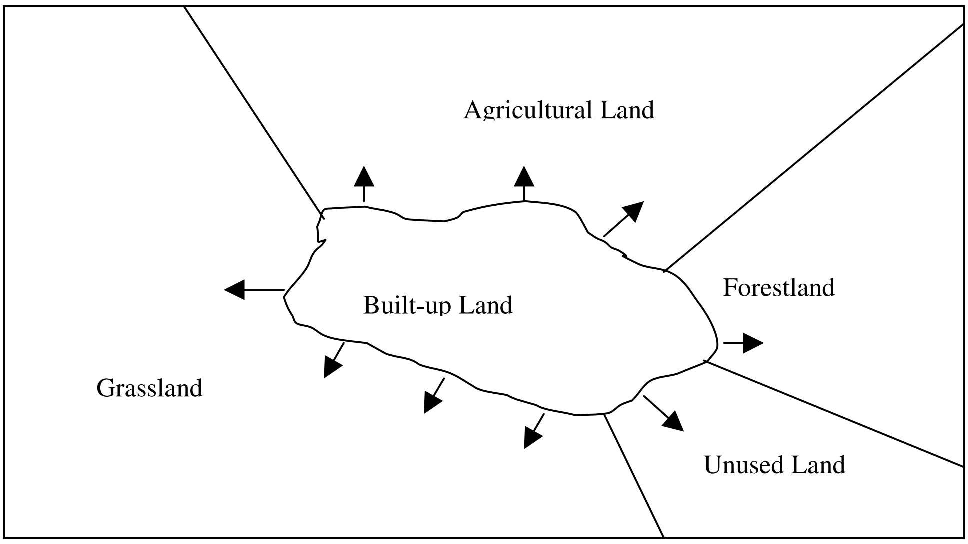
Productive land is lost not only due to growing land requirements of cities, towns, villages, rural industries, and infrastructure, but also because of degradation caused by natural disasters, water and wind erosion, and other chemical and physical deterioration. To make up for these losses or to even extend the existing land base, farmland reclamation has been emphasized in China's agricultural policy. However, the reclamation seems to lag behind farmland conversion following the pace of economic development in general and the booming of rural industries in particular. Losses of fertile farmland mainly occurred in the southeastern part of the country, where irrigation conditions are good and the multi-cropping index is high. In contrast, the reclamation mainly took place in the marginal zones located along the boundary between cropping and non-cropping areas (Sun and Li 1997, p. 22). The average productivity of newly reclaimed land is usually between 30 and 50 percent of that of existing farmland, depending on the available technology, and is even lower for grassland (Ministry of Agriculture 1998). In addition, conversion possibilities of other land categories to farmland have become very restricted and would require substantive investments.

Due to increasing awareness of land scarcity in recent years, we can expect that great efforts will be made to increase land reclamation and to protect agricultural land. Hence, we assume that degradation-induced total losses of cultivated land, grassland, and forestland between 1992 and 2025 could be fully compensated by land reclamation and preservation. This assumption reflects also the policy orientation of the Chinese government. Nevertheless, land conversion from agricultural uses to more profitable non-agricultural uses and to residential uses will certainly continue. This conversion will take place mainly around economic centers. To capture this conversion, we employ GIS technique to calibrate our scenarios. We overlay a map of existing population agglomerations with a map containing current land uses. We expand existing agglomerations by adding an additional ring of one-kilometer width, to the outskirts of each existing built-up area. The determination of this width is based on the scenarios of future demand for residential and non-agricultural uses of lands, which will be discussed in Section 4.5.4. In this way, we can see how the expansion of existing built-up areas reduces the amount of other land-use categories as shown in Figure 2.

Deducting land requirements for additional built-up land from the three major land categories and assuming that the share of cultivated land used for other crops will increase by about 6 percentage points, we obtain the estimates of land area available in 2025, as presented in Table 6. These numbers may be regarded as upper bounds of land available for the development of the associated economic sectors.

For the calculation of land requirements per land-use category, we apply a land distribution matrix (*R* in Equation 3) as shown in Table 7. This matrix establishes the linkage between land-uses by economic sectors and natural categories of land.

Figure 2: Scheme of Extension of Built-up Land in a GIS scenario



Notes: The existing urban areas are captured with remote sensing. Unfortunately, this method only recognizes built-up areas beyond a certain size. As a consequence, the so-derived land conversions reflect only the extension of larger agglomerations.

Table 6. Total Land Availability for each Land-use Category in 2025 (In 1000 hectares)

Economic Regions	Agricultural Land	Other Crops	Forestland	Grassland	Built-up Land
R1 – North	23,023	9,305	4,021	6,593	6,743
R2 – Northeast	17,706	3,531	21,240	8,357	4,226
R3 – East	10,114	4,201	4,052	561	4,120
R4 – Central	7,689	3,682	10,526	5,157	3,480
R5 – South	8,102	3,858	12,851	5,558	2,932
R6 – Southwest	15,494	5,280	17,779	29,039	3,839
R7 – Northwest	17,990	5,923	17,444	149,649	4,785
China	100,911	36,038	94,292	251,764	30,475

Notes: We assume that land losses due to erosion could be fully compensated by reclamation. Land losses due to development of other economic sectors or residential use are subsumed in the category built-up land and subtracted from the other categories. The share of cultivated land used for other crops is assumed to increase by six percentage points.

Table 7. Regional Distribution Matrix in 2025

	Major Land Categories					
Economic Sectors	**Cultivated Land**[c]	**Forestland**	**Grassland**	**Water Areas**	**Unused**	
Grains	1	0	0	0	0	1.00
Other Crops	1	0	0	0	0	1.00
Forestry	0	1	0	0	0	1.00
Livestock [a]	0	0	1	0	0	1.00
Fishery	0.10	0	0	0.89	0.01	1.00
Developed [b]	0.72	0.13	0.07	0	0.08	1.00

Notes: [a] In reality, only pasture livestock production directly corresponds to grassland. Because it is impossible to distinguish pasture and farm-based livestock production for China in an I-O setup, we use this simple assumption and leave the indirect linkage between livestock production and other land-use categories to the I-O tables. On the other hand, we include land uses for keeping pork and poultry in the grassland category. These land uses are not a part of grassland and amount to a small share of residential land. In our change-focused analysis, such a simplified assumption may still induce an over-estimated requirement for grassland productivity improvement.

[b] The category "Developed" includes residential land, infrastructures, and industrial and commercial uses. Its land distribution can be further differentiated between land for the production of grains and for other crops.

Source: Based on scenarios in the GIS: expansion of existing agglomerations by adding an additional ring of one kilometer width, to the outskirts of each existing built-up area.

The entries in Table 7 are numbers between 0 and 1, which indicate the percentage distribution of land used by the respective economic sector in each of the major land categories. The numbers do not represent current patterns of land-use but rather future land-use development. As the table shows, we assume that various land-use options, such as residential land, industrial land, horticulture, and fish, compete for cultivated land, grassland, and forestland. The category of unused or multiple use land represents a residual value. In the case of fish production, for example, parts of it takes place on agricultural land without diminishing the usage of agriculture land. This type of multiple use does not decrease the ability to use land for other production purposes. Sectors utilizing built-up land are assumed to expand also in part on previously unused land.

4 Driving Forces of Land-use Change

This section develops scenarios for each of the major forces that drive land uses and changes in a large and rapidly modernizing economy like China. Undoubtedly, population growth together with the modernization-driven income growth, urbanization, and lifestyle changes will continue to shape the patterns of land uses and to drive the changes in land uses in the coming two or three decades as they did in the past two decades.

After establishing scenarios for each of the major driving forces, we organize them in a specific-to-comprehensive manner to show step by step the additional effects. Starting from the base year representation of the economy and society, a set of scenarios representing each of the major factors is added to show its additional effects on land requirements (Table 8). *Scenario A* represents the situation in the base year 1992, with the technology and population level, share of urban and rural population, consumption pattern, and economic structure of 1992. *Scenario B* applies improved yet plausible technology assumed to be available in year 2025 to the socioeconomic and demographic structure of 1992. In *Scenario C*, we add to Scenario B final demand changes and additional direct land requirements caused by a population of 1.49 billion people. S*cenario D* includes per capita income growth as well as lifestyle changes as represented by a set of income elasticities. S*cenario E* deals with the aggregate effects of Scenario D plus urbanization. *Scenario F* is designed to quantify the overall effects of a higher population estimate of 1.55 billion people and a higher share of urbanization, in combination with Scenario E.

Table 8: Major Driving Forces and Scenarios

	Scenarios					
Major	**A**	**B**	**C**	**D**	**E**	**F**
Driving Forces	(China1992)	(A + Technology)	(B + Population)	(C + Income Growth)	(D+ Urbanization)	(E + Population high)
Technological Change	1992	**2025**	**2025**	**2025**	**2025**	**2025**
Population Growth [a]	1.17	1.17	***1.49***	**1.49**	**1.49**	***1.55***
Income Growth	1992	1992	1992	***2025***	**2025**	**2025**
Urbanization	1992	1992	1992	1992	***2025***	**2025** [b]

Notes: [a] Population is in billion.

