# A scenario analysis on availability of land resources in China

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# 1. Introduction

China is a country with large population and relatively scarce arable land resources. In 2000, the population in the mainland is 1.26 billion, about one-fifth of the world total, while farmland area is 128 million ha, only 0.1 ha per capita. In several provinces in the coastal zone, such as Beijing, Shanghai, Guangdong, Fujian, Zhejiang, mean farmland area per capita is already below 0.05 ha. Even so, farmland area is shrinking, particularly in the eastern part of China. According to the land monitoring data of the Ministry of Land and Resources of China (MLRC), in the last 13 years (1987 – 1995; 1997 – 2000), China's farmland area decreased by 4.02 million ha, i.e., 0.31 million ha per year. Several factors led to the loss of farmland, including expansion of built-up land, natural disasters and land degradation, and restructuring of land use pattern. These factors will continuously affect the future farmland availability.

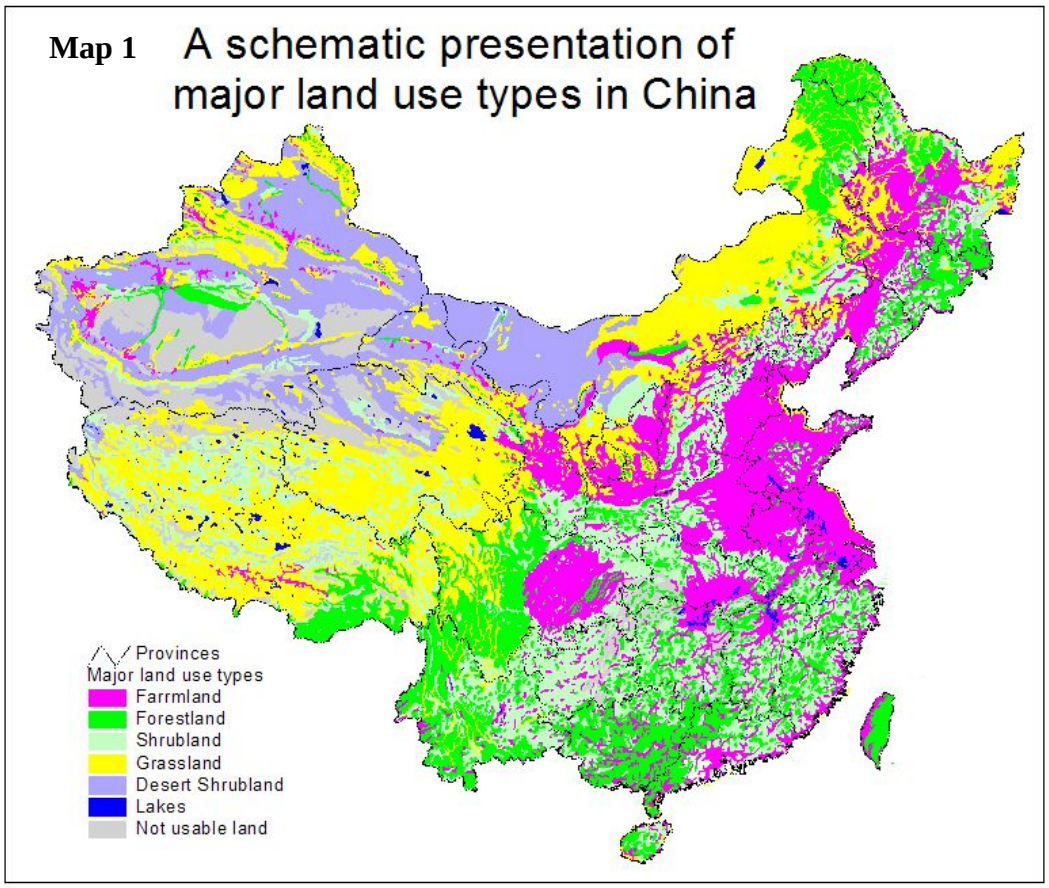
In general, most cultivable lands in China have already reclaimed. In the coastal zone where is densely populated and is experiencing a rapid economic growth, there are almost no land available for further cultivation, to compensate the farmland loss mainly caused by the urban and rural residence sprawl. It is therefore anticipated that farmland area will be further reduced in the future, although strict cropland protection measures has been implemented. This farmland reduction will certainly affect China's food security.

This study presents a scenario analysis on the availability of land resources (farmland and grassland) in the year 2010, 2030 and 2050. A multiple regression model was developed for estimating built-up land expansion, by linking it to GDP (gross domestic production) and population growth, and land use efficiency. The results in this study can be used as boundary conditions of further model analysis.

# 2. Current land use and land use changes

## 2.1. Current land use

Cropland, forest/shrub-land and grassland are three major forms of land use in China, comprising 13.7, 23.9 and 28.0% of the total land, respectively, according to land survey data of the MLRC in 1996. Other land types include horticultural land, non-agricultural land (built-up land), water bodies, and not used/unusable land, comprising an area of 1.1, 3.7, 2.4 and 27.4%, respectively.




Farmland is mainly distributed in areas of high population density in eastern China (Map 1). The North China Plains, the Plains of the Mid-lower Reaches of the Yangtze Rivers and the Northeast China Plains are the most important regions of farmland distribution and food production in China. In these areas, land resources are most intensively used. For instance, nearly half (49%) of the lands have been cultivated for growing crops in Hennan and Shandong provinces in the North China Plain. In Anhui and Jiangsu provinces in the lower reaches of the Yangtze River, the cultivated area covers 42.6 and 47.4% of the total land, respectively. By contrast, only limited area is cultivated for cropping in the western parts of China, due to the dry climate, shortage of irrigation water, and low population density, e.g., the cultivation area covers only 0.3% of the total land in Tibet, 1.0% in Qinghai, 2.4% in Xinjiang, and 7.2% in Inner Mongolia. In other provinces, the ratio of cultivated to total land is mostly between 10 and 30%.

In the total farmlands, quite a big part, i.e., 27.1% is sloping land with problems of degradation. In the west parts of China, such as the southwestern region and the Qing-Zang Plateau, even 63.3% and 48.5% of the farmlands are sloping lands, respectively (Table 1). In the semi-arid and arid areas of China, some 6.67 million ha of cropland is threatened by wind erosion or sandification. In total, about 38% of the farmland in China is affected by water and wind erosions. According to 1996 land survey data, 40% of the farmlands including paddy and vegetable lands are accessible to irrigation, while 60% are dry lands without irrigation.

