Journal of Global Environment Engineering, Vol. 8, pp. 67-78, 2002

ESTIMATION OF POTENTIAL AND CONVERTIBLE ARABLE LAND IN CHINA DETERMINED BY NATURAL CONDITIONS

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Abstract

In order to estimate the land production capability in China, it is important to know the geographical distribution of potential arable land. In this study, a digital map of potential arable land in China with the grid size of 2km x 2km (below: 2-km grid map) was created, taking into consideration natural conditions, such as topographical, climatic, soil and land-use properties. Furthermore, a map of convertible arable land was created by overlaying the map of potential arable land on that of land actually cultivated in 1997. The results showed that: (1) A large area of convertible arable land exists in northern China, such as in Inner Mongolia, Heilongjiang, and Liaoning provinces, while there is a small area of convertible land in the south and on the Qinghai-Xizang Plateau; (2) Some areas in Shanxi and Shaanxi provinces in the Loess Plateau and in Sichuan Province that are considered to be unsuitable for cultivation have been cultivated. In such areas, we suggest that cultivation is better to be stopped and the cultivated land should be returned to grassland or forest from the viewpoint of natural conservation.

KEYWORDS: Land use, land productivity, 2-km digital maps, vulnerable area, GIS

1. Introduction

The balance between food supply and demand in China would make a great influence on global food security. In 1995, Lester Brown, President of the World Watch Institute published his book "Who will feed China?" in which he presented his conclusion that China would become a massive grain importer overwhelming world markets in the early 21st century (Brown, 1995). Brown's report put into grave doubt China's capacity to feed itself, particularly about the year 2030 when China's population is expected to reach 1.6 billion. Unfortunately, Brown's research is based on a greatly exaggerated arable lose and an underestimated arable land published by the official State Statistical Bureau (SSB) in China. An estimate of arable land by the PRC State Land Bureau in 1996 exceeds the SSB estimate by forty percent. The SSB figures are based on reports from local officials while the higher State Land Bureau estimate is derived from LANDSAT photography and other survey data. The Land Bureau's estimate is 128 million hectares compared with the State Statistical Bureau estimate of 93 million hectares. Besides, the Chinese Academy of Science (CAS) in 1992 published a study titled "Land Resource Production Capability and Population Supporting Capacity in China" showing a considerably larger figure of 132.80 million hectares. Recently, the Ministry of Land and

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Resources of China promulgated that the area of arable land in 1996 was 130.04 million hectares. All these figures give us a clouded picture even for current situation of arable land, which makes it difficult to identify changes in arable land and to estimate grain production capability. In order to predict the maximal grain production capability, we need to clarify two basic issues: one is to make clear how much land in China is suitable for crop cultivation, and another is to estimate potential land productivity.

An authorized investigation on potential arable land in China was finished in 1982 (Shi et al., 1985) based on data from both regional and national departments of agricultural cultivation. The main task of that investigation was to clarify characteristics, cultivation conditions, and utilization directions of wasteland in the regions where the wasteland largely distributed. Although a complicated classification system of arable wasteland was designed in that investigation, it could not be put into use because of the shortage of standardized data and backward of GIS technology. As a result, only a rough assessment of arable wasteland at a national scale and several relatively detailed example studies at a regional level were conducted. In this study, the authors gathered plenty of climatic, soil, and land use data and established a GIS (K. Otsubo, 1999, 2000), with which we can develop a set of maps of restriction factors and finally the maps of potential and convertible arable land with a grid scale of 2km x 2km.

2. Data set Processing

We use GIS technology to create a set of 2-km digital maps of China, which include both spatial and attribute datasets. The spatial datasets include the boundaries of administrative districts at the national, provincial, and county level, soil types, and topographical contours, and the attribute datasets include various hydro-climatic factors, soil and land use properties. In order to perform an overlay analysis of these data sets, it was necessary to standardize the size of the grid cells and the geo-referenced projection. Here we adopted the following map projection as our standard.