[b] Higher urbanization rate of 59% for 2025 (Shen and Spence 1996).

4.1 Economic Growth and the Consequent Per Capita Income Growth

Since 1978, China's GDP has expanded at an average rate of nearly 10 per cent - and total exports at 17 percent - per year. China's Five-Year Plan for 1996-2000 targeted an annual GDP growth of 8 percent. The Fifteen-Year Perspective Plan identifies two fundamental transitions to sustain future growth: from a traditional planned economy to a socialist market economy; and from the extensive growth path, based on increases in inputs, to an intensive growth fashion, driven by improvements in efficiency. Measures to sustain further growth include the restructuring of the largest state-owned enterprises, promoting science and technology, developing machinery, electronics, petrochemicals, automobiles, and construction as the pillar industries, and stimulating the growth of basic agricultural products, especially grain, cotton, and oilseed (World Bank 1997b). Assuming the continuance of high saving rates supporting high investment rates, of the market-oriented reforms, and of high factor productivity growth, the World Bank projected growth rates of annually 6.6 percent until 2020. The projection for individual sectors are ranging from 3.8 percent for agricultural sectors, 6.6 percent for industrial sectors, to 7.6 percent for service sectors (World Bank 1997b, p. 21). According to the World Bank, the pace of GDP growth will be slowing down over time, from some 8 percent of today to 5 percent in 2020 due to a then stagnating labor force, diminishing marginal returns, and lower gains from structural change.

These aggregate growth trends mask diverging paths for different parts of China. There is a large body of literature dealing with the regional disparity in China (Liu et al. 1999; Tian 1999, among others). It is generally acknowledged that there emerged three regions with discerned development paths in the past two or more decades: the leading coastal areas characterized by high income level and high growth rate; the catching up central regions with average income level but rapid structural changes from agriculture to industry and services; and the economically backward regions in the west, with a much slower growth rate, and with a small share of population in the national total, which is dominated by national minorities. Another significant disparity exists between rural and urban areas. The per capita income ratio of rural to urban residents has been around 1 to 2.5 in the past two decades.

GDP growth rate is a comprehensive indicator that is not independent of population growth (implying labor force growth) and technological progress. To make income growth rate be independent of other driving forces, we subtract the foreseen growth rate of population and further the part corresponding to technological progress (about 40 percent of GDP growth) from the projected national GDP growth rate (World Bank 1992). As a result, we obtained a net per capita income growth rate. For simplicity, we call it per capita income growth rate. In order to accommodate to the regional and rural versus urban differences discussed above, we distinguish growth rates for urban and rural areas and for two large development zones: the East Zone comprised of regions 1-5 and the West consisting of regions 6 and 7. The basic scenarios for per capita income growth are presented in Table 9.

Table 9: Annual Income Growth Rates in China for the period 1992 - 2025

Regions	1992-2004		2005-2025	
	Rural	**Urban**	**Rural**	**Urban**
East Region: R1-R5	0.0475	0.0525	0.0425	0.0475
West Region: R6 and R7	0.0450	0.0500	0.0400	0.0450
China	0.0470	0.0520	0.0420	0.0470

4.2 Population growth

When the People's Republic of China was founded in 1949, it had a population of 540 million; three decades later its population was more than 800 million; China's present population has approached 1.3 billion. Today's high share of young Chinese in reproduction age has created a strong population momentum that is now driving China's population growth despite already low levels of fertility. China is confronted with two counteracting trends: while economic growth, urbanization and the associated lifestyle change may lead to lower fertility rates, modernization and the opening of society might lead to opposition to the government's strict one-child rule in family planning (Heilig 1999). In its most recent (medium variant) projection, the UN Population Division estimates that China's population will increase to 1.49 billion in 2025 and then slightly decline to 1.488 billion in 2050 (United Nations Population Division 1998). A somewhat higher projection estimates 1.55 billion people for 2025 (Shen and Spence 1996).

A crucial characteristic of China's demographic situation is the concentration of its large population in the eastern part of the country, especially in the coastal zone. A large part of China's land is virtually uninhabited, such as the Gobi Desert, the steep slopes of the Himalayas, and the vast dry grasslands of the Plateau and Inner Mongolia. Roughly 1.1 billion people (or about 90% of the population) live in only a little more than 30% of China's land area. The average population density of this area is 354 people per square kilometer. The skewed spatial distribution of the population is a consequence of the country's uneven distribution of agro-climatic and bio-physical environments, as well as the uneven development pace of industrialization.

In the past two decades, two opposite trends have coexisted to shape the population dynamics across regions. On one hand, migration from Western and Central China to the eastern regions, especially the coastal areas, has added percentage points to population shares of the eastern regions. However, on the other hand, the fertility rates increasing from the eastern to the western regions have basically counter-balanced, if not outweighed, the impact of migration (Jiang and Zhang 1998).

To project the regional population dynamics for the coming two and a half decades, besides the above-mentioned two trends, a third one has to be taken into account as well. This includes the moving of traditional industries, particularly, heavy industry, from the eastern regions inward to the western regions and the new strategic movement of the Chinese government to reduce regional disparity. As a comprehensive result of these three trends, although the migration from the inland to the coastal areas may outweigh the other two trends in the coming decade, its accumulative impact up to 2025 may not be very significant. Based on this consideration, we establish in Table 10 the scenario for regional distribution of population in 2025. We assume that the population shares of East and South Regions, the most developed regions, in the national total will increase by one percentage point, respectively; the population shares of Central and Southwest Regions, the regions with high population density and the highest proportion of agricultural population, will decrease by one percentage point, respectively; and the population shares of other regions will stay unchanged.

Table 10. Regional Distribution of Population in 1992 and 2025 (In thousands)

Economic Regions	1992 [a]	%	2025 [b]	%
R1-North	281,700	24.7	367,693	24.7
R2-Northeast	99,930	8.8	130,435	8.8
R3-East	179,470	15.7	234,256	16.7
R4-Central	153,770	13.5	200,710	12.5
R5-South	143,070	12.6	186,744	13.6
R6-Southwest	178,030	15.6	232,376	14.6
R7-Northwest	97,330	8.5	127,041	8.5
China	1,140,000	100	1,488,000	100

Sources: [a] State Statistical Bureau (1997a).

[b] United Nations Population Division (1998) and population forecasting by Jiang (1998).

Note: The population share of the Plateau region in the national total was 0.6 percent in 1992, and it is assumed to be at the same level in 2025.

4.3 Urbanization

Despite the fact that the urban population is rapidly increasing, China can still be considered a predominantly rural society. In 1997, only some 30% of the population lived in urban areas as officially defined. The rather recent increase in urban population is mainly due to the promotion of towns into cities, thus increasing the number of cities altogether. In 1980, there were 223 cities throughout China; by 1990, the number had more than doubled to 467. In the last 10 years, the number of large cities has increased from 70 to 119, small cities from 108 to 289 and towns from 2,874 to 12,084 (Heilig 1999). Another reason for the increase in urban population has been the loosening of strictly controlled internal migration to meet the labor demand of the growing cities and towns. In addition, in recent years, there has been a wave of temporary "illegal" rural-urban labor migration, called the "floating population". Some estimation puts the number of the floating population in large cities as high as 25 percent of the urban population (Heilig 1999). We assume that this urbanization trend will continue in the future and that by 2025 about 50 percent of the Chinese population would live in urban areas. This assumption is consistent with the corresponding UN projection (United Nations Population Division 1998). We further assume that both the agricultural population living in and the rural population migrating to cities and towns will gradually adopt urban lifestyles.

There are no reliable estimates of the urbanization rate for different regions since even present data on city growth and rural-urban migration is in poor quality. However, as discussed in the previous sub-section, two large zones can be distinguished due to the striking development disparity between them. For the more developed eastern zone (regions R1-R5), we assume a level of urbanization of some 54 percent, and for the less developed western zone (regions R6 and R7), about 44 percent, respectively.

Table 11. Urban and Rural Population in 2025 (In thousands)

Economic Regions	**Urban**	**Rural**
R1-North	192,301	175,391
R2-Northeast	68,217	62,218
R3-East	130,297	118,839
R4-Central	97,188	88,642
R5-South	105,448	96,176
R6-Southwest	92,684	124,812
R7-Northwest	54,138	72,903
China	744,000	744,000

Source: Total population for China: United Nations Population Division (1998).

Notes: Regional distribution is calculated based on the assumption that 50 percent of China's population will live in cities. Urbanization rates in 2025 for regions R1-R5 are assumed as 54 percent and for regions R6-R8 as 44 percent, respectively. The corresponding population figures in the Plateau region are 3,727 and 5,019, respectively.