Table 1. Percentage of various farmland types, based on 1990 and 1996 land survey data

| Regions [a] | Flat farmlands | Terraced farmlands | Sloping farmlands | | | | |
|---|---|---|---|---|---|---|---|
| | | | Total | 2–6° | 6–15° | 15–25° | > 25° |
| North | 74.1 | 14.2 | 11.3 | 5.1 | 4.3 | 1.9 | 0.4 |
| Northeast | 70.2 | 1.3 | 28.1 | 19.8 | 7.0 | 1.4 | 0.3 |
| East | 77.6 | 9.8 | 11.7 | 7.3 | 2.8 | 1.6 | 0.9 |
| Southeast | 39.6 | 38.4 | 18.1 | 6.2 | 6.8 | 5.1 | 3.9 |
| Central | 53.1 | 18.2 | 27.1 | 14.8 | 7.6 | 4.7 | 1.7 |
| Southwest | 10.9 | 25.8 | 63.3 | 6.1 | 21.0 | 24.0 | 12.1 |
| Northwest | 49.4 | 7.3 | 37.1 | 13.7 | 13.7 | 9.7 | 6.3 |
| Qing-Zang | 38.9 | 11.5 | 48.5 | 12.6 | 21.8 | 14.1 | 1.1 |
| China | 54.4 | 14.7 | 27.1 | 10.4 | 9.5 | 7.2 | 3.8 |

[a] North: Beijing, Tianjin, Hebei, Henan, Shandong, Shanxi; Northeast: Liaoning, Jinlin, Heilongjiang; East: Shanghai, Jiangsu, Anhui, Zhejiang; Southeast: Guangdong, Guangxi, Fujian, Hainan, Central: Hubei, Hunan, Jiangxi; Southwest: Yunnan, Guizhou, Schuan (include Chongqing); Northwest: Inner Mongolia, Shaaxi, Gansu, Ningxia, Xinjiang; Qing-Zang: Tibet, Qinghai.

Forestland (including shrub-land) covers an area of 227.6 million ha in 1996, mostly distributed in northeastern and southern China (Map 1). About 25% of the total forestland is distributed in the Daxinganling Mountain area in the northwest region, including eastern part of Inner Mongolia, Heilongjiang and Jilin provinces; and nearly 25% is in the Hengduan Mountains in the southwestern China involving western Sichuan, Yunnan provinces and eastern Tibetan Autonomous Region. The remaining part is mostly distributed in provinces in south and southeastern China, such as Hunan, Jiangxi, Guandong, Guangxi, and Fujian. By contrast, grassland is mostly distributed in the semi-arid and arid areas of western China (Map 1). In the total grassland area of 266.1 million ha, the four major provinces/autonomous regions, i.e., Inner Mongolia, Tibet, Xinjiang and Qinghai cover 84.4%. In most provinces of the coastal zone, there is almost no grassland available.

Horticultural land includes all lands used for growing tree crops in producing fruits and industry products. The area in 1996 is 10 million hectares, of which 10.3, 7.9, 6.1, and 6.1% are distributed in provinces of Shandong, Guangdong, Yunnan and Zhejiang, respectively. In the Qing-Zang plateau, fruit production is very limited due to limitations of low temperature for fruit tree growth.

Built-up lands include all lands used for non-agricultural purposes, comprising urban/town areas, rural residences, transportation, industry areas, mining plots, and irrigation systems and water conservancy. In 1996, the total built-up land area in China is 29.54 million ha, of which 65% is residential areas. According to land survey data of the MLRC, mean residential area per capita ranged between 117 and 242 $m^2$ per capita, varying among different regions (Table 2).

Table 2. Total and per capita residential area in the eight regions in 1996

| Region [a] | Total residential area ($10^3$ ha) | As percentage of total built-up land areas | Per capita residential area ($m^2$) | Urban residences ($10^3$ ha) | Rural residences ($10^3$ ha) |
|---|---|---|---|---|---|
| North | 4909 | 65 | 165 | 633 | 4275 |
| Northeast | 2443 | 62 | 234 | 475 | 1968 |
| East | 2741 | 69 | 145 | 382 | 2359 |
| Southeast | 2205 | 73 | 135 | 243 | 1962 |
| Central | 1814 | 66 | 117 | 351 | 1464 |
| Southwest | 2337 | 70 | 123 | 204 | 2133 |
| Northwest | 2550 | 55 | 242 | 339 | 2211 |
| Qing-Zang | 106 | 32 | 145 | 23 | 83 |
| China | **19106** | **65** | **156** | **2650** | **16456** |

[a]: See footnote of Table 1.

## 2.2. Land use change

In the past 50 years, China experienced a great change in the land use. In the 1950s, China faced a serious problem of food shortage. As to increase food production, China started large-scale land reclamation in whole China, particularly in Xinjiang, Heilongjiang, and Inner Mongolia, resulting in a rapid expansion of farmland area. In the eight years between 1949 and 1957, the farmland area was increased by 13.96 million ha, averaged at 1.74 million ha per year (Zhang et al., 2000), mainly distributed in the arid and semi-arid areas. Due to natural disasters, and problems of sandification and soil salinity, these newly reclaimed lands had to be largely abandoned. Up to 1965, a total amount of 8.24 million ha farmland was lost, i.e., 1.03 million ha per year. After then, the rate of farmland reduction was decreased (Table 3).

Table 3. Changes in the farmland area in the different periods ( $10^4$ ha )

| Farmland change | 1957 – 1965 | | 1966 – 1975 | | 1957 – 1986 | | 1987 – 2000[*] | |
|---|---|---|---|---|---|---|---|---|
| | Total | Annual | Total | Annual | Total | Annual | Total | Annual |
| Gained area | na | na | na | na | 2513.3 | 86.7 | 511.2 | 39.3 |
| Lost area | na | na | na | na | 4073.3 | 140.5 | 913.1 | 70.2 |
| Net lost area | 824.0 | 103.0 | 388.0 | 38.8 | 1560.0 | 53.8 | 401.9 | 30.9 |

[*] Data are from the Ministry of Land and Resources of China. Other data are from Zhang (2000) and Zhang et al. (2001). na: not available

Since the reform in the late 1970s, China has experienced a rapid growth in its socio-economy. This development stimulates a restructuring of land use, a quick sprawl of urban/town and rural settlement areas, and an increase of land requirements for infrastructure and industries. These greatly increased land demands, and thus caused a marked loss of farmland in China (Fig. 1). According to survey data of MLRC, a total area of 9.13 million ha of farmland, or an area of 0.7 million ha per year was transformed into forestland, grassland, horticultural land, fishponds, and built-up areas, or destroyed by disasters in the last 13 years. At the same period, 5.11 million ha of farmland were gained by reclamation of 'wastelands' and by restoration of abandoned farmlands. On balance, China lost 4.02 million ha of croplands, i.e., 0.31 million ha per year (Table 3). In the total lost area of farmlands, 37% were converted into forestland and grasslands for the conservation purpose, 27% into orchards and fishponds, and 15% destroyed by disasters. The remaining 21% were lost due to expansion of built-up areas, such as urban and rural residences, industries and mining, and construction of infrastructure and irrigation systems.

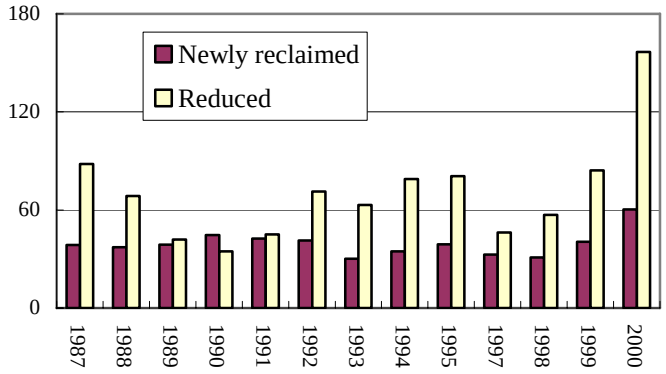



Figure 1. Changes in the farmland area during the period of 1987 – 2000 (excluding the year 1996). The Y-axis presents farmland area ($10^4$ ha). Data are from the MLRC.