Projection: Albers Conic Equal Area
Units: Meters
Spheroid: Krasovsky
Parameters:
1st standard parallel: 25. 00, N
2nd standard parallel: 47.00, N
Central meridian: 110.00 E
Latitude of projection's origin: 12.00 N

This involved transforming the polygon-based data into grid-based data by meshing, or transferring, the point-attribute data into the grid-based data using interpolation approaches. For example, a 2-km topographical map of slope gradients (Figure 1) has been calculated from the map of topography in China (1:1 million) based on CIESIN's Data Collection (http://sedac.ciesin.org). Climatic data, such as solar radiation, temperature, and precipitation, were obtained from the China Meteorological Data Center and transferred onto the grid-based maps by the least-squares method. Figures 2a and b are examples of maps showing accumulated temperature $\geq$ 10 °C (°C) and annual mean precipitation (mm), respectively. In this way, a map of the potential arable land, and then a map of the possible convertible arable land can be finally produced.

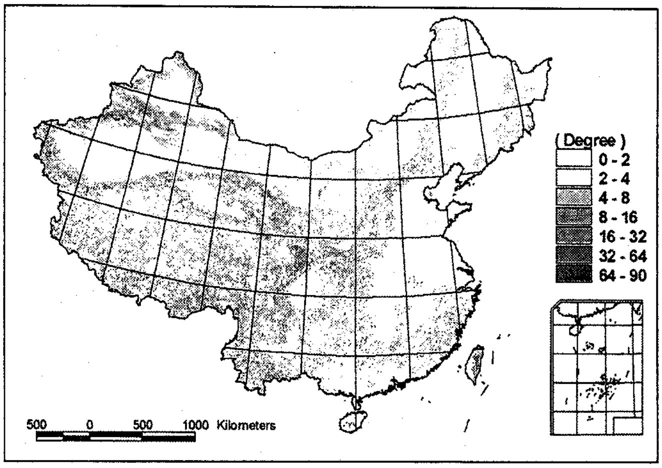

Figure 1 Digital maps of topographical slope gradients

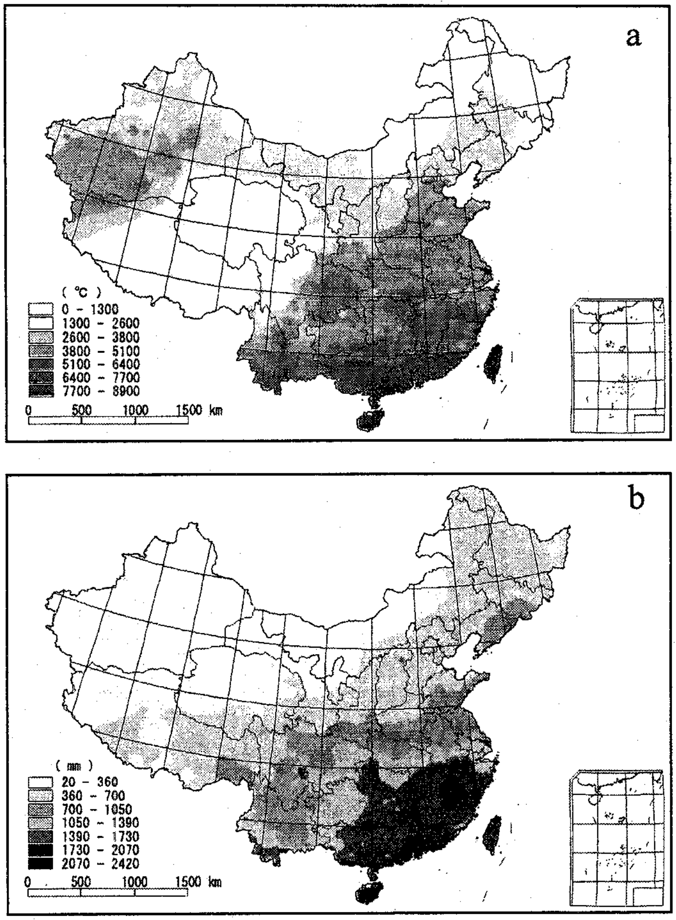

Figure 2 Digital maps of (a) accumulated temperature ≥ 10 °C and (b) annual mean precipitation

3. Potential Arable Land

Potential Land arability is generally restricted by natural conditions such as topographical characteristics, climatic conditions, and soil properties, of which topography and climate are considered to have the most influence because soil properties are changeable along with climatic changes in history. Here we created distribution maps of the potential arable land for each main crop by overlaying maps of these restricting factors. Figure 3 is an example that shows the arable land potentially available for main crops and the frequency with which they can be planted determined only from thermal conditions. Table 1 shows how the maps in Figures 3a–f correspond to planting frequencies and possible crops.