4.4 Change in Consumption Pattern

Changes in consumption patterns, particularly in diet structure, are most relevant to the study of land-use change. In China's food tradition, cereal products have been of overriding importance. Other food products such as meat, fishery products, vegetables, and fruit played only a residual role in human diet. This pattern has been changing due to recent social and economic developments. Urban residents typically prefer a more diverse diet and eat more processed foods. Today's Chinese eat more meat and dairy products, which has boosted livestock production. China's population has enormously increased its meat consumption and also eats more fruits and vegetables, whereas direct consumption of grain per capita has started to decline. For example, over the period from 1981 to 1995, the direct food grain consumption per capita in urban areas dropped from 145 kg to about 100 kg;[5] whereas in rural areas, the per capita consumption of milled grain initially increased in the early 1980s and then gradually decreased, and by 1995, it had reached again the 1981 level (Wu and Findlay 1997, p. 49). Despite these developments, China's average food calorie supply per person per day is still below the average level of developed countries (FAOSTAT 1998). Therefore, some increase in per capita calorie consumption can still be expected in the future.[6]

A comparison of per capita calorie intake across some representative countries shows that today's food calorie supply of animal products in China is about 467 kcal per person compared to 503 in South Korea, 600 kcal in Japan, and 1,006 in USA. The average consumption for developed countries is 867 kcal. In addition, today's calorie intake of fish in China falls short of other Asian countries. Currently, food calorie supply of fish in China is 29 kcal, compared to 92 kcal in South Korea and 194 kcal in Japan (FAOSTAT 1998).

To incorporate these considerations in a consistent way and in line with our I-O modeling, we establish the scenarios of income elasticities for two periods, 1992-2005 versus 2005-2025, as presented in Table 12. The combination of both scenarios of per capita income growth (Section 4.1) and income elasticities give the per capita expenditure pattern for the year 2025. A sensitivity analysis of various elasticities and growth rates on land demands are presented in the Appendix in Table 21.

To calculate aggregate final demand from households for the products of each production sector, we multiply the above-listed average expenditures of urban and rural residents, respectively, by the total numbers of urban or rural residents in each region. To obtain total final demand corresponding to each production sector, we link other final demand components to household consumption according to their current ratio to the level of aggregate household consumption.

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[5] Under-reporting of food consumption for urban households may be increasing in the reform era, because eating in restaurants and in working places become increasingly popular and fashionable, and the official household survey has limitations to fully incorporate this kind of consumption. If this trend is taken into consideration, the decrease of per capita grain consumption in urban areas may not be so significant.

[6] Estimates of future demand for meat are difficult to make. The vast differences in the estimated results are directly related to the different parameters and research methods adopted in different studies. Furthermore, great inconsistencies of the data on meat consumption and output exist due to a combination of shortcomings in reported data on the supply side and in survey data on the demand side (Feng 1997).

Table 12. Change in Consumption Pattern and Income Elasticities

	Per Capita Expenditures (in Yuan)		**Income Elasticities** [a] **for the Period 1992 – 2025**				**Per Capita Expenditures**[b] (in Yuan)	
Sectors	**1992**		**1992-2005**		**2005-2025**		**2025**	
	Rural	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**
Grains	112.3	10.8[c]	0.250	0.150	0.100	-0.03	135.9	11.5
Other Crops	69.2	147.3	0.435	0.450	0.450	0.470	109.8	248.4
Forestry	3.2	6.0	0.757	0.835	0.600	0.650	6.0	12.5
Livestock	112.5	184.2	0.757	0.835	0.650	0.700	215.3	390.2
Handicraft	13.8	29.6	1.100	1.100	1.100	1.100	33.9	78.0
Fish	19.8	58.5	1.244	1.290	1.244	1.290	52.4	170.7
Industry	306.0	887.4	1.100	1.100	1.100	1.100	750.3	2,336.9
Construction [d]	44.0	115.1	1.100	1.100	1.100	1.100	107.8	303.2
Transportation	4.9	19.2	1.200	1.200	1.200	1.200	12.5	53.3
Commerce	65.5	197.0	1.200	1.200	1.200	1.200	169.3	548.2
Services	67.7	278.8	1.200	1.200	1.200	1.200	174.8	775.7
Sum	819.0	1934.0					1,768.2	4,929.5

Notes: [a] Income elasticities are based on the estimates and calibrations in Huang and Rozelle (1998) and Huang and Chen (1999), and on our own adjustments to accommodate the sectoral setup in the input-output model. To our knowledge, these two studies give the most comprehensive and systematic estimations of demand systems for both rural and urban China so far.

[b] The calculation of household expenditure in 2025 is based on the following relationship:

$$EX(2025) = \left(1 + \varepsilon \times \frac{IN(2025) - IN(1992)}{IN(1992)}\right) \times EX(1992)$$

where *IN* stands for Income and *EX* for Expenditure in the respective years, and ε represents income elasticities. For the annual growth rates of per capita income, see Table 9.

[c] This figure represents the direct purchase from the grain sector by urban residents (typically via free markets). Purchases of processed foods from the industrial, commerce, and service sectors are incorporated in expenditure figures in these sectors, respectively, following the input-output setup of China.

[d] The input-output table does not give any values for construction expenditures of urban and rural households. We assumed that households account for 15 percent of the total final demand for construction.

4.5 Technical Change and Land Productivity

This section contains a description of present and future technologies, and their impacts on land uses. We further describe sector specific technologies that allow us to calibrate the land-requirement coefficients for each economic sector in different regions in 2025.

4.5.1 Grains and Other Crops

The average increase in land productivity in the grain sector for the period of 1952-1996 was 3 percent (*Statistical Yearbook of China* 1991, p. 353; 1998, p. 406). In grain production, average yields in China are generally above average yields in developing countries but still well below the averages in developed countries. Future growth of grain production via significant yield growth could be achieved by spreading applications of updated hybrid seeds, balanced utilization of chemical fertilizer and pesticides, increasing use of other modern inputs such as plastic film, farming machines, investment in agricultural infrastructure such as irrigation and drainage facilities, and agricultural research (Heilig 1999; Lin 1995; Lin et al. 1996; Nickum 1982; World Bank 1985; World Bank 1997a). In addition, the Ministry of Agriculture plans to classify over 80% of farmland as basic farmland conservation zones by 2010, indicating a firm effort to insure the sustainable development of the food sector.

There is a debate on the magnitude of future growth of grain yields. For example, the World Bank used yield growth rates of 0.5 to 1% for their estimations assuming favorable water availability (World Bank 1997a). Huang and Kalirajan (1997) came up with similar estimates using a stochastic varying coefficients frontier approach based on household survey data. Lin *et al.* (1996, p. 83) used projections of yield increases in grain production of 1.4 to 1.7% per year, depending on investment in research and irrigation, world price impact, salinity and erosion, and opportunity costs of labor and land. Cao, Ma, and Han (1995) estimated that the average potential yield of all cereal crops could be 92% higher than the current actual yield based on average potential primary productivity. This would translate into a yield growth rate of some 2% until the year 2025. Lin (1995) argues that the grain yield potentials are in general two to three times the current actual yield levels.

For our scenarios, we follow the *Agricultural Action Plan* of China's Ministry of Agriculture with a target for grain yield increase of 1% per year. We apply the same productivity growth rate for other crops.

In order to derive regional differences, we use an assessment of the crop production potential in China by Xie and Jia (1994) based on the AEZ method. This allows us to calculate regional differences based on natural factors assuming similar technologies in all of China. Due to the fact that land suitability changes along with changes of different land utilization types prescribed by certain social and economic conditions, Xie and Jia (1994) developed three production scenarios: low, medium, and high input level scenarios. The differences among these three input levels lie in the differences in multi-cropping indexes, scale and intensity of land, pest and weed management, factor-intensity of labor, capital, and modern energy utilization, utilization of organic and chemical fertilizers, and other operational technologies employed.

Table 13 reports the resultant scenarios of land requirement coefficients for year 2025 and compares these 2025 coefficients with 1992 ones. Further technical details are presented in the notes of Table 13.

Table 13. Land-Output Ratio for Grains and Other Crops

(Hectares per one million Yuan of output)

Economic Regions	Grains		Other Crops	
	1992	2025	1992	2025
R1 – North	363.8	249.5	145.0	102.6
R2 – Northeast	513.3	366.5	169.5	75.0
R3 – East	236.8	183.1	121.2	83.5
R4 – Central	231.9	178.3	105.1	64.9
R5 – South	326.6	226.7	76.4	50.6
R6 – Southwest	450.1	329.5	149.8	110.0
R7 – Northwest	786.5	517.5	233.7	154.7
China	391.3	281.8	152.1	101.0

Sources: Figures for 1992 are calculated based on regional I-O tables and Table 4. Procurement Prices are taken from *China Price Statistical Yearbook* (1992, pp. 302-334). Assessment of Crop Production Potential is taken from Xie (1994).