In the last decade, built-up land increased by 0.16 – 0.36 million ha among different years, averaging at 0.25 million ha per year, of which about 60% was converted from farmlands. In total, built-up land expansion caused an annual loss of productive farmlands between 8.39 and 20.54 $10^4$ ha per year (Fig. 2). In 1989 – 1991, China's economy slowed down after about 10 year's rapid growth, due to the reduced investment, particularly in the infrastructure. This slowing economic growth was associated with a low land requirement, and thus a lower farmland conversion. After the three-year's adjustment, China's economy re-started a high growth, associated with an increased demand of built-up land.

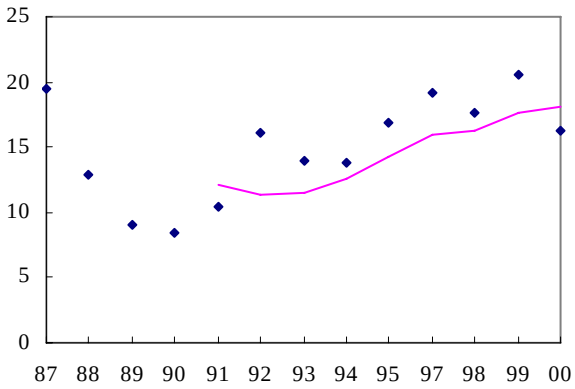



Figure 2. Farmland loss due to built-up land expansion in 1987 – 2000. The X-axis represents years, and the Y-axis represents farmland loss area ($10^4$ ha). The curve is five-year's moving average, reflecting an increasing trend of farmland conversion into built-up land.

Although the amount of farmland converted to built-up land differed among years, the five-year's moving averages indicate an increasing trend, particularly in 1992 onwards (Fig. 2).

## 3. The procedure for scenario analysis

Scenario analysis is a useful tool in dealing with complex problems that often involve much uncertainty, such as the estimation of future land resource availability, based on a series of well-formulated assumptions. This section describes a procedure for determination of available farmland and grassland in the year 2010, 2030 and 2050.

Three factors determine availability of farmland in the year *y* ($F_y$), i.e., available farmland area in the reference year ($F_0$), and total lost area of farmland ($L_y$) and total gained area of farmland by land reclamation ($R_y$) during the period from the reference year to the year *y*. The relationship can be presented as equation (1):

$$F_y = F_0 - L_y + R_y \quad (1)$$

A similar equation is used to estimate the grassland area in the year *y* ($GR_y$), comprising three factors, i.e., grassland area in the reference year ($G_0$), and total lost area ($GL_y$) and total gained area ($GG_y$) from the reference year to the year *y*, presented as:

$$GR_y = G_0 - GL_y + GG_y \quad (2)$$

To estimate the available area of farmland and grassland in the year 2010, 2030 and 2050, the reference year is set to 2000.

### 3.1. Estimation of farmland and grassland losses

#### 3.1.1. General procedure

Four major factors cause farmland losses, i.e., ecological conversion of marginal farmlands, conversion into built-up land, land destruction by natural disasters and land degradation, and transformation into horticultural land and fishponds.

The government-promoted ecological conversion generally concerns marginal farmlands with serious degradation problems. According to the China Water and Soil Conservation Law, cultivated lands with a slope exceeding 25° should be compulsorily converted into their original forms of land use, i.e., grassland, shrub-land or forestland. By excluding these steep farmlands, we estimated the farmland area for each province in the base year 2000 (Table 4), for which no further ecological conversion will be considered. Therefore, the total farmland loss ($L_y$) in the equation (1) is the summation of areas transformed into built-up land, and into horticultural land and fishponds, and destroyed by natural disasters and land degradation, represented as:

$$L_y = B_y \cdot f_b + F_{y-1} \cdot (f_d + f_h) \quad (3)$$

In which, $B_y$ = increased area of built-up land in the year *y*, $F_{y-1}$ = total farmland area in the year *y-1*, $f_b$ = fraction of annually increased built-up land transformed from farmland, $f_d$ = relative rate of farmland loss due to the natural disasters (fraction of total farmland), and $f_h$ = relative rate of cropland converted to horticulture and fishponds (fraction of total farmland).

Grassland degradation could be the major factors leading to grassland losses. In addition, grassland may also be lost due to grassland cultivation, and the conversion into forests/natural preservation, built-up land, and horticulture and fishponds. In this study, total grassland loss is considered as a summation of areas lost by the above factors, and can be estimated with a similar equation:

$$GR_y = G_{y-1} \cdot (g_d + g_e + g_h) + B_y \cdot g_b + R_y \cdot g_f \qquad (4)$$

In which, $G_{y-1}$ = total grassland area in the year *y-1*; $g_d$, $g_e$ and $g_h$ = relative rate of grassland loss due to degradation, conversion into forestland/conservation, and conversion into horticultural land/fishponds (fraction of the total grassland), respectively; $g_b$ = fraction of annually increased built-up land transformed from grasslands, and $g_f$ = fraction of annual farmland reclamation from grassland.

3.1.2. Estimation of built-up land expansion

Built-up land expansion is driven by increasing land requirements for rural residences, cities/towns, industries, services and infrastructure. These increasing land demands are affected by three factors, i.e., economic development, population growth, and land use efficiency. Regression analyses indicate that the annually increased area of built-up land is positively related to the annual growth rate of GDP and population (Fig. 3), based on mean values for each province in the six-year's period of 1993 – 1999 (excluding the year 1996 due to no land change data available).

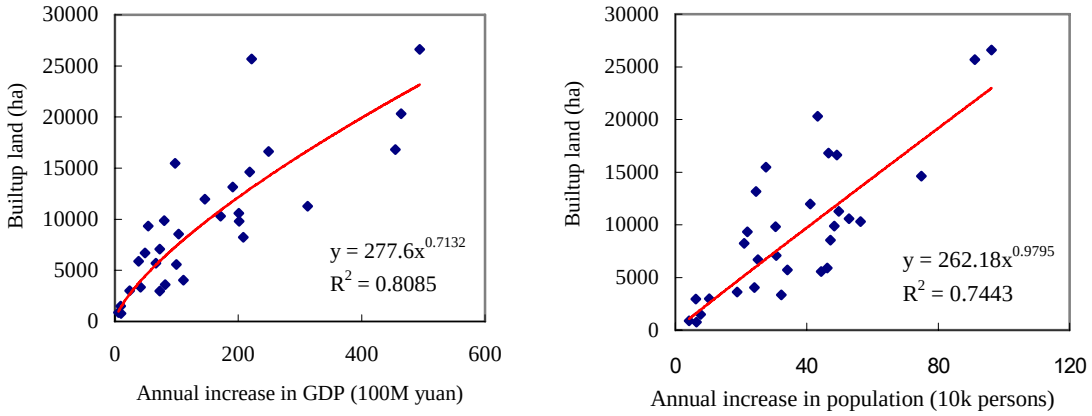



Figure 3. Relationship between annual expansion of built-up land and annual growth rate of GDP and population