Table 1 Thermal index for potential arable land (ECCAE, 1986)

Figure 3 maps	Accumulated temperature ≥ 10 °C	Description of Potential Arable Land
a.	1000 °C–3400 °C	One planting per year
b.	3400 °C–4800 °C	Three plantings in two years or two plantings per year
c.	≥ 4800 °C	Three plantings per year
d.	1000 °C–2000 °C	Suitable for potatoes, barley, spring wheat, buckwheat, soybeans, beets, and rape
e.	2000 °C–3500 °C	Suitable for rice, winter wheat, corn, kaoliang, and soybeans
f.	≥ 3500 °C	Suitable for cotton, peanuts, rice, and sweet potatoes

As indicated in Table 1, Figures 3a–c show the planting frequencies possible in different regions of China, and Figures 3d–f show which regions are suitable for various crops. Large regional differences exist in the potential arable land. For example, there is only one growing season per year in northeastern and northwestern China (Figure 3a). However, crops can be planted twice a year or three times every two years in the North China Plain and southern part of the Xinjiang Autonomous Region (Figure 3b). Three growing seasons per year are possible in the plains of southern China to the south of the Changjiang River (Figure 3c). From the viewpoint of regions suitable for various crops, it was found that in the northeastern tip of China, where temperature is low, crops such as potatoes, barley, spring wheat, buckwheat, soybeans, beets, and rape are suitable for planting (Figure 3d). However, in northeastern China and the northern part of the Xinjiang Autonomous Region, crops such as winter wheat, rice, corn, kaoliang, and soybean are suitable (Figure 3e). Finally, in the North China Plain and southern part of China, crops such as cotton, peanuts, rice, and sweet potato are also suitable for planting (Figure 3f).