Notes: An annual productivity growth rate of 1.00 percent is assumed at the national level. To calculate the regional variations, the incremental output from the low input level to that at the intermediate input level is used. To calculate the incremental output, rice, wheat, maize, sorghum, and soybean are selected for the grain sector and are added up in monetary terms; oilseeds, cotton, sugar crops, fruits and vegetables are selected for the other crops sector and are added up in monetary terms as well.

4.5.2 The Forestry Sector

Most forests in China are sub-tropical and temperate forests, which have fewer species and require longer growth cycles than tropical forests. Forestland covers about 263 million hectares of land, representing 27.5% of China's land area. Closed forests are about 108 million hectares. The biggest share is for timber production (78.7%). Further uses are protection (16%), fuel-wood (4.3%), and special use forest (3.4%) such as forest plasm garden. The remaining area includes forest stand area, scattered forests, shrub wood, and reforestation areas.

The estimations of forest stock are quite diverse. For example, Fischer *et al.* (1996) report that the stock has steadily increased, from about 7 billion cubic meters (m^3) in the 1950s to about 10 billion m^3 in the late 1980s. Liu (1998) claims that timber stocks are drastically decreasing due to increased consumption, withering, fire damage, and insect damage. For 1992, Liu estimates the existing forest stock to be about 5.3 billion m^3. Liu states that if no action were taken, China would lose all its timber stocks in the near future. Nilsson (1999) shows that the felling of industrial wood at the current rate of 197 million m^3 per year exceeds the annual increment of 176 million m^3 per year in growth of natural forests and industrial plantations. Shi and Xu (2000) on the other hand, using all four forest resource censuses data (Ministry of Forestry 1978; 1983; 1990; 1996) show that the forest resource stock had been slightly increasing between 1973 and 1993 and the total timber stock was about 11.8 billion m^3 in the early 1990s.

Based on the forest resource census data, we establish the productivity change scenarios for the forestry sector in line with Fischer *et al.* (1996) and Shi and Xu (2000). We first calculate the land requirement coefficient in the forestry sector for 1992 directly from the total output of forest sector as provided by the I-O tables and the corresponding areas. The resulting land coefficient at the national level is consistent with a sustainable yield factor of about 4.2 m^3/ha (Ministry of Agriculture 1998; Shi and Xu 2000) while being weighted by the corresponding prices of major forest products.

In consideration of the fact that timber densities in China are very low with 30 m^3/ha to 84 m^3/ha in comparison to World's timber densities of about 100 m^3/ha (Ministry of Forestry 1990) and that the efforts to improve forest management are under way through property right reform, strengthening monitoring and preservation institutions, and employing other effective management practices, we assume a total productivity growth of 25 percent in this sector from 1992 to 2025. Due to the lack of AEZ assessment, we have to ignore the regional variation in growth for this sector.

Table 14. Land-Output Ratio in the Forestry Sector

(Hectares per one million Yuan of output)

Economic Regions	1992	2025
R1-North	510.7	382.99
R2-Northeast	8,663.3	6,497.48
R3-East	730.7	548.00
R4-Central	1,438.8	1,079.10
R5-South	1,112.0	833.97
R6-Southwest	2,599.3	1,949.45
R7-Northwest	5,387.5	4,040.62
China	2,088.9	1,566.69

Sources: Regional I-O tables and Tables 4 and 5.

Notes: No information was available to permit regional specific assumption on forestland productivity growth. An total productivity growth of 25 percent was assumed, which implies an annual productivity increase of 0.68 percent.

4.5.3 The Livestock Sector and Grassland

There are two basic modes in livestock production: grazing mode in pastoral areas and feeding mode in farms. In the early 1990s, feeding mode accounted for about 65 percent of the total livestock production.

In terms of the feeding mode, the most popular practice in the 1990s was household feeding in backyards. In this way, livestock relies on surplus grain produced by farming households, as well as on crop residues, green fodder, household garbage, and other mixed feed. In the coming decades, it is widely expected that specialized livestock farms will gradually become the dominant form of production in this sector. These livestock farms are characterized by a much higher degree of specialization and productivity. Their animal feeds are in most cases purchased from the feed-processing sector.

To evaluate productivity of the grazing-based livestock production system, it helps to distinguish three major grassland utilization types: natural pasture, improved pasture, and sown pasture. The majority of grassland in China is unimproved natural grassland. Improved grassland or semi-artificial pasture refers to pastures which have been improved by measures such as fencing, air seeding, irrigation, insect control, fertilizer application, and desertification control. With these measures, the forage yield can be improved by 20 – 90 percent over natural grassland. Sown pastures are established through land preparation and sowing of higher-yielding grass species. Management measures include fertilization, irrigation, drainage, and plantation of windbreaks. The forage yield of sown pastures is 4 –5 times that of natural grassland. According to the *National Grassland Regional Development Plan* for (1991-2020) and the Outline of the *Eighth Five-year Plan* (1991-1995), the future orientation of grassland is to expand the area of improved pastures and sown pastures. But the extent for such improvement is limited and the corresponding expectation is not high. For example, the Ministry of Agriculture (1999) hopes that China can maintain a stable output of animal husbandry in the pastoral areas until 2010 and can start to increase the pastoral land productivity afterward.

Given the very limited capability of the grazing mode, it is widely expected that by 2020, feeding mode would produce more than 80 percent of the total livestock output (Ministry of Agriculture 1999). We put this figure at 85 percent for 2025. In line with the expectation of the Ministry of Agriculture (1999), we assume a cumulative land productivity growth in the pasture sector of 25 percent for the period of 1992-2025, which is equivalent to 0.68 percent per year.

In the calculation of land requirement coefficients for the livestock sector, it is worth noting that the real land requirement would be a combination of the direct land uses, including pasture land and those land uses for keeping pork and poultry, and the indirect land uses for growing processed and unprocessed feed-crops. Once the scenarios of land productivity growth for both the cropping and pastoral sectors are established, the overall land-productivity growth in the livestock sector can be interpreted as the value-share weighted average of the corresponding growth in the cropping and pastoral sectors. For example at the national level, if the annual land-productivity growth rate is 1 and 0.68 percent in the cropping and pastoral sector, respectively, and the output share of pasture in the total livestock production decreases from 35 to 15 percent during 1992-2025. The overall land-productivity growth in the livestock sector would be 0.95 percent per year.

To derive the regional variation of land productivity growth in the livestock sector, we use the estimation by Zheng and Tang (1994). Their study considers both livestock production modes of grazing and feeding. Their herd distribution between the grazing and feeding modes for the low input and intermediate input levels is in line with our corresponding output distribution for years 1992 and 2025. Their assessment of grassland productivity consists of two major parts: the calculation of the primary production (forage output) and the secondary production (livestock products). The calculation of forage supply is based on the AEZ method, which allows the calculation of attainable yields for a wide range of agro-ecological conditions found in China. To calculate forage production potential, the attainable forage yield was multiplied with the actual acreage of grassland in each agro-ecological class. The grassland areas were based on the national grassland resources survey conducted in the 1980s. To obtain the feed supply potential, the yields for each zone were adjusted by feed intake rates of livestock and different moisture content for hay-making of different grassland types (Zheng and Tang 1994, p. 33). In a second step, the characteristics of the livestock system were highlighted and different herd proportions and livestock production potentials were calculated based on the balance between feed supply potential and feed requirements.

Similar to what we present in Section 4.5.1, the increasing livestock output from the low-input level to the intermediate-input level shows a clear variation across regions. We use this variation to regionalize the average national productivity-growth rate. Results are reported in Table 15.

Table 15. Land-Output Ratio in the Livestock Sector

(Hectares per one million Yuan of output)

Economic Regions	**1992**	**2025**
R1 – North	115.6	104.7
R2 – Northeast	396.3	353.2
R3 – East	14.0	12.6
R4 – Central	152.1	136.2
R5 – South	155.4	141.8
R6 – Southwest	806.0	752.0
R7 – Northwest	24,608.5	17,774.6
China	2,928.0	2,661.8

Sources: Regional I-O tables, Table 4, and Zheng et al. (1994).

4.5.4 Non-agricultural Sectors and Built-Up Land

It may be universal that there is a natural overlap among settlement areas, service sectors, and transportation in urban areas. However, in the case of China, the existing data for settlement areas are not consistent among different sources and the numbers vary by about 10 percent (Fischer *et al.* 1996). Furthermore, the given categories are not clearly distinguished. The major category of settlement area includes industry and mining areas as well. The sub-categories of rural and urban settlement areas include housing areas, commerce and services, as well as urban infrastructures, parks and other public space. In our research, we adopt the definition and data source of State Land Administration (Fischer *et al.* 1996). Table 16 shows the different categories of built-up land in China.

Rural settlements account for almost two thirds of total settlement and mining areas. Within urban areas, industrial areas occupy a considerable share: industries located in the built-up area of the cities use 20-30 percent of the settlement land. An additional 3-6 percent is taken up by warehouses (Hin 1999; World Bank 1993).