Two criteria may be used to approximately indicate the use efficiency of built-up

land, i.e., the ratio of total built-up land area to total GDP, and the ratio of total built-up land area to total population. Here, we combine these two factors as one, named as use efficiency index of built-up land, expressed in ha (M Yuan)$^{-1}$ (M Inhabitants)$^{-1}$. Using this and the above two factors as dependent variables, we obtained a multivariate equation based on the data of 30 provinces (Sichuan includes Chongqing), to estimate annually increased area of built-up land ($B_y$).

$$B_y = 218.89 \cdot G_y^{\,0.7132} + 148.32 \cdot P_y - 1168.02 \cdot e_y^{\,-0.5956} \quad (R^2 = 0.94) \qquad (5)$$

In which, $G_y$ = annual growth rate of GDP in $10^8$ Yuan at 1992 constant price, $P_y$ = annual growth rate of population in $10^4$ persons, and $e_y$ = use efficiency index of built-up land in ha (M Yuan)$^{-1}$ (M Inhabitants)$^{-1}$.

This equation illustrates that annual expansion of built-up land increases with annual growth rate of GDP and population, but the increasing rate decreases with an increase of the use efficiency. In this formula, the value of $e_y$ can be estimated using the total built-up area (in the year *y-1*), divided by total GDP and then total population. Total built-up land can be calculated using that in the reference year plus the increased area between the reference year and the year *y-1*, while total GDP and population can be simply calculated using their relative growth rates, respectively. Hence, only relative growth rates of GDP and population are actually needed to estimate an annual increase in the built-up land area.

### 3.2. Cultivable land

Land reclamation of cultivatable lands is a major way to compensate the cropland losses. In recent years, China has implemented several policy measures to control the conversion of conductive cropland into built-up land, and issued a regulation to maintain a balance in the farmland area. Realization of this aim is largely dependent on the availability of cultivable lands.

Based on agricultural resources survey data of the Agricultural Ministry in 1993 (Zhang et al., 1998), total cultivable land in China is 9.48 million ha. During 1993 – 2000, it is estimated that an area of 2.68 million ha has been opened up according to land use change monitoring data from the MLRC. By subtracting this area, total cultivatable land in 2000 is 6.8 million ha, mainly distributed in the northern part of China (Table 4). Nearly half of the land, i.e., 4.59 million ha is distributed in provinces of Heilongjiang, Inner Mongolia and Xinjiang. In several provinces in eastern and central China, there is already no land available for further cultivation.

### 3.3. Scenario definition

To investigate future farmland availability, four scenarios are developed with following assumptions:

1) Relative rate of farmland loss due to degradation and natural disasters ($f_d$) decreases

by 20%, compared to that in the period of 1990 – 2000 (Table 4), considering that soil conservation measures could be more effectively implemented, and cropping management could be improved because of increasing awareness of land degradation problems.

2) Grassland is mostly distributed in west parts of China (Table 4), which is experiencing a serious problem of degradation or desertification due to the dry climate and over-grazing problem. According to data of Inner Mongolia, land sandification caused an area of 0.92 million ha grassland lost in the six years of 1990 – 1995, i.e., around 1.5% of the total grassland. Although grassland protection measures have been implemented, grassland loss by degradation may not be effectively stopped, due to the population pressure, the lack of financial sources, and the poor environmental conditions. However, a decreasing degradation rate could be anticipated in the future. In this study, it is assumed that the total grassland loss by degradation is 1.5, 2.0 and 1.5% of the grassland in the periods of 2001 – 2010, 2011 – 2030, and 2031 – 2050, respectively. This assumed farmland loss is applicable to provinces of Inner Mongolia, Ningxia, Gansu, Shaanxi, Xinjiang and Qinghai, where the grassland is seriously threatened by desertification problems. In other provinces, grassland land loss due to degradation is not very apparent, and therefore assumed to be controlled by appropriate measures.

3) Conversion of grassland into cropland is linked to annual farmland reclamation, with assumptions that half of the reclamation is covered from grassland. In provinces where the pastureland is less than half of the total cultivable land (Table 4), fraction value of $g_f$ (Eqn. (4)) is assumed equal to ratio of the total grassland to the total cultivable land.

4) Relative rate of cropland conversion into horticultural land and fishponds decreases by 20% in 2001 – 2010, 35% in 2011 – 2030, and 50% in 2030 – 2050, compared to the average during 1990 – 2000 (Table 4), assuming that increasing requirements for fruit and fish products could be largely met by an increase in the productivity.

5) Annual built-up land expansion for each of the 30 provincial units (Sichuan and Chongqing are considered as one unit, because data for individual is lacking) is fully determined by Equation (5).

6) Annually increased number of population ($P_y$ in Eqn. (5)) is simply projected using its relative growth rate shown in Table 5, which is derived from data of the Family Planning Committee of China. To capture the regional variation, mean population growth rate in 1990 – 1999 based on the yearbook of China, is used to derive the growth rate for each province[1].

[1] Population growth rate in a province ($P_i$) is derived with equation: $P_i = p_i \cdot r_p$, in which $p_i$ = mean population growth rate of province *i* in 1990 – 1999, *Rp* = ratio of the assumed population growth rate for the scenarios (Table 5) to the mean population growth rate of China in 1990 – 1999.

7) Regarding GDP growth, the World Bank (1997, cited by Hubacek and Sun, 2001) projected that it would be slowing down over time, from some 8% today to 5% in 2020. In this study, two growth rates are assumed, represented as *high*, with a mean growth rate at: 7.3% in 2001 – 2010, 6.0% in 2011 – 2030, and 3.5% in 2031 – 2050; and *low* at 7.0% in 2001 – 2010, 5.0% in 2011 – 2030, and 2.5% in 2031 – 2050. For each province, the GDP growth rate is determined with a procedure as described in the footnote[2].

8) For the factor $f_b$ (Eqn. (3)), two assumptions are made. One is assumed that the fraction of annually increased built-up land that is converted from cropland, is the same as today, and another one is assumed to be 20% lower, taking into account that the enhanced policy measures of farmland protection implemented in recent years, could continuously play roles in controlling the conversion of productive cropland into built-up land.

9) It is no data available concerning the conversion of grassland into built-up land. In this study, it is assumed that the grassland conversion is positively related to the fraction of grassland in the total land ($r$) by linking it to the fraction factor $g_b$ for the Eqn. (4), i.e., $g_b = (1 - f_b) \cdot r$.

10) Based on the assumed GDP growth rates and the factor $f_b$, four scenarios are defined, i.e., A = high GDP growth + toady $f_b$; B = high GDP growth + lower $f_b$; C = low GDP growth + toady $f_b$; and D = low GDP growth + lower $f_b$.