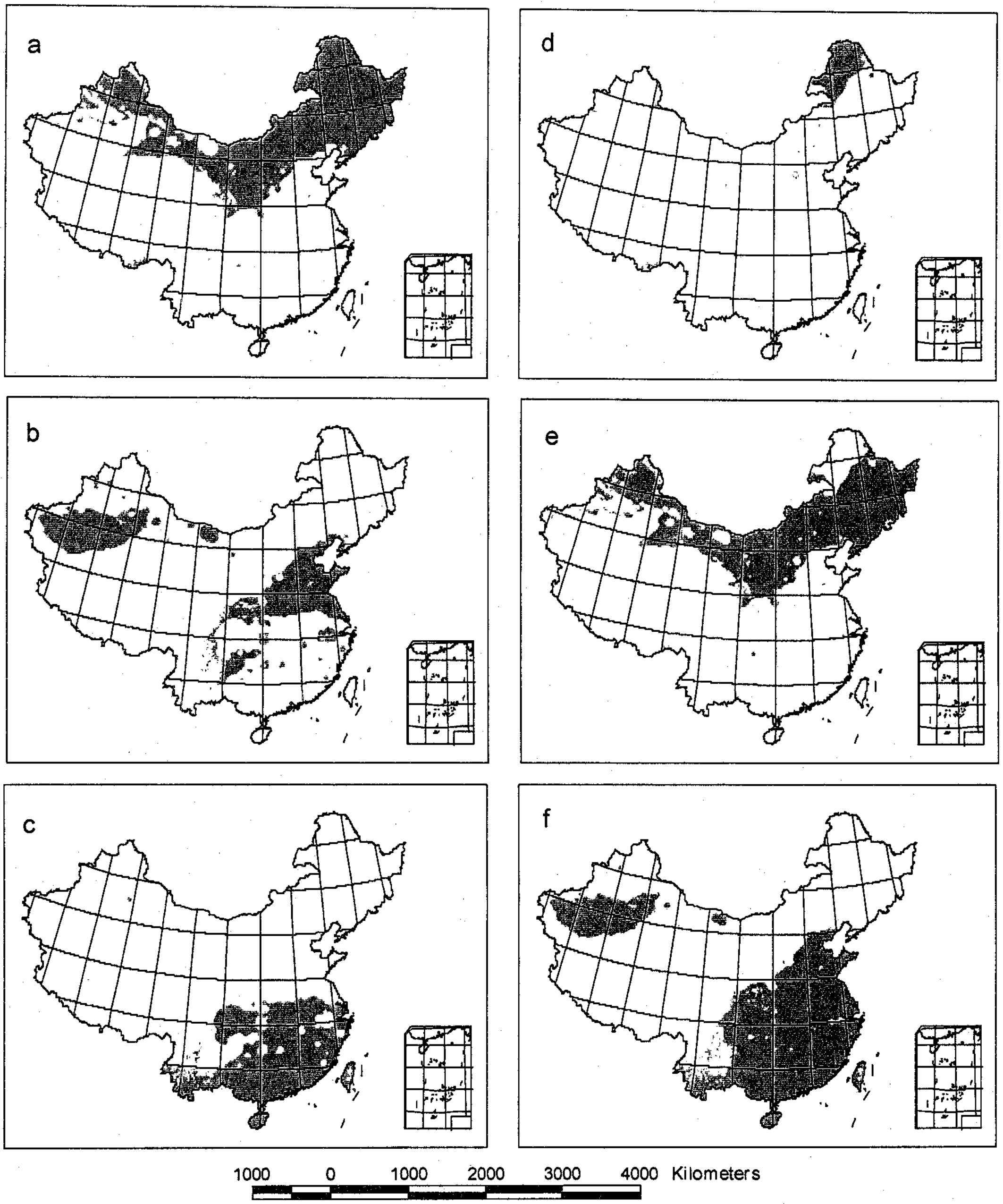

Figure 3 Distribution maps of the potential arable land determined by temperature only

In reality, of course, the distribution of the potential arable land cannot be determined only by thermal conditions; many other restricting factors such as soil moisture, geographical characteristics, and land use must be taken into account as well. A 2-km digital map of the potential arable land (Figures 5) was created following the steps in Figures 4.

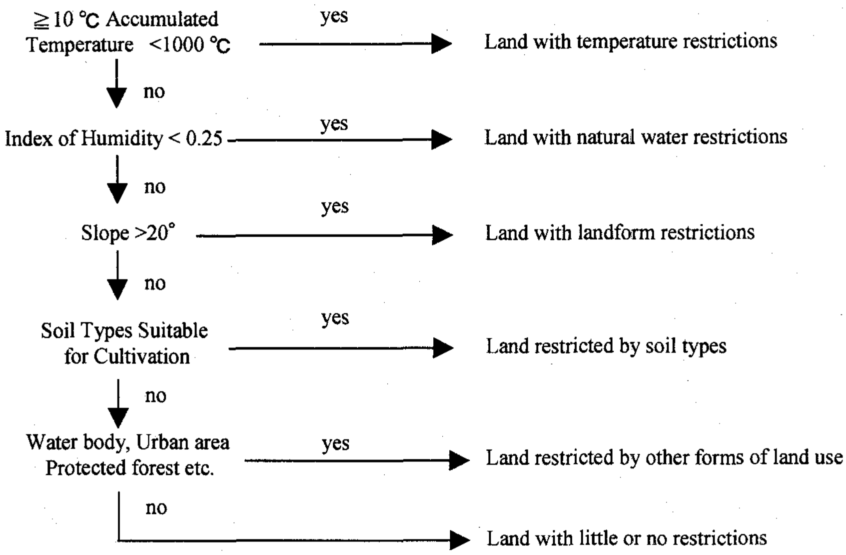

Figure 4 A procedure to determine the potential arable land

In Figure 4, the index of humidity (K) is computed by the formula: $H = P/E_0$, where P is precipitation and E_0 is potential evapotranspiration. Based on the study of Nanjing Institute of Soil Science, Chinese Academy of Sciences (NISS, CAS, 1978), we summarized the soil types both suitable and unsuitable for cultivation as shown in Table 2. According to the map of the potential arable land shown in Figures 5A and 5B, the authors can come to the following conclusions:

(1) Land unsuitable for cultivation because of thermal conditions is mainly found on the Qinghai-Xizang Plateau and in the Tianshan mountainous region in western China; in these regions, the elevation above sea level is too high. Such unsuitable land occupies about 22.1% of the total territory of China.