Settlement area per capita amounts on average to 155 m^2 for rural population and 90 m^2 for urban population. Its regional variation ranges from 69 m^2 in the South Region to 136 m^2 in the Northwest Region for urban population and from 89 m^2 in the South Region to 322 m^2 in the Northeast Region for rural population (Table 18). These numbers are similar to the findings of the Center for Policy Studies within the Ministry of Construction, and of the

World Bank. Their estimates show that large cities are far more efficient users of land than smaller towns: land use per capita increases drastically with decreasing settlement size (World Bank 1993, p. 1). They show also more efficient land use in crowded and heavily developed areas.

Table 16. Built-up land in 1992

(In 1000 ha)

Economic Regions	Settlement area			Transport	Built-up/ Total land (%)
	Rural	Urban	Industry & Mining		
R1 – North	3,702	420	453	1,421	8.6
R2 – Northeast	1,879	388	381	896	4.5
R3 – East	2,131	270	229	874	9.9
R4 – Central	1,621	255	137	957	5.3
R5 – South	1,026	189	133	908	4.0
R6 – Southwest	1,678	268	109	832	2.6
R7 – Northwest	1,901	311	243	1,153	1.0
China	14,023	2,124	1,737	7,136	2.6

Source: IIASA-database based on the land survey conducted in the 1980s at the county level.

If urbanization can be well combined with urban redevelopment, residential areas per capita could be decreasing along with an increase in living space per capita. The notion of urban redevelopment represents a mechanism that is, on a site-by-site basis, raising floor-to-area ratios[7] from very low levels (0.3-0.6) to much higher levels of about 2.5-10.0 (World Bank 1993, pp. 107). Table 17 shows a demonstrative example of land-use transformation at the city block level. In the table, notably the proportion of land devoted to industrial and residential uses decline. The shares of other uses show dramatic increases.

However, in the case of China, directly used living space per capita[8] is still rather little: urban residents used in 1992 on average 7.1 m^2 per capita and rural residents lived on some 18.9 m^2 (State Statistical Bureau 1997b, p. 324). Combining both considerations for further improving living conditions and intensifying land use through the redevelopment of cities and particularly towns, we assume a moderate increase of urban settlement area, including residential areas, public space, infrastructure, and services and trade, of about 20 percent per person for urban residents in central and eastern China (R1-R5) between 1992 and 2025. For the less efficient western zone (R6-R7) in terms of urban land-use intensity, we assume the settlement areas to remain constant. For rural residential land, due to the effect of urbanization and migration from rural to urban areas, a general decrease in per capita use is

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[7] A floor-to-area ratio (FAR) of 0.3 indicates that every 3 square meters of built space needs ten square meters of land providing other supporting systems.

[8] The actual living space, excluding corridor, kitchen, bathroom, and toilet is measured between the inner walls.

expected. We assume that rural residential land areas per capita will between 1992 and 2025 decrease by 20 percent in regions R2 and R7, by 10 percent in regions R1, R3, R4 and R6, and will remain unchanged in region R5,.

Table 17. Typical Land-Use Conversion in City Centers

Land area	Before Redevelopment in %		After Redevelopment in %	
Street	8.0		18.0	
Residential	55.0		30.0	
Office	20.0		25.0	
Commercial	12.0	‘	27.0	
Industrial	5.0		0.0	
Floor area	in %	FAR	in %	FAR
Residential	49.7	0.6	24.3	2.5
Office	24.1	0.8	36.4	4.5
Commercial	21.7	1.2	39.3	4.5
Industrial	4.5	0.6	0.0	0.0
Total	100.0	0.7	100.0	3.1

Source: World Bank (1993, p. 108).

Table 18. Residential Land (m^2/per person)

	1992		**2025**	
Economic Regions	**Rural**	**Urban**	**Rural**	**Urban**
R1 – North	161	81	145	97
R2 – Northeast	322	93	258	112
R3 – East	151	71	136	85
R4 – Central	128	95	115	114
R5 – South	89	69	89	82
R6 – Southwest	111	102	100	102
R7 – Northwest	255	136	204	136
China	155	90	137	103

Sources: Tables 11 and 16, and our scenario assumptions.

Notes: Residential land includes housing, infrastructure, and services.

Due to the heterogeneity of industrial production, there is no systematic aggregate data available on land requirements of various industries beyond case studies on a local or regional level (e.g. Borchard 1999). Furthermore, it is difficult to estimate how redevelopment of urban areas and organizational evolution will effect land productivity of the industrial sector. International data usually includes commercial and industrial land with various shares of services and industrial production. Given the conventional structure of Chinese industry and the backward technologies it employs, increases in industrial value-added might happen without any additional industrial land use, simply because most of this growth will be outside the traditional smoke-stack industries, allowing for a redistribution and more efficient use of industrial and commercial land. Given the widely reported enormous inefficiencies in industrial land use and potential for improvement, we assume that future industrial development will stay within the spatial boundaries of present day industrial and commercial areas.

The state of the infrastructure has been considered one of the main bottlenecks for future economic development (China's Agenda 21; EAAU 1997; World Bank 1985). China's annual investment in the transport sector has been small in comparison to other countries. Major investments in both the extension and the increasing efficiency of the current structure are necessary. China does not have a well-coordinated long-term vision for infrastructure development beyond five-year plans. Some authorities have 10-year indicative plans but these are generally prepared in isolation without consideration for what happens elsewhere. The *Ninth Five-Year Plan* targeted an increase by 12 percent for roads, 17 percent for railways, 35 percent for waterways, and more than 100 percent for aviation capacity (Spear et al. 1997). There is no information on longer-term infrastructure development plans available.

A good proxy for land-consuming infrastructure development is the future increase of roads. Currently, China averages 1.1 km of roads per 100 km^2, in comparison to 7km/100 km^2 in the USA and 4.7-km/100 km^2 in India, respectively. Even the better-developed coastal areas have only 2.5 km/100km^2. Of the total length of roads, only 23 percent are asphalt-paved, and most of the roads are in poor condition (CIA 1999; EAAU 1997, p. 228). Projections show that cars might more than triple within the next 10 years in China (China's Agenda 21; TEI 1994). According to the World Bank (World Bank 1994, p. 26), in low-income countries, paved roads increased by 1.6 percent annually during the last 15 years, in comparison to 0.9 percent in middle-income countries. In our study we distinguish the coastal regions from the inland and use two different growth rates of transportation infrastructure development for them in the period 1992 to 2025. For the coastal area, we assume a relatively high annual growth rate of 1.9 percent, which would bring coastal China to the road-infrastructure level of today's India. For Central China and Western China, we assume annual growth rates of 1.6 percent.

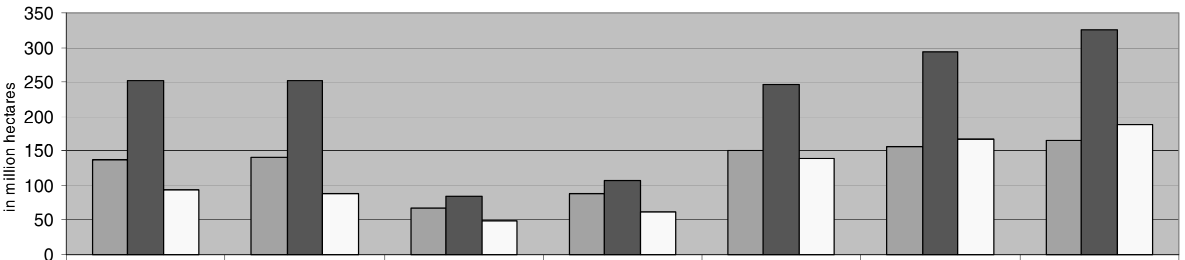
5 Model Results

In this study, we construct a diverse set of scenarios based on different combinations of widely expected developments on population growth, changes of lifestyles, level of urbanization and per capita income growth for the period 1992 to 2025. In Section 5.1, we show how these combinations might affect demand for different types of land at the national level, given the assumed technological progress. In Section 5.2, we show how restrictions in land availability and increases in final demand at regional level might affect the inter-regional trade flows for primary products in China.

5.1. National Level Land Requirements in 2025

Major results of the scenario analysis for the national level are presented in Figure 3. It shows how the range of assumptions regarding demographic, social, and economic changes affects the total land requirement. We also compare these effects across scenarios for three major land categories: cultivated land, forestland, and grassland.