11) Considering serious problems of land degradation that are largely induced by over-cultivation of marginal lands, we assume that farmland reclamation is only to compensate the lost farmland. This compensation is limited within each province, i.e., the reclaimed area in a province should not be more than the total lost area. In several provinces in the coastal zone (Table 4), the lost farmland cannot be compensated by land reclamation, due to no cultivable lands available.

12) Grassland building as promoted by the Chinese government could enhance the protection of grassland, to reduce the degradation rate of pastureland. Possibly gained area of pastureland ($GG_y$) because of grassland improvement and sowing, is not considered in this study, assuming that this grassland gain is in balance with the area converted into forest and horticultural lands.

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[2] GDP growth rate for each province ($R_i$) is determined by the equation: $R_i = r_i \cdot (1 + f_i) \cdot R_{GDP}$, in which $r_i$ = mean GDP growth rate for province $i$ in 1996 – 2000, and $f_i$ = a factor to account effect of the Western Region Development Program on the GDP growth in the relevant provinces. A value of 0.1 is assumed for the 12 concerned provinces in the west region, and it sets to 0 for other provinces in this study. $R_{GDP}$ = a ratio of the growth rate assumed for the scenario analysis to the mean GDP growth rate of China in 1996 – 2000.

Table 4. Basic data used for the estimation of farmland and grassland in the four scenarios

| Province | Area (k ha) in 2000 | | | Farmland loss fraction (in %) due to | | | Growth rate (%) | |
|---|---|---|---|---|---|---|---|---|
| | Farmland ($F_0$) | Grassland ($G_0$) | Cultivable Land | Disasters ($f_d$) | H&F [a] ($f_h$) | BLT ($f$) | GDP | Population |
| Beijing | 332.1 | 3.0 | 0.0 | 0.088 | 0.296 | 57.0 | 9.97 | 2.194 |
| Hebei | 6842.2 | 753.4 | 156.2 | 0.030 | 0.061 | 60.3 | 11.07 | 0.800 |
| Henan | 8081.3 | 6.7 | 129.7 | 0.012 | 0.095 | 73.8 | 10.09 | 0.910 |
| Shandong | 7672.0 | 30.7 | 143.8 | 0.017 | 0.131 | 58.5 | 10.97 | 0.608 |
| Shanxi | 4385.3 | 843.7 | 193.8 | 0.062 | 0.329 | 67.3 | 8.68 | 1.087 |
| Tianjin | 483.4 | 0.0 | 23.2 | 0.002 | 0.117 | 54.1 | 11.31 | 1.190 |
| Heilongjiang | 11739.4 | 2308.9 | 1105.1 | 0.144 | 0.027 | 44.7 | 8.89 | 0.783 |
| Jilin | 5558.1 | 1062.0 | 252.0 | 0.106 | 0.022 | 60.6 | 9.85 | 0.780 |
| Liaoning | 4155.3 | 376.7 | 51.8 | 0.117 | 0.191 | 63.7 | 8.58 | 0.599 |
| Anhui | 5898.5 | 35.9 | 0.0 | 0.026 | 0.108 | 75.1 | 10.40 | 1.040 |
| Jiangsu | 5016.3 | 14.9 | 53.3 | 0.016 | 0.279 | 82.0 | 11.18 | 0.746 |
| Shanghai | 289.0 | 0.0 | 0.0 | 0.146 | 0.399 | 73.1 | 11.36 | 1.119 |
| Zhejiang | 2026.5 | 0.0 | 21.2 | 0.081 | 0.221 | 74.7 | 10.98 | 0.639 |
| Hebei | 4535.0 | 49.2 | 83.5 | 0.030 | 0.187 | 69.0 | 10.81 | 1.003 |
| Hunan | 3858.4 | 100.9 | 166.5 | 0.088 | 0.208 | 35.1 | 9.95 | 0.741 |
| Jiangxi | 2816.5 | 1.9 | 152.7 | 0.081 | 0.560 | 46.2 | 9.78 | 1.143 |
| Fujian | 1381.5 | 0.0 | 0.0 | 0.096 | 0.089 | 57.2 | 12.12 | 1.004 |
| Guangdong | 3127.8 | 18.3 | 0.0 | 0.045 | 0.484 | 42.8 | 10.35 | 1.405 |
| Guangxi | 4202.6 | 794.8 | 56.2 | 0.054 | 0.190 | 48.6 | 8.89 | 1.117 |
| Hainan | 727.9 | 18.2 | 55.3 | 0.023 | 0.704 | 42.9 | 8.17 | 1.507 |
| Guizhou | 4115.5 | 1694.6 | 190.0 | 0.090 | 0.025 | 65.5 | 9.56 | 1.341 |
| Sichuan | 8244.4 | 13979.0 | 264.8 | 0.068 | 0.150 | 58.2 | 9.85 | 0.860 |
| Yunnan | 5551.6 | 770.9 | 227.2 | 0.139 | 0.200 | 54.4 | 9.27 | 1.255 |
| Gansu | 4948.9 | 12906.0 | 348.5 | 0.009 | 0.094 | 53.2 | 10.17 | 1.326 |
| Inner Mogolia | 7590.3 | 67994.1 | 1075.5 | 0.152 | 0.004 | 42.5 | 10.88 | 0.982 |
| Ningxia | 1265.9 | 2465.2 | 282.3 | 0.030 | 0.006 | 63.4 | 9.92 | 1.691 |
| Shaanxi | 4035.6 | 3173.0 | 42.5 | 0.085 | 0.251 | 75.9 | 9.87 | 0.985 |
| Xinjiang | 3985.7 | 51537.8 | 1452.4 | 0.134 | 0.050 | 41.9 | 8.79 | 1.577 |
| Qinghai | 669.2 | 40343.3 | 191.8 | 0.018 | 0.001 | 41.1 | 9.63 | 1.380 |
| Xizang | 356.3 | 64465.3 | 21.8 | 0.031 | 0.000 | 45.7 | 11.82 | 1.720 |
| China | 123892.3 | 265748.3 | 6741.1 | 0.076 | 0.157 | 60.0 | 10.31 | 0.965 |

[a] H&F: Fraction of farmland per year converted into horticultural land and fishponds; BLT: fraction of annually increased built-up land converted from farmland

Table 5. Mean population growth rate assumed in different periods

| Period | Mean growth rate (%) |
|---|---|
| 2001 – 2005 | 0.8470 |
| 2006 – 2010 | 0.7696 |
| 2011 – 2015 | 0.7148 |
| 2016 – 2020 | 0.5630 |
| 2021 – 2025 | 0.4155 |
| 2026 – 2030 | 0.2975 |
| 2031 – 2040 | 0.1875 |
| 2041 – 2045 | -0.0585 |
| 2046 – 2050 | -0.1930 |

# 4. Results

## 4.1. Farmland area

Table 6 presents farmland area for each province in 2010, 2030 and 2050 for the four scenarios. It shows that farmland area is lost at a much faster speed in the costal provinces, such as Shanghai, Beijing, Tianjin, Gangdong, Jiansu, Zhejiang, than that in other areas. Since the lost cropland is largely compensated by reclamation, the farmland area in 2010 is rather similar for the four scenarios (Fig. 4) without much difference from that in 2000. With the decreasing availability of cultivable lands, the farmland reclamation cannot compensate the farmland loss, and therefore, a considerably lower farmland area than that in 2000, is found for all scenarios in 2030 and 2050 (Fig. 4).