(2) Land unsuitable for cultivation because of water restrictions is distributed over a vast arid and semiarid area in northwestern China, where evapotranspiration is much higher than precipitation (less than 400mm). Such unsuitable land occupies about 28.9% of the total area of China.

(3) About 67% of the territory of China is mountainous area. Land unsuitable for cultivation because of topographical slope restrictions is mainly distributed in central China, the Qinghai-Xizang Plateau and the mountainous and hilly areas of southern China. Such unsuitable land occupies about 23% of the total area of China.

(4) Land restricted by soil types is mainly distributed on western part of China, which occupies about 47.7% of the total area of China.

(5) In the northeastern and southern mountainous region, cultivation is restricted because the forest is specified as important for conservation. Besides, urban area and water bodies are also considered as the restriction land use types for cultivation. The total area restricted by other forms of land use occupied about 16.2% of China's total area.

(6) Finally, areas such as the Northeast China Plain, the Sichuan Basin, the middle and lower

reaches of the Changjiang River, and the Zhujiang delta are the major areas suitable for cultivation in China. Such areas are considered as the potential arable land in China, which occupies about 19.2% of the total territory of China. However, most of these areas are already under cultivation.

Table 2 Soils suitable and unsuitable for cultivation in China

Soil types suitable for cultivation	Soil types unsuitable for cultivation
Southern paddy soils	Cinnamon soils
Middle paddy soils	Gray-cinnamonic soils
Northern paddy soils	Dark brown forest soils
Cultivated yellow-brown earth	Podzolic soils
Cultivated burozems	Gray forest soils
Cultivated drab soils	Gray desert soil
Old manural loessial soil	Gray-brown desert soils
Dark loessial soils	Brown desert soils
Cultivated loessial soils	Coastal colonchaks
Cultivated black soils	Solonchaks
Fluvo-aquic soils	Inland solonchak
Irrigating warped soils	Alkali soils (solonetz)
Oasis soil	Phospho-calcic soils
Laterite (latosol)	Limestone soils
Lateritic red earths	Eolian sandy soils
Red earths	Mountain shrubby -meadow soil
Torrid red earths	Mountain shrubby-steppe soils
Yellow earths (zheltozem)	Subalpine meadown soils
Yellow -brown earths	Subalpine steppe soils
Burozems	Alpine meadow soils
Black soils	Alpine steppe soils
Albic soils	Alpine desert soils
Chernozems	Alpine frozen soils
Chestnut soil (castanozems)	Glacier and snow
Brown pedocals	Salt crust
Sierozems	
Dark meadow soils	
Gray meadow soils	
Bog soils	
Purplish soils	
Takgr soils	