Figure 3: Land Requirements of Different Scenarios



	Maximum Available Land in 2025	A	B	C	D	E	F
▨ Cultivated	137	141	67	88	151	156	166
■ Grass	252	252	85	108	247	293	326
□ Forest	94	88	49	63	140	168	188

	Scenarios					
Major	**A**	**B**	**C**	**D**	**E**	**F**
Driving Forces	(China1992)	(A + Technology)	(B + Population)	(C + Income Growth)	(D+ Urbanization)	(E + Population high)
Technological level	1992	**2025**	**2025**	**2025**	**2025**	**2025**
Population (in billion)	1.171	1.171	***1.49***	**1.49**	**1.49**	***1.55***
Income level	1992	1992	1992	***2025***	**2025**	**2025**
Urbanization level	1992	1992	1992	1992	***2025***	**2025***

Note: * Higher urbanization rate of 59% for 2025 (Shen and Spence 1996).

Main assumptions: B: A+ Annual land productivity gains of 1%, 1.38%, and 0.68% for cropping, livestock, and forestry, respectively. C: B+ population of 1.49 billion. D: C+ 4.2 to 5.7 % average annual growth rate of per capita income with the associated income elasticities (thus lifestyle). E: D+ 50% urban population with the associated expenditure patterns. F: E with population of 1.55 billion. Urban and rural infrastructure, residential land, and services are linked to a set of land per capita ratios, industrial land is assumed to remain constant. In all of the scenarios, trade balances of land intensive products are kept proportional to today's imports and exports.

In the category representing cultivated land, the scenarios that add, step by step, per capita income growth with the associated lifestyle change, urbanization, and higher population growth (*D, E, F*) to the previous scenarios are exceeding the limits of available land. The biggest jump in demand for farmland is triggered by the income growth scenario (*D*). The difference between Scenario *C* and *E* indicates that given the income level, the land-saving effects of urbanization (more efficient use of infrastructure and residential land) would be offset by an increase in indirect demand for feed-grain caused by the higher consumption of animal products.

In the case of grassland, the available grassland areas are exceeded only in the scenarios that add 2025 urbanization (E) and further a higher population level (F) to the previous scenarios. Similar to the case of cropping land, the biggest jump in demand for additional grassland is caused by per capita income growth with the associated lifestyle change (*D*), in particular, by the significant increase in per capita meat consumption, given the pre-assumed production share of the pastoral sector in the total livestock production.

Similar to the case of cultivated land, the demand for forestry products exceeding the available forestland appears in the most aggregate scenarios *(D, E, F).*

When demand for a land category exceeds its availability, additional imports would be necessary. Without additional net imports the growth in land-productivity need to be higher than assumed in our technology scenario (Technology 2025), which reflects the common expectation for the next 25 years in the literature. In order to see what growth rate in land productivity would be required, we compare the growth rates assumed in our scenario of Technology 2025, with those necessary to keep the demand as specified in *Scenario E* within the land limits. Table 19 shows the corresponding results. We can see from this table that the required land productivity growth rate for other crops, forestry, and livestock are considerably higher than the ones commonly assumed in the literature.

It is worth noting that the necessary high growth rate for land productivity in the livestock sector reflects in fact the strong desire for growth in feed grain production. The generally excepted scenarios in each specific field are characterized by the relatively even growth rates in land productivity across the major food-producing sectors. The synthesizing of these scenarios ends up with the uneven growth desire across these three sectors. In the following section, we will translate a higher level of the desired land productivity growth rate into a higher level of supply deficit or net import requirement.

Table 19: Necessary Annual Growth Rates in Land Productivity (%)

Economic Sectors	**Assumed Growth Rate in Technology 2025** (in %)	**Necessary Growth Rate**[a] (in %)
Grain	1.00	1.03
Other Crops	1.00	2.04
All Crops	1.00	1.28
Forestry	0.68	2.65
Pasture	0.68	1.12[b]

Note: [a] These annual growth rates would keep the demand specified in Scenario E within the land limits.

[b] Once the production share of feeding mode is raised to 14 and 13 percent, the corresponding necessary growth rates in the pastoral sector become 0.91 and 0.69 percent, respectively.

To summarize, given the commonly excepted scenario for technological progress and the increases in final demands, sectoral outputs would drive the associated land requirements to exceed the available land area. In other words, China would not be able to support the increased demand for land-intensive products with its land base without significant improvement in land productivity and/or increasing imports.

5.2. Possible Net Import Demand at both the Regional and National Levels

As we have seen in the previous section, there is a trade-off between extra productivity improvement and net imports. Given the constraint of the immobile land and the technological scenario “Technology 2025”, we proceed at both regional and national levels to show how much net import will be required to meet the regional and national demand for grain, other crops, livestock products and forest products. Table 20 reports the resulting net import requirements.

Table 20: Deficit or Surplus of the Major Agricultural Products at Regional and National Levels in 2025 (In million Yuan)

Economic Sectors	**R1-N**	**R2-NE**	**R3-E**	**R4-C**	**R5-S**	**R6-SW**	**R7-NW**	**7-Regions**[a]	**China**[b]
Grains	14,744	20,331	11,456	19,522	10,402	12,154	11,565	100,173	18,106
Other Crops	-8,457	8,538	-34,470	18,319	-22,431	-19,694	6,787	-51,408	-137,562
Livestock	-18,926	3,318	-41,014	16,046	-17,353	-2,719	3,151	-57,497	-104,133
Forestry	-5,163	751	-551	-19,174	-12,383	-85	-1,969	-38,574	-34,182
Sum	-17,803	32,938	-64,579	34,713	-41,765	-10,345	19,534	-47,306	-257,771

Notes: Negative numbers mean deficit (or import requirement) and positive numbers mean surplus.

[a] Category “7-Regions” is the sum of Regions R1 to R7.

[b] Differences between the categories 7-Regions and China include the Plateau region and the economic sector run by the central government.

At the national level, the net import demand for livestock products is at a scale of more than 100 billion (1992) Yuan, being equivalent to the domestic production cost of 100 million tons of wheat. The net import demand for products of the other crop sector is at an even larger scale. Such a large-scale net import of animal and crop products would go beyond the limits of political feasibility and the capacity of the world food market. Therefore, these figures would indicate that if maintaining the moderate pace of technical progress across these three major land-use sectors, as assumed in Technology 2025, the other crop sector will compete with the grain sector for claiming much more land and the livestock sector will put much stronger pressure on the grain sector for feed-grain production than we have assumed before.

At the regional level, the highest requirements for net import of crop and livestock products occur in the economically most developed regions, namely East and South, closely followed by the fairly well-developed North region, in the coastal zone. The traditional food export regions Northeast and Central continue to be the leading contributors to the national food pool, followed by the relatively backward Northwest region. The traditional food export region, Southwest, becomes one requiring a moderate net import of food. In terms of forest products, Northeast and the central government-run forest sector (including the Plateau region) continue to show their significant advantages in forest resource endowment, and the more industrialized regions in the coastal areas require large net import. The Southwest region, ranking second closely following the Northeast region in terms of rich forest resources, ends up with a very moderate demand for net import.[9]

Putting the seven regional models together, their aggregate deficit in the livestock and other crop sectors can be approximately balanced by their aggregate surplus in grain production. This means that there is no agricultural surplus left to meet the demand in the central government-run economic sector and to close the food gaps of the Plateau region, which has historically depended on other regions to meet a large proportion of its food demand.

This assessment confirms our argument raised in the previous section. In order to meet the expected demand increase for major agricultural products, China needs to make efforts to improve land productivity in the cropping, pasture, and forestry sectors. China also needs to modernize its feeding mode at a fast pace in order to increase both output and efficiency in the farm-based livestock sector.

6. Implications for Future Land-Use Change

In this report, a range of scenarios have been developed to quantify how population growth, changes in lifestyles, levels of urbanization and migration, and per capita income growth during the next decades might affect the demand for different types of land in China. Given the moderate pace of technological progress as assumed in the scenario Technology 2025, the estimated increases in final demands and sectoral outputs would drive the associated land requirements to exceed the available land area. All three land categories face shortages for the most-aggregate scenarios. If the traditional policy of grain and food self-sufficiency were maintained intact, to keep the farmland requirement feasible, an annual growth rate of land productivity of about 1.28 percent would be required. Taking into account the implicit substitution between the productivity growth rate of the grain sector and that of the livestock sector, an even higher rate would be required to make a proper balance between these two sectors. On the other hand, however, it is widely believed that due to current inefficiencies and structural problems, land productivity in China's cropping agricultural sector may have ample room to significantly increase above current levels even without having to rely on future technologies but by further exploiting the best currently available practices (Ministry of Agriculture 1998; 1999). With the help of newly available technology in the next two decades, China's cropping agriculture may have a great potential to reach a higher land productivity growth than 1.3 percent per annum.

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[9] For a recent assessment on regional distribution of China's forest resources, see Albers et al. Albers, H.J., S.D. Rozelle and L. Guo. 1998. "China's Forests under Economic Reform: Timber Supplies, Environmental Protection, and Rural Resource Accesss." *Contemporary Economic Policy*, XVI, pp. 22-23..