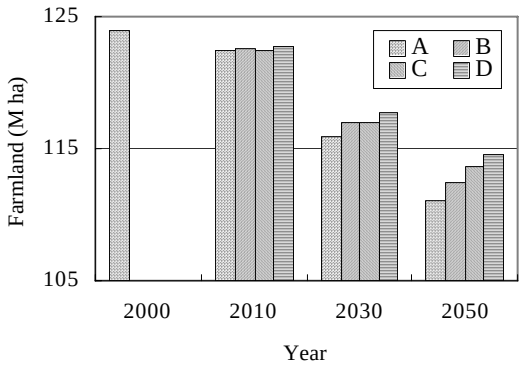


Figure 4. Farmland area in the year 2010, 2030 and 2050 for the four scenarios

Net farmland loss is calculated as a difference between the total lost area and the total farmland reclamation. Fig. 5a presents net farmland loss per year in the three periods. More detailed data (Fig. 5b) show that annual net farmland loss increases with time, and reach their maximum at the period 2025 – 2030 for scenarios A and B, and 2016 – 2020 for scenarios C and D, and then decreases. This trend is largely in agreement with the area of farmland converted into built-up land (Fig. 6), implying that built-up land expansion might be most important one of factors resulting in farmland loss in the future.

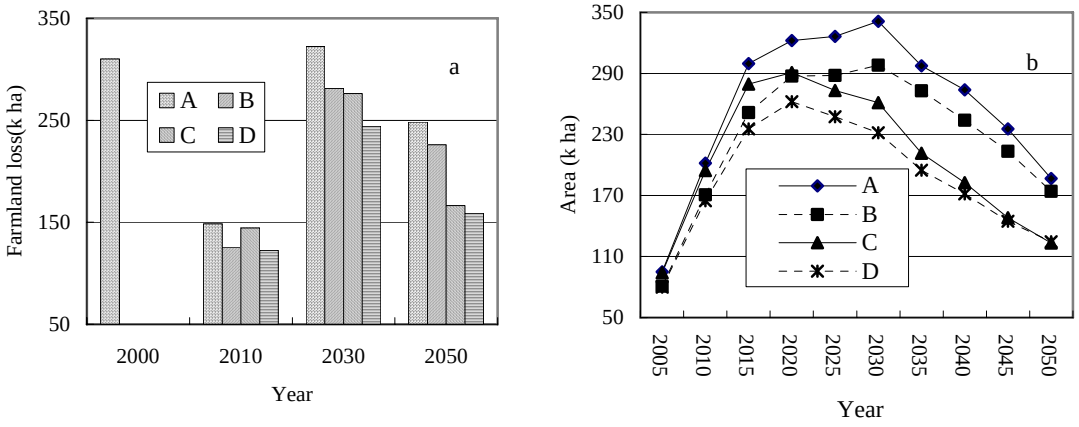


Figure 5. Mean net farmland loss per year for the four scenarios. a: mean value in 2001 – 2010, 2011 – 2030 and 2031 – 2050, b: mean value per five-years

The annually lost cropland area due to built-up land expansion is strongly driven by GDP growth. In scenarios A and B, a high rate of farmland conversion in the future 50 years was found, ranging between 0.13 and 0.21 million ha per year for the different periods. In scenario C and D, the area of farmland loss decreases greatly in the period 2031 – 2050 (Fig. 6), mainly due to the decreased land requirement associated with the slow GDP growth.

Table 6. Farmland area (k ha) in the year 2000, 2010, 2030 and 2050 for the four scenarios