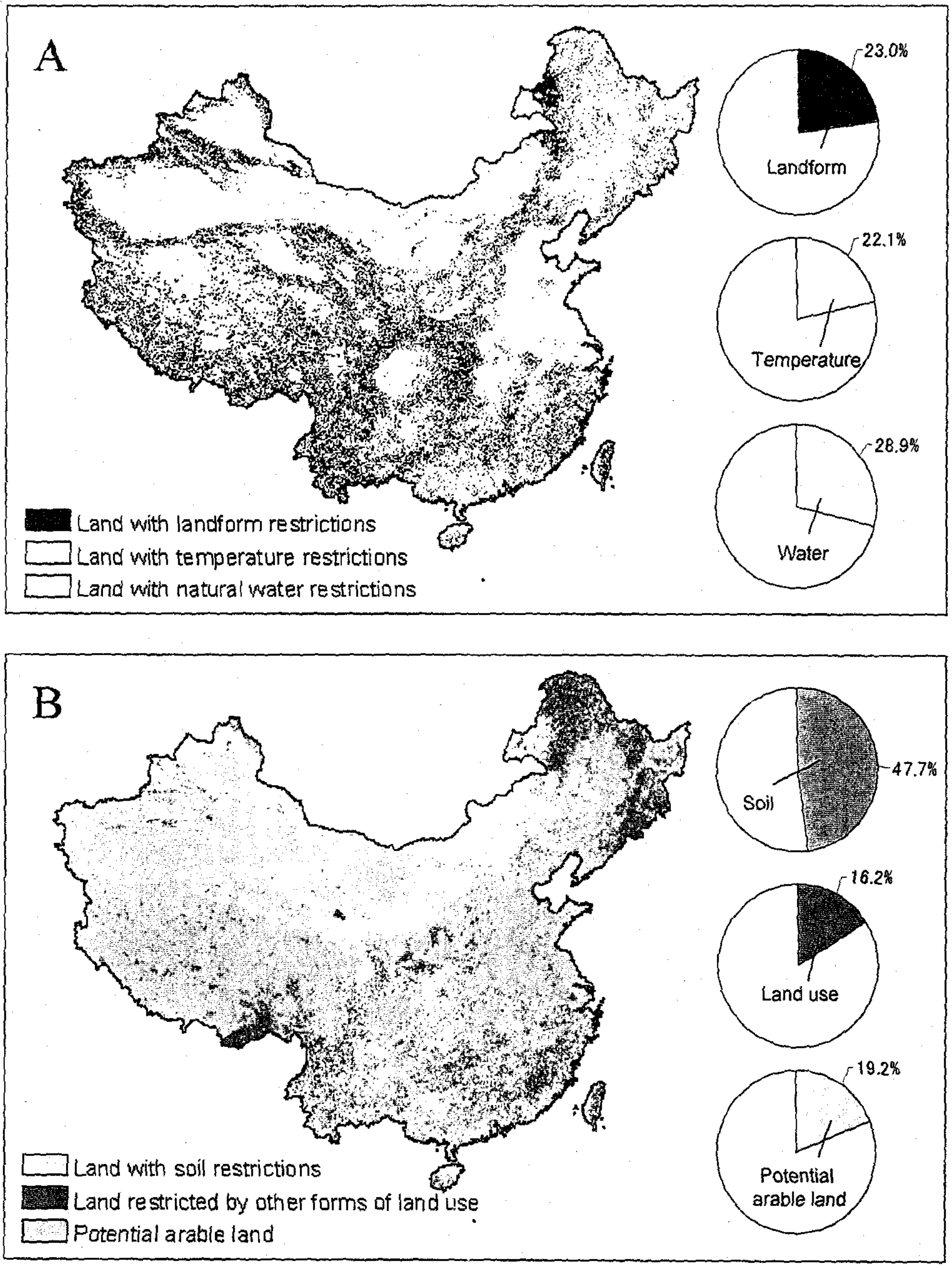

Figure 5 Distribution maps of various restriction factors and the potential arable land in China

4. Convertible Arable Land

In order to compare the derived potential arable land with actually cultivated land, a distribution map of land actually under cultivation (Figures 6) was created from the Land Use Map of China (1:1 M) produced by the Institute of Remote-sensing Application, Chinese Academy of Sciences (Luo, D., 1999). A regression analysis between the area of potential arable land and actually cultivated land was carried out at the provincial level, and a correlation coefficient of about 0.85 was obtained. This implies that the potential arable land as determined by this evaluation basically coordinated with the distribution of lands actually under cultivation. However, there is still a difference between two, which can be considered as the convertible arable land.