To realize the desired productivity gains in the cropping sector, large investments are needed to develop additional and efficient water supplies by improving irrigation systems as well as by increasing efficiency of on-farm use of water. The most significant contribution of sustainable and extended irrigation will occur in the North and Northwest regions. According to a recent AEZ assessment of water issue in China (Heilig et al. 2000), if geophysically feasible irrigation can be guaranteed in these two regions, irrigation would be able to boost the gross grain production potential by about 100 million tons in the North and by 45 million tons in the Northwest, as compared with purely rain-fed cropping.

To increase the application of fertilizer, new facilities using modern technologies for fertilizer production and imports will be necessary. Currently, China is importing some 20 to 25 percent of internationally traded fertilizer to meet about 30 percent of its fertilizer nutrient needs (World Bank 1997a).

An alternative to the policy of self-sufficiency is the import of grains. However, one bottleneck for this is the lack of infrastructure such as port handling equipment and transit storage. Here, large investments are needed to improve grain-handling efficiency (World Bank 1997a).

Further productivity growth is also required to compensate for loss and degradation of current cropland. Often cropland converted for non-agricultural purpose is used inefficiently by land-extensive development projects and "horizontal" expansion of urban agglomerates. Strict measures must be implemented and enforced to minimize construction-related losses of cultivated land. China needs concepts for infrastructure development that minimize land requirements, especially in the rapidly developing coastal provinces.

Given today's practice of livestock production, China will have great difficulties to meet increasing demands for animal products. Transformation of livestock production from the peasant's backyard feeding mode and sedentary grazing to medium and large-scale "factory" type of production systems, with growing dependence on modern feeding methods and genetic techniques introduced from abroad, has already begun. The shortage of grassland can be partly relieved by increasing the already high share of feed-grain production, in doing so increasing the pressure on cropland. The competition for grassland between livestock production and urban and industrial uses is less pronounced than in the case of cropland due to its remote location from economic growth centers. However, this remoteness, causing prohibitive transportation costs as well as lack of infrastructure, poses severe hindrances to reaching higher productivity rates for grassland.

The remoteness of the locations of major forests areas also makes it difficult to improve land productivity. In addition, excessive harvesting and insufficient regeneration have caused long-term deficits in stocking. The increasing needs for timber logs in a growing economy and the enormous demand for residential firewood will require increasing efficiency as well. Policies are needed to encourage such efforts as improving forest management, increasing forest densities, and maintaining stable political and institutional environments for long-term investment. The importance of forestland for protecting cropland in fighting soil erosion and desertification has already been widely recognized. Direct investments in regional reforestation projects show already some visible and encouraging impacts at the national level (Albers *et al.* 1998, p. 27). However, the quality of these planted forests is so poor that they will not play any significant role in timber production in the near future (Yin 1994).

To summarize, there is ample room for further growth in land productivity of major land-use sectors of China's economy. However, it is uncertain that sufficient investments for the agricultural sector will be provided. The political goal of self-sufficiency in (regional) grain production will certainly collide with its high opportunity costs given the higher productivity of land and water for urban and industrial uses. Increasing shortages in land resources might lead to increasing interest in remote areas and to closer ties across the regions within China as well as to closer trading relationships with other parts of the world.

The results of our study must be interpreted with caution. Even if future land requirements could be satisfied, we do not say anything about the sustainability of the utilization of land by the various economic sectors. Also, questions of diversity are not addressed. For example, decreasing diversity and elimination of old growth forests, although there being not declining aggregate tree-covered areas, may be considered the most serious environmental problem in the forest sector (Rozelle et al. 1998). In the cropping agricultural sector, the reclamation potential and yield growth potential are largely dependent on irrigation and water control. Currently the input-output analysis is being extended to include estimation of water availability and its effects on future land-use changes. In addition, some productivity growth scenarios presented in this paper imply a higher use of pesticides, fertilizer, fossil fuel and equipment. In this regard, future work should also pay attention to the energy needs, the emission of greenhouse gases, and other pollutants accompanying the various development and technical options of the primary sectors. Another interesting direction for future work would be to incorporate the possible impacts of climate changes on land and water into the input-output modeling framework.

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Appendix

I-O Tables for the various regions can be provided upon request.

Table 21: Reductions in Land Requirement due to different Assumptions for Annual Income Growth and Income Elasticities

(In percent*)*

	Annual Income -10%	**Income Elasticity Reduction for Grains and Other Crops -20%**	**Income Elasticity Reduction for Animal Products -20%**	**Income Elasticity Reduction for Animal Products for Industrial Products and Services -20%**
Cultivated Land	-4.58	-2.67	-2.00	-4.08
Grassland	-5.80	-0.05	-7.29	-4.12
Forestland	-5.64	-0.12	-0.22	-3.49

Table 22: Input-Output Table for China's Economy in 1992 (in million Yuan)

	Grain	Other Crops	Forestry	Livestock	Handicraft	Fish	Industry	Construction	Transport	Trade	Services	Rural	Urban	Government	Investment	Inventory	Exports	Error	SUM
Grain	27,171	3,610	33	43,814	3,353	1,710	97,785	19	9	2,701	1,193	95,265	3,486	0	0	7,644	21	-1,054	**286,760**
Other Crops	1,645	8,562	18	5,391	617	108	82,393	112	2	3,616	1,039	58,722	47,695	352	0	3,124	4,957	-1,089	**217,264**
Forestry	147	338	4,330	344	551	24	17,927	519	3	323	270	2,730	1,946	0	13,891	558	-1,249	-391	**42,261**
Livestock	0	0	0	11,301	0	0	63,520	0	0	5,554	702	95,402	59,631	0	7,836	1,618	1,937	-1,449	**246,052**
Other	481	604	91	1,555	7,278	37	20,579	1,192	6	603	365	11,738	9,584	0	0	866	-58	-143	**54,778**
Fish	0	0	0	0	0	3,423	10,269	0	1	7,857	653	16,816	18,952	12	0	1,419	1,957	-2	**61,356**
Industry	49,397	39,299	2,811	35,214	5,684	9,888	1,869,922	293,287	66,887	152,720	233,337	259,486	287,262	24,439	271,093	95,128	12,127	13,208	**3,721,189**
Construction	37	39	7	24	5	13	1,679	3,570	330	5,703	11,828	37,273	37,273	0	422,426	0	0	96	**520,303**
Transport	2,516	2,233	316	3,449	474	703	60,073	14,613	2,235	61,333	23,230	4,115	6,201	249	3,707	-318	12,045	1,544	**198,717**
Commerce	6,256	4,620	390	5,740	1,149	1,438	277,870	44,697	9,630	25,469	39,450	55,546	63,785	60,259	36,180	21,863	-22,830	3,379	**634,891**
Services	6,473	5,793	1,204	7,634	1,519	2,348	156,689	8,337	7,247	78,067	91,346	57,379	90,258	327,796	2,021	0	16,170	2,545	**862,826**
Capital	5,632	3,877	1,186	5,575	1,697	2,399	184,355	12,242	27,991	21,142	87,642								
Labor	167,833	126,950	27,512	109,605	28,198	32,947	277,002	99,087	29,831	91,949	214,329								
Taxes	6,009	8,087	1,517	4,283	1,120	2,243	242,316	14,214	9,603	8,851	29,141								
Profits	13,162	13,253	2,846	12,124	3,132	4,075	358,811	28,413	44,941	169,004	128,301								
SUM	**286,760**	**217,264**	**42,261**	**246,052**	**54,778**	**61,356**	**3,721,189**	**520,303**	**198,717**	**634,891**	**862,826**								

Table 23: Input-Output Table for the North Region in 1992 (in million Yuan)

	Grain	Other Crops	Forestry	Livestock	Handicraft	Fish	Industry	Construction	Transport	Trade	Services	Rural	Urban	Government	Investment	Inventory	Exports	SUM
Grain	6,797	859	6	10,823	622	394	27,142	1	1	336	394	14,497	629	0	0	7,217	53	**69,770**
Other Crops	339	1,733	3	1,085	99	22	17,551	7	0	397	289	8,597	6,300	39	0	2,418	13,195	**52,073**
Forestry	38	88	1,040	89	134	6	4,382	42	0	49	89	645	383	0	3,143	533	-3,292	**7,368**
Livestock	0	0	0	2,751	0	0	17,753	0	0	754	220	17,768	9,479	0	1,693	1,448	5,651	**57,518**
Other	95	119	17	305	1,392	7	3,975	76	1	70	92	2,053	1,409	0	0	633	-120	**10,125**
Fish	0	0	0	0	0	655	1,889	0	0	874	163	2,803	2,608	1	0	1,009	4,268	**14,270**
Industry	16,507	12,406	509	10,446	1,123	2,495	545,140	66,554	15,605	26,507	54,242	71,382	52,451	3,061	54,828	91,264	-28,237	**996,284**
Construction	11	12	1	7	1	3	492	1,059	114	1,021	2,925	0	0	0	112,027	0	-2,474	**115,199**
Transport	412	393	61	424	95	167	25,736	3,869	1,141	3,432	5,022	1,375	1,801	38	4,657	1,391	-677	**49,337**
Commerce	696	606	65	675	190	245	41,997	6,345	1,113	6,864	7,439	12,284	11,354	6,184	5,839	13,910	8,372	**124,177**
Services	911	891	218	915	287	508	36,628	3,805	4,273	32,744	22,619	18,763	24,993	45,547	98	0	13,732	**206,933**
Capital	1,297	891	190	1,218	280	539	49,028	3,287	9,319	6,213	22,331							
Labor	38,129	29,404	4,559	24,965	5,187	7,803	85,137	19,601	8,099	24,218	43,859							
Taxes	1,006	1,141	233	778	179	459	63,623	3,229	2,120	6,315	7,262							
Profits	3,531	3,530	468	3,038	535	967	75,813	7,323	7,550	14,383	39,989							
SUM	**69,770**	**52,073**	**7,368**	**57,518**	**10,125**	**14,270**	**996,284**	**115,199**	**49,337**	**124,177**	**206,933**							