| Province | Present | Scenario A | | | Scenario B | | | Scenario C | | | Scenario D | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2010 | 2030 | 2050 | 2010 | 2030 | 2050 | 2010 | 2030 | 2050 | 2010 | 2030 | 2050 |
| Beijing | 332.1 | 282.1 | 170.0 | 97.3 | 289.9 | 196.1 | 134.5 | 283.7 | 197.7 | 175.0 | 291.1 | 218.3 | 197.1 |
| Hebei | 6842.2 | 6842.2 | 6526.8 | 6238.1 | 6842.2 | 6592.9 | 6346.2 | 6842.2 | 6586.6 | 6429.9 | 6842.2 | 6640.8 | 6499.7 |
| Henan | 8081.3 | 8008.3 | 7611.0 | 7358.2 | 8034.8 | 7693.2 | 7471.7 | 8011.8 | 7671.6 | 7525.9 | 8037.6 | 7741.7 | 7606.2 |
| Shandong | 7672.0 | 7612.5 | 7146.3 | 6722.4 | 7634.8 | 7230.9 | 6867.0 | 7616.8 | 7226.8 | 6980.5 | 7638.2 | 7295.3 | 7073.7 |
| Shanxi | 4385.3 | 4385.3 | 4081.3 | 3877.6 | 4385.3 | 4107.2 | 3908.4 | 4385.3 | 4100.8 | 3919.1 | 4385.3 | 4122.9 | 3941.8 |
| Tianjin | 483.4 | 474.8 | 382.9 | 285.5 | 480.2 | 404.9 | 325.5 | 476.0 | 406.4 | 364.2 | 481.2 | 423.7 | 388.5 |
| Heilongjiang | 11739.4 | 11739.4 | 11739.4 | 11739.4 | 11739.4 | 11739.4 | 11739.4 | 11739.4 | 11739.4 | 11739.4 | 11739.4 | 11739.4 | 11739.4 |
| Jilin | 5558.1 | 5558.1 | 5497.3 | 5307.9 | 5558.1 | 5526.3 | 5353.1 | 5558.1 | 5523.1 | 5385.2 | 5558.1 | 5546.9 | 5415.0 |
| Liaoning | 4155.3 | 4044.1 | 3722.0 | 3472.2 | 4056.1 | 3762.8 | 3532.9 | 4046.6 | 3761.6 | 3582.9 | 4058.1 | 3794.4 | 3621.7 |
| Anhui | 5898.5 | 5734.1 | 5414.4 | 5203.9 | 5754.2 | 5476.9 | 5290.8 | 5736.6 | 5458.2 | 5328.1 | 5756.2 | 5511.9 | 5390.4 |
| Jiangsu | 5016.3 | 4783.3 | 4109.3 | 3473.0 | 4816.6 | 4238.3 | 3699.2 | 4789.9 | 4234.8 | 3882.7 | 4821.8 | 4338.8 | 4027.1 |
| Shanghai | 289.0 | 220.7 | 5.0 | 0.0 | 230.9 | 51.7 | 0.0 | 224.0 | 71.7 | 0.0 | 233.5 | 105.1 | 28.5 |
| Zhejiang | 2026.5 | 1928.4 | 1645.5 | 1402.1 | 1941.9 | 1697.4 | 1486.9 | 1932.0 | 1713.1 | 1612.2 | 1944.8 | 1751.6 | 1655.8 |
| Hebei | 4535.0 | 4437.0 | 4059.8 | 3772.5 | 4457.3 | 4128.7 | 3877.4 | 4440.3 | 4120.8 | 3959.7 | 4460.0 | 4177.6 | 4027.5 |
| Hunan | 3858.4 | 3858.4 | 3645.2 | 3465.6 | 3858.4 | 3670.5 | 3500.3 | 3858.4 | 3669.4 | 3529.4 | 3858.4 | 3689.9 | 3551.6 |
| Jiangxi | 2816.5 | 2782.9 | 2473.1 | 2276.8 | 2791.2 | 2496.2 | 2304.1 | 2784.0 | 2491.0 | 2315.7 | 2792.1 | 2510.6 | 2335.4 |
| Fujian | 1381.5 | 1306.0 | 1107.0 | 911.2 | 1316.6 | 1148.9 | 984.2 | 1308.4 | 1157.2 | 1083.6 | 1318.6 | 1189.2 | 1122.7 |
| Guangdong | 3127.8 | 2903.1 | 2496.4 | 2229.2 | 2921.4 | 2553.9 | 2307.9 | 2905.8 | 2544.4 | 2364.7 | 2923.6 | 2592.3 | 2417.1 |
| Guangxi | 4202.6 | 4135.1 | 3930.4 | 3809.1 | 4143.2 | 3951.5 | 3832.1 | 4136.1 | 3945.4 | 3835.0 | 4144.0 | 3963.6 | 3853.1 |
| Hainan | 727.9 | 727.9 | 646.6 | 595.6 | 727.9 | 651.7 | 601.1 | 727.9 | 650.9 | 603.2 | 727.9 | 655.2 | 607.3 |
| Guizhou | 4115.5 | 4115.5 | 4074.9 | 3997.7 | 4115.5 | 4098.1 | 4021.7 | 4115.5 | 4089.3 | 4019.4 | 4115.5 | 4109.6 | 4039.4 |
| Sichuan | 8244.4 | 8244.4 | 7794.7 | 7505.2 | 8244.4 | 7857.3 | 7582.9 | 8244.4 | 7841.8 | 7614.2 | 8244.4 | 7895.0 | 7670.7 |
| Yunnan | 5551.6 | 5551.6 | 5231.4 | 4992.1 | 5551.6 | 5256.8 | 5020.2 | 5551.6 | 5248.6 | 5025.1 | 5551.6 | 5270.6 | 5047.0 |
| Gansu | 4948.9 | 4948.9 | 4948.9 | 4948.9 | 4948.9 | 4948.9 | 4948.9 | 4948.9 | 4948.9 | 4948.9 | 4948.9 | 4948.9 | 4948.9 |
| Inner Mongolia | 7590.3 | 7590.3 | 7590.3 | 7590.3 | 7590.3 | 7590.3 | 7590.3 | 7590.3 | 7590.3 | 7590.3 | 7590.3 | 7590.3 | 7590.3 |
| Ningxia | 1265.9 | 1265.9 | 1265.9 | 1265.9 | 1265.9 | 1265.9 | 1265.9 | 1265.9 | 1265.9 | 1265.9 | 1265.9 | 1265.9 | 1265.9 |
| Shaanxi | 4035.6 | 3916.7 | 3632.9 | 3449.4 | 3927.2 | 3663.7 | 3487.7 | 3918.2 | 3658.2 | 3506.9 | 3928.4 | 3684.0 | 3533.8 |
| Xinjiang | 3985.7 | 3985.7 | 3985.7 | 3985.7 | 3985.7 | 3985.7 | 3985.7 | 3985.7 | 3985.7 | 3985.7 | 3985.7 | 3985.7 | 3985.7 |
| Qinghai | 669.2 | 669.2 | 669.2 | 669.2 | 669.2 | 669.2 | 669.2 | 669.2 | 669.2 | 669.2 | 669.2 | 669.2 | 669.2 |
| Xizang | 356.3 | 356.3 | 356.3 | 350.5 | 356.3 | 356.3 | 354.9 | 356.3 | 356.3 | 356.3 | 356.3 | 356.3 | 356.3 |
| China | 123892.3 | 122408.0 | 115959.6 | 110992.3 | 122635.2 | 117011.7 | 112490.0 | 122449.2 | 116924.9 | 113598.1 | 122668.1 | 117784.6 | 114606.8 |

In all scenarios, the cultivable land could be mostly opened up in the first ten years, to compensate farmland loss. The abrupt decrease in the annual farmland reclamation (Fig. 7) in 2011 – 2050 reflects the limited availability of land for farmland cultivation. In general, the national aim to maintain a balance in the farmland area can probably be only possible in provinces of Heilongjiang, and the western region of Xinjiang, Inner Mogolia, Ningxia, Qinghai, Tibet and Gansu, where the population density is relatively low, while there is cultivable land available to compensate the cropland losses. In other provinces, this aim may be hardly achieved, particularly in the year 2030 and 2050, when the GDP growth is kept at a high rate (scenario A and B), because of their considerable demands of non-agricultural land by the big population and rapid economic development, and the lack of cultivable lands. In Shanghai, there will be no farmland available in 2050 in scenarios A – C.

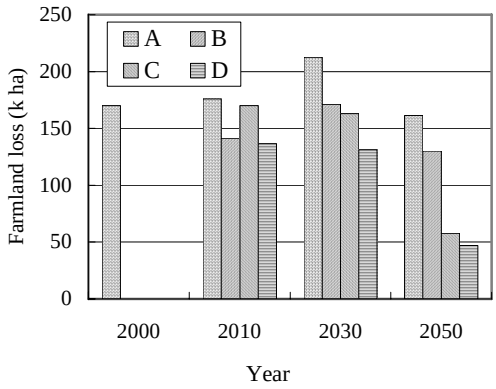


Fig. 6. Mean annual farmland loss due to built-up land expansion in the periods of 2001 – 2010, 2011 – 2030 and 2031 – 2050 for the four scenarios

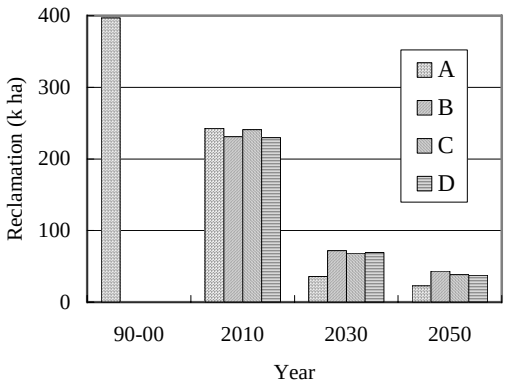


Figure 7. Mean annual farmland reclamation area in the periods of 2001 – 2010, 2011 – 2030 and 2031 – 2050 for the four scenarios

## 4.2. Grassland area

Available area of grassland in the year 2010, 2030 and 2050 for the four scenarios, is presented in Table 7. In 2000, the grassland in China is estimated at 2657.48 million ha, accounting for 28% of the total land. In all scenarios, the grassland area is no much difference from that in 2000, with a small decrease at a range of 1.37 – 1.41% in 2010, 1.95 – 2.05 in 2030, and 2.42 – 2.58% in 2050, compared to that in the year 2000.