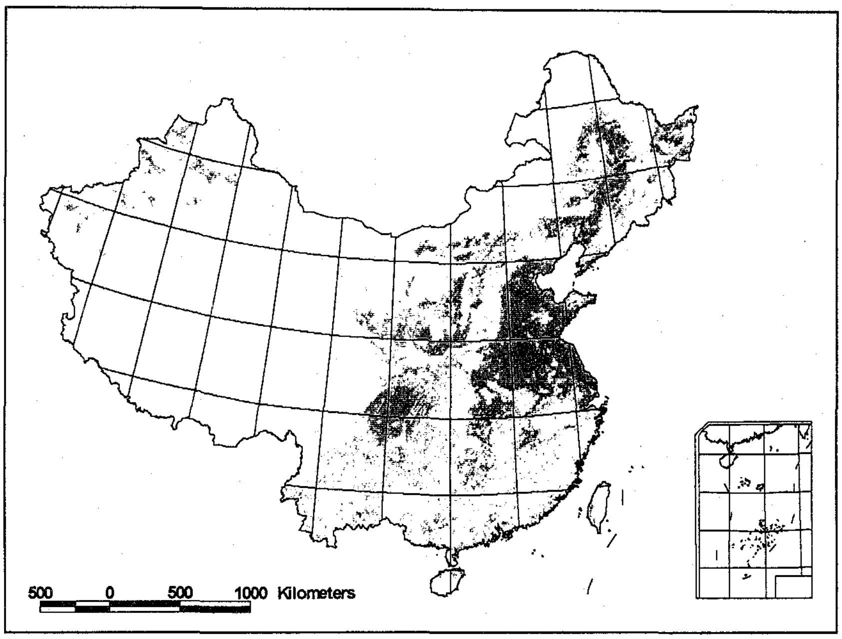

Figure 6 Distribution map of land actually under cultivation in 1997

A digital map of convertible arable land that was created by overlaying the maps of potential arable land and land under cultivation in 1997 is shown in Figure 7. The area of convertible arable land is large in Inner Mongolia, northeastern China, and the mountainous and hilly areas of southern China, but small in the North China Plain, the Northeast China Plain, and the Sichuan Basin (Figures 7). The area of convertible land is about 35 million ha, or about 26.8% of the currently cultivated land area in 1997. However, this includes all kinds of other land use types, such as grassland, shrubs and even sea beaches that are only marginally suitable for cultivation. In other word, the convertible areas are China's ultimate land reserve for grain production. The vulnerable area is about 48 million ha, or about 36.8% of the currently cultivated land area. The vulnerable areas are mainly located in Shanxi, Shaanxi, and Gansu provinces on the Loess Plateau, and in the mountainous areas of Sichuan Province and the Yunnan-Guizhou Plateau. These areas correspond to areas with serious environmental problems such as land degradation, soil erosion, and desertification as well as an increase of dust storm (Wang Q. and Otsubo K., 2000) as shown in Figures 8. It is recommended that cultivation in these areas should be stopped, and the cultivated vulnerable area should be returned to grassland or forest.

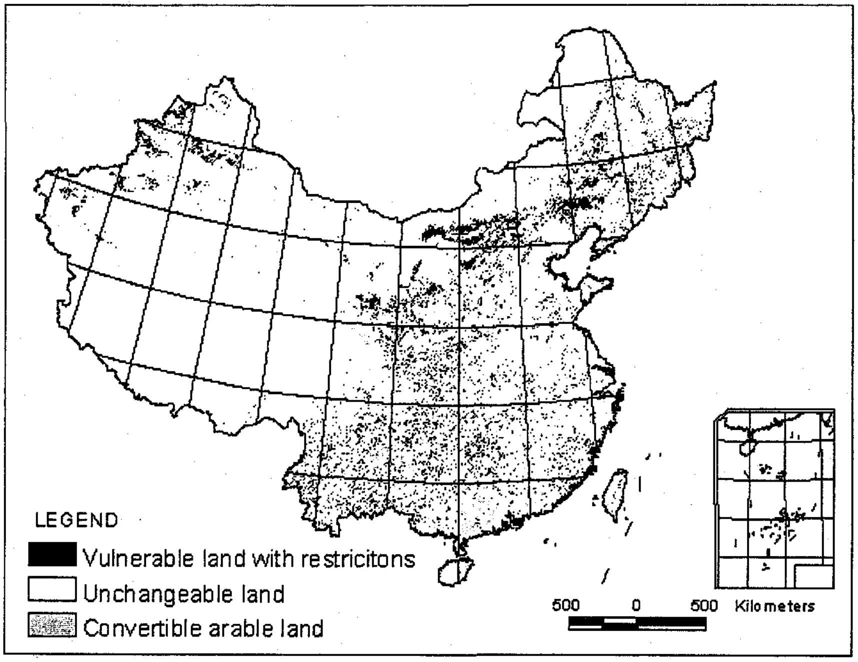

Figure 7 Distribution map of convertible arable land and land unsuitable for cultivation