Table 24: Intermediate Coefficients (A-matrix) of China’s Economy in 1992

	Grain	**Other Crops**	**Forestry**	**Livestock**	**Handicraft**	**Fish**	**Industry**	**Construction**	**Transportation**	**Trade**	**Services**
Grain	0.09475	0.01661	0.00079	0.17807	0.06121	0.02786	0.02628	0.00004	0.00004	0.00425	0.00138
Other Crops	0.00574	0.03941	0.00042	0.02191	0.01126	0.00176	0.02214	0.00022	0.00001	0.00569	0.00120
Forestry	0.00051	0.00156	0.10245	0.00140	0.01006	0.00039	0.00482	0.00100	0.00002	0.00051	0.00031
Livestock	0.00000	0.00000	0.00000	0.04593	0.00000	0.00000	0.01707	0.00000	0.00000	0.00875	0.00081
Other	0.00168	0.00278	0.00214	0.00632	0.13287	0.00060	0.00553	0.00229	0.00003	0.00095	0.00042
Fish	0.00000	0.00000	0.00000	0.00000	0.00000	0.05579	0.00276	0.00000	0.00001	0.01238	0.00076
Industry	0.17226	0.18088	0.06652	0.14311	0.10377	0.16115	0.50251	0.56369	0.33660	0.24055	0.27043
Construction	0.00013	0.00018	0.00016	0.00010	0.00010	0.00021	0.00045	0.00686	0.00166	0.00898	0.01371
Transportation	0.00877	0.01028	0.00749	0.01402	0.00866	0.01146	0.01614	0.02809	0.01125	0.09660	0.02692
Commerce	0.02182	0.02126	0.00923	0.02333	0.02097	0.02344	0.07467	0.08591	0.04846	0.04012	0.04572
Services	0.02257	0.02666	0.02849	0.03102	0.02774	0.03827	0.04211	0.01602	0.03647	0.12296	0.10587

Table 25: Intermediate Coefficients (A-matrix) of China’s Economy in 2025

	Grain	Other Crops	Forestry	Livestock	Handicraft	Fish	Industry	Construction	Transportation	Trade	Services
Grain	0.11510	0.02003	0.00185	0.14595	0.08026	0.04185	0.00263	0.00001	0.00003	0.00048	0.00014
Other Crops	0.00908	0.06304	0.00103	0.03045	0.01557	0.00311	0.01060	0.00020	0.00001	0.00366	0.00084
Forestry	0.00079	0.00241	0.25146	0.00182	0.01383	0.00067	0.00106	0.00081	0.00001	0.00026	0.00016
Livestock	0.00000	0.00000	0.00000	0.06724	0.00000	0.00000	0.01539	0.00000	0.00000	0.00667	0.00071
Other	0.00257	0.00430	0.00526	0.00823	0.18254	0.00103	0.00120	0.00185	0.00003	0.00049	0.00022
Fish	0.00000	0.00000	0.00000	0.00000	0.00000	0.09980	0.00239	0.00000	0.00001	0.00934	0.00065
Industry	0.27972	0.29731	0.16487	0.20927	0.14425	0.28850	0.44696	0.55397	0.34018	0.18281	0.23604
Construction	0.00021	0.00029	0.00040	0.00013	0.00013	0.00037	0.00021	0.00614	0.00159	0.00570	0.00936
Transportation	0.01466	0.01741	0.01865	0.02170	0.01210	0.02087	0.02875	0.03041	0.01206	0.08865	0.03036
Commerce	0.03636	0.03593	0.02298	0.03593	0.02931	0.04263	0.12498	0.09223	0.05168	0.03620	0.05039
Services	0.03758	0.04500	0.07090	0.04768	0.03875	0.06955	0.06859	0.01714	0.03880	0.11013	0.11551

Table 26: Matrix of Multipliers or Leontief Coefficients for 1992:

	Grain	**Other Crops**	**Forestry**	**Livestock**	**Handicraft**	**Fisheries**	**Industry**	**Construction**	**Transportation**	**Commerce**	**Services**
Grain	1.1219	0.0364	0.0086	0.2249	0.0913	0.0491	0.0787	0.0493	0.0297	0.0349	0.0293
Other Crops	0.0187	1.0534	0.0058	0.0379	0.0233	0.0138	0.0560	0.0352	0.0212	0.0261	0.0209
Forestry	0.0034	0.0046	1.1154	0.0048	0.0151	0.0032	0.0129	0.0091	0.0049	0.0052	0.0049
Livestock	0.0094	0.0095	0.0041	1.0580	0.0073	0.0091	0.0430	0.0273	0.0165	0.0246	0.0162
Other	0.0055	0.0068	0.0042	0.0117	1.1560	0.0041	0.0156	0.0124	0.0059	0.0068	0.0060
Fisheries	0.0024	0.0024	0.0011	0.0026	0.0019	1.0614	0.0094	0.0070	0.0042	0.0172	0.0049
Industry	0.4884	0.4913	0.2123	0.5075	0.3713	0.4701	2.2982	1.4109	0.8526	0.7918	0.7854
Construction	0.0019	0.0020	0.0013	0.0022	0.0018	0.0022	0.0049	1.0113	0.0047	0.0135	0.0178
Transportation	0.0269	0.0280	0.0166	0.0356	0.0254	0.0298	0.0628	0.0773	1.0414	0.1298	0.0583
Commerce	0.0689	0.0676	0.0312	0.0773	0.0617	0.0698	0.1940	0.2130	0.1260	1.1233	0.1236
Services	0.0632	0.0667	0.0512	0.0802	0.0667	0.0806	0.1440	0.1212	0.1025	0.2009	1.1776
SUM	**1.8107**	**1.7688**	**1.4519**	**2.0427**	**1.8219**	**1.7933**	**2.9195**	**2.9741**	**2.2096**	**2.3740**	**2.2449**

Table 27: Matrix of Multipliers or Leontief Coefficients for 2025:

	Grain	**Other Crops**	**Forestry**	**Livestock**	**Handicraft**	**Fisheries**	**Industry**	**Construction**	**Trans-portation**	**Commerce**	**Services**
Grain	1.13565	0.02980	0.00750	0.18342	0.11517	0.05828	0.01388	0.00881	0.00534	0.00629	0.00477
Other Crops	0.02057	1.07737	0.00907	0.04577	0.02839	0.01472	0.02650	0.01660	0.01015	0.01170	0.00934
Forestry	0.00251	0.00481	1.33706	0.00428	0.02368	0.00245	0.00338	0.00321	0.00131	0.00138	0.00132
Livestock	0.01332	0.01360	0.01033	1.08464	0.00968	0.01464	0.03687	0.02286	0.01414	0.01757	0.01247
Handicraft	0.00504	0.00717	0.00974	0.01292	1.22495	0.00317	0.00391	0.00471	0.00155	0.00187	0.00158
Fisheries	0.00361	0.00366	0.00286	0.00350	0.00275	1.11491	0.00876	0.00632	0.00389	0.01337	0.00413
Industry	0.73651	0.75257	0.56634	0.68894	0.52863	0.80483	2.09854	1.25860	0.77919	0.56588	0.63454
Construction	0.00256	0.00273	0.00305	0.00268	0.00223	0.00337	0.00424	1.00969	0.00402	0.00863	0.01245
Transportation	0.05663	0.05971	0.05842	0.06574	0.04799	0.06941	0.09559	0.09852	1.05458	0.12514	0.07007
Commerce	0.15002	0.15054	0.11909	0.15040	0.12136	0.17053	0.29204	0.27574	0.16610	1.13059	0.15143
Services	0.12905	0.13758	0.17053	0.14486	0.12089	0.17878	0.20843	0.15923	0.12943	0.19337	1.20383
SUM	**2.25549**	**2.23955**	**2.29399**	**2.38715**	**2.22571**	**2.43509**	**2.79214**	**2.86430**	**2.16971**	**2.07580**	**2.10594**