Table 7. Grassland area (k ha) in the year 2000, 2010, 2030 and 2050 for the four scenarios

| Province | Present | Scenario A | | | Scenario B | | | Scenario C | | | Scenario D | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2010 | 2030 | 2050 | 2010 | 2030 | 2050 | 2010 | 2030 | 2050 | 2010 | 2030 | 2050 |
| Beijing | 3.0 | 3.0 | 2.8 | 2.6 | 3.0 | 2.8 | 2.7 | 3.0 | 2.8 | 2.8 | 3.0 | 2.9 | 2.8 |
| Hebei | 753.4 | 680.0 | 669.9 | 664.0 | 689.5 | 667.8 | 662.8 | 681.7 | 667.9 | 665.6 | 690.9 | 669.1 | 667.2 |
| Henan | 6.7 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| Shandong | 30.7 | 1.7 | 1.0 | 0.3 | 1.8 | 1.2 | 0.6 | 1.7 | 1.2 | 0.9 | 1.8 | 1.3 | 1.1 |
| Shanxi | 843.7 | 750.4 | 745.1 | 744.1 | 755.2 | 743.2 | 742.3 | 751.0 | 743.2 | 742.9 | 755.7 | 743.7 | 743.4 |
| Tianjin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Heilongjiang | 2308.9 | 2206.4 | 2101.1 | 2004.9 | 2210.6 | 2012.0 | 1828.6 | 2207.2 | 2009.7 | 1841.6 | 2211.2 | 2021.6 | 1856.6 |
| Jilin | 1062.0 | 1012.3 | 971.8 | 970.2 | 1016.4 | 933.2 | 931.6 | 1013.1 | 933.8 | 933.2 | 1017.0 | 933.7 | 933.1 |
| Liaoning | 376.7 | 349.6 | 346.7 | 344.5 | 349.8 | 347.4 | 345.6 | 349.7 | 347.4 | 346.7 | 349.9 | 348.1 | 347.4 |
| Anhui | 35.9 | 35.5 | 34.6 | 34.0 | 35.6 | 34.9 | 34.5 | 35.5 | 34.7 | 34.5 | 35.6 | 35.0 | 34.9 |
| Jiangsu | 14.9 | 1.1 | 0.0 | 0.0 | 1.2 | 0.1 | 0.0 | 1.1 | 0.0 | 0.0 | 1.2 | 0.4 | 0.0 |
| Shanghai | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Zhejiang | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Hebei | 49.2 | 15.6 | 15.1 | 14.8 | 15.6 | 15.2 | 14.9 | 15.6 | 15.2 | 15.1 | 15.6 | 15.3 | 15.2 |
| Hunan | 100.9 | 48.1 | 41.0 | 40.9 | 51.3 | 34.1 | 34.0 | 48.7 | 34.1 | 34.1 | 51.7 | 34.1 | 34.1 |
| Jiangxi | 1.9 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Fujian | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Guangdong | 18.3 | 18.1 | 17.7 | 17.4 | 18.1 | 17.8 | 17.6 | 18.1 | 17.8 | 17.7 | 18.1 | 17.9 | 17.8 |
| Guangxi | 794.8 | 766.0 | 764.9 | 764.6 | 766.1 | 765.0 | 764.8 | 766.0 | 765.1 | 765.1 | 766.1 | 765.3 | 765.2 |
| Hainan | 18.2 | 2.5 | 1.9 | 1.8 | 3.0 | 1.4 | 1.4 | 2.5 | 1.4 | 1.4 | 3.1 | 1.5 | 1.5 |
| Guizhou | 1694.6 | 1649.7 | 1619.8 | 1619.4 | 1654.6 | 1594.2 | 1593.8 | 1650.2 | 1594.3 | 1594.3 | 1655.0 | 1594.9 | 1594.8 |
| Sichuan | 13979.0 | 13832.7 | 13791.7 | 13775.6 | 13847.0 | 13799.1 | 13785.7 | 13834.6 | 13797.3 | 13792.5 | 13848.5 | 13806.0 | 13802.0 |
| Yunnan | 770.9 | 670.4 | 661.9 | 661.5 | 675.3 | 655.4 | 655.1 | 671.0 | 655.2 | 655.1 | 675.8 | 655.6 | 655.6 |
| Gansu | 12906.0 | 12857.0 | 12799.6 | 12764.1 | 12862.8 | 12781.6 | 12728.9 | 12857.6 | 12774.8 | 12735.2 | 12863.3 | 12790.5 | 12753.4 |
| Inner Mongolia | 67994.1 | 67907.2 | 67775.9 | 67651.0 | 67916.7 | 67743.0 | 67575.6 | 67908.5 | 67731.4 | 67591.1 | 67917.6 | 67760.3 | 67630.9 |
| Ningxia | 2465.2 | 2452.6 | 2434.4 | 2423.5 | 2454.5 | 2431.0 | 2416.2 | 2452.9 | 2430.5 | 2423.1 | 2454.8 | 2435.7 | 2428.9 |
| Shaanxi | 3173.0 | 3149.1 | 3143.8 | 3141.5 | 3149.0 | 3143.4 | 3141.1 | 3149.2 | 3145.1 | 3144.5 | 3149.1 | 3144.8 | 3144.1 |
| Xinjiang | 51537.8 | 51483.2 | 51416.6 | 51367.6 | 51489.1 | 51392.5 | 51315.8 | 51483.8 | 51383.6 | 51316.4 | 51489.5 | 51399.5 | 51335.6 |
| Qinghai | 40343.3 | 40332.5 | 40312.7 | 40299.6 | 40335.0 | 40315.9 | 40303.1 | 40332.9 | 40313.4 | 40307.2 | 40335.3 | 40320.3 | 40315.3 |
| Xizang | 64465.3 | 64459.6 | 64449.1 | 64443.7 | 64460.8 | 64449.9 | 64443.2 | 64459.8 | 64449.6 | 64447.1 | 64460.9 | 64452.8 | 64450.6 |
| China | 265748.3 | 264684.6 | 264119.4 | 263752.1 | 264762.3 | 263882.6 | 263340.4 | 264695.7 | 263850.1 | 263408.5 | 264771.2 | 263950.6 | 263532.1 |

## 5. Concluding remarks

Increasing requirement of built-up land, which is highly driven by economic and population growth, will have a great impact on the farmland availability in the future 50 years. With the decreasing availability of cultivable land, complete compensation of farmland losses due to expansion of built-up areas, and restructuring of land use seems to be hardly possible in most provinces, particularly those in the coastal provinces. It is highly possible that farmland area could continuously decrease, especially after 2010. Conductive farmland conversion into built-up land could be reduced by an improvement of the land use efficiency. However, the national aim to maintain a balance in the farmland area may not be realistic for most provinces, because the maintenance of a high economic growth, increasing demand for a bettering life, and the big population will keep a high requirement for non-agricultural lands. Achievement of the compulsory aim in balance between farmland loss (due to built-up land expansion) and farmland gain (by reclamation and restoration of abandoned lands) may be only possible at a cost of economic growth in the most parts of China.

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