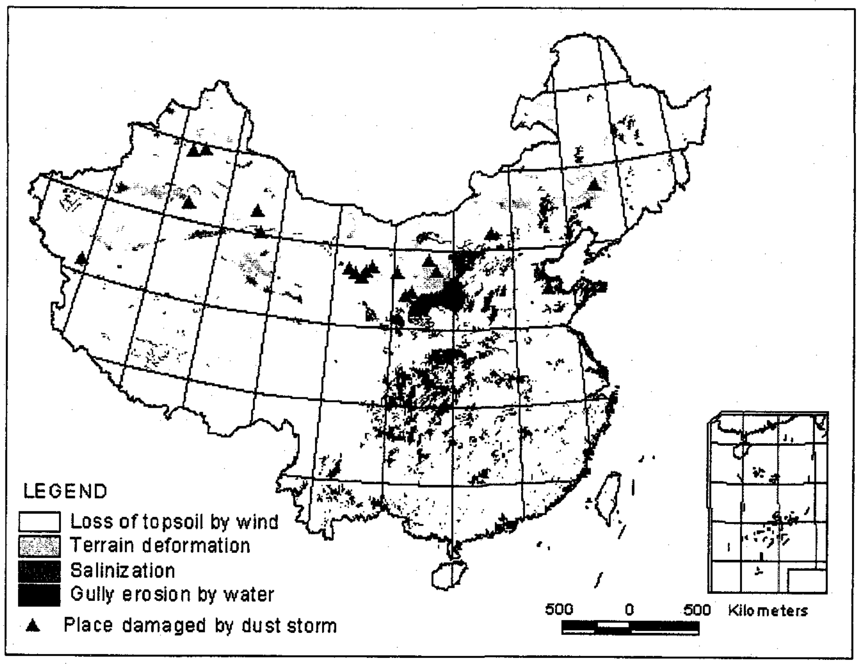

Figure 8 Land degradation map based on soil investigation database (China Office of Soil Survey, 1998)

Finally, the vulnerable arable land can also be divided into various types due to restriction of low temperature, aridity, slopes and soil types. Figure 9 shows the percentage of vulnerable arable land restricted by these factors, from which we can find that vulnerable land restricted by natural water, topographical slope and soil types has almost same proportions, and that restricted by low temperature is very small.

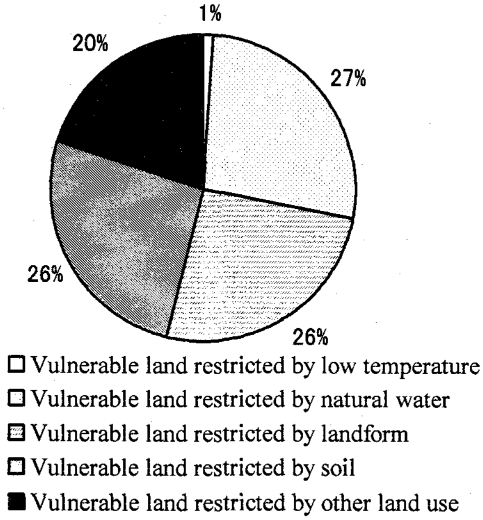

Figure 9 Percentage of vulnerable land restricted by various factors

5. Discussions and Conclusions

Human intervention may overcome the restrictions of natural conditions. For example, although the water limitations are severe in some arid and semiarid areas, cultivation might be possible if suitable irrigation techniques were introduced. We can see from Figure 6 that high productive arable land distributes in northern part of Xinjiang and Hexi District of Gansu Province, where water melted from Glacier has been introduced to irrigation. Moreover, in some mountainous and hilly areas, although topographical restrictions are significant, cultivation might be possible if the landscape were terraced. Soil conditions can also be improved by biological or chemical technologies. In future studies, we will try to take such kinds of artificial interventions into consideration.

Secondly, we want to stress that the result of this study is still a relatively rough one because it is just on the basis of the dataset at the scale of 1:1 million. For instance, topographical characteristics can be described completely at such a large scale. It is expected that such a research approach can be applied to maps with a large scale greater than 1:50000, then, a true value of potential arable land and convertible area can be calculated.

Finally, we would come to a simple conclusion that 2-km digital maps of both potential and convertible arable land in China have been created by a designated procedure. These maps clearly show us where are the potential arable land, and where are the vulnerable areas limited by various restriction factors. Such results may be useful to decision makers to promote land use policy at the national level.

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