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A New Digital Georeferenced Database of Grassland in China

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Abstract

Grassland covers some 40 percent of China's territory and constitutes an important territorial resource serving critical economic and environmental functions. Pastoralism has been an important pillar of the rural economies in the dry and cold areas of the plateau region, Nei Mongol and north-western China. Grass cover plays also an important environmental role in the protection of highly erodible soils of sloped land, and in arresting sand in areas prone to wind erosion and desertification.

In the 1980s and early 1990s, Chinese institutions have undertaken detailed county-level surveys of grassland resources, and compiled maps and databases of grassland distribution and productivity.

The *Map of Grassland in China* at the scale of 1:4M was recently completed and implemented as a digital database of 17 grassland types on GIS. This report describes the features of the database and summarizes the extents and geographical distribution of grassland in China.

Acknowledgments

About the Authors

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A New Digital Georeferenced Database of Grassland in China

Yufeng Chen and Günther Fischer

Introduction

Grassland with its herbaceous and woody forage plants constitutes an important element of land resources in China and the World. According to the definition of IBP News (SCIBP, 1969), *grasslands* are one of the most important terrestrial ecosystem types, occupying large areas in the interior of the principal continents. They provide, when managed for crop or meat production, a major source of man's food. An investigation of grassland biomes at global scale was carried out during 1966 to 1972. In this period, some thirty nations joined the grasslands assessments, and several hundreds of scientists were involved along with a much greater number of support staff (Cragg, 1979).

The scientific investigation of grassland resources in China started after 1949. Two phases can be distinguished. The first phase is from 1949 to 1978. It focused on regional surveys and studies of grasslands, such as in Xizang (Xizang Integrated Survey Team of Chinese Academy of Sciences, 1966), Gansu and Qinghai (Qinghai and Gansu Integrated Survey Team of Chinese Academy of Sciences, 1963), Xinjiang (Xinjiang Integrated Survey Team of Chinese Academy of Sciences, 1964), and Nei Mongol and Ningxia (Nei Mongol and Ningxia Integrated Survey Team of Chinese Academy of Sciences, 1980).

The second phase of grassland investigation began in 1979 and has lasted up to now. The objective has been to thoroughly understand the grassland potentials in China and to rationally develop the livestock production sector, thus improving the standard of living of pastoralists, enhancing their food and income situation, developing the

economy of the minorities in the border regions, and sustainably managing and protecting the grassland ecosystems. With these goals in mind, the State Science and Technology Commission of China (SSTC) and the former State Agricultural Commission jointly issued a document in the second half of 1979, initiating the task of investigating the country's grassland resources and the compilation of the *Atlas of China's Rangeland Resources* at the scale of 1:1M (DAHV and GSAHV, 1996). Founded in this research, the *Map of Grassland in China* at the scale of 1:4M was recently compiled based on the 1992 edition of the *Atlas of Grassland Resources in China* at 1:1M scale (CISNR, 1995).

Since establishing the project on *Modeling Land-Use and Land-Cover Change in Europe and Northern Asia* (LUC) at the International Institute for Applied Systems Analysis (IIASA) in 1995, a number of fairly large and detailed geographical databases on China including biophysical attributes of land, and a large set of statistical data by county have been implemented in the LUC geographical information system (LUC-GIS). Recently, much progress could be achieved in recording extents of cultivated land and estimating land conversion from and to crop agriculture (Fischer et al., 1998). However, there existed some gaps in the LUC-GIS with regard to georeferenced distribution of grassland types which were filled by this new database.

The characteristics of the *Map of Grassland in China* (1:4M) will be introduced in the first part of this paper. In Section 2 follows a description of the associated grassland georeferenced database based on the 1:4M Map. Derived by analysis using the geographical information system, the extents and location of the main grassland types in China and their productive levels are discussed in Section 3. Finally, some applications of the grassland database in global change research at IIASA are indicated in the concluding summary.

1. General description of the source map

1.1 Contents of the source map

Grassland types distinguished in the *Map of Grassland in China* (1:4M) are specific ecosystems providing forages of herbaceous and ligneous plants for livestock grazing. They include various types of natural grassland with a vegetation cover of more

than 5%, permanent secondary grassland, sparsely wooded grassland with a tree crown density of less than 30%, sparse shrub grassland with a shrub crown density of less than 40%, and alpine shrub grassland with a shrub crown density of less than 40%, shrub height of less than 50 cm and high value for grazing (Su, 1997).

1.2 The minimum area of mapped polygons

The smallest area of mapped polygons in the *Map of Grassland in China* (1:4M) has been chosen to be 4 mm^2, and the width of polygons is limited to no less than 1.0 mm. The following kinds of mapping units may therefore be exaggerated or cancelled in the process of map integration (Su, 1997):

(1) Polygons that signify the extreme boundaries of the eco-geographic distribution of zonal grassland types, such as the eastern boundary of alpine grassland, the northern boundary of tropical tussock, and the southern boundary of warm-temperate tussock, etc.

(2) Line or belt-shaped polygons that distribute along rivers, shores and lakes, such as lowland meadow, temperate montane meadow, and alpine marsh-meadow.

(3) Narrow-shaped polygons that are important but difficult to be drawn in the map, such as temperate montane meadow and temperate montane steppe distributed within temperate desert, alpine steppe and alpine meadow zones in Tianshan, Altay, Qilian, Kunlun and Hengduan Mountains.

(4) Polygons of grassland with a small extent but a high yield, valuables for hay making or cold season grazing.

(5) Polygons of grassland types scattered in the farming areas starting along the line from Da Hinggan Ling mountains, Yanshan Mountains, Great Wall, northern section of Lüliang Mountain, Liupan mountains to the eastern verge of Tibetan Plateau eastward and southward.

1.3 Compilation of the map

The Department of Animal Husbandry and Veterinary (DAHV) and the General Station of Animal Husbandry and Veterinary (GSAHV) of Ministry of Agriculture conducted the first nationwide coordinated investigation of grassland resources during

1979-1995. In each province, the investigation was organized and undertaken by the respective animal husbandry bureaus. This assessment proceeded in great detail, combining conventional and remote sensing techniques county-by-county. To certify and validate the surveying accuracy, the territory of China was divided into three regional types[1,2,3] according to "*The Outline and Technical Regulations for Investigation of the Rangeland Resources of the Country's Major Ranching Areas*" and "*The Guidelines and Technical Regulations for Investigation of Pastureland Resources in the Southern Part of China*" (DAHV and GSAHV, 1996). This thorough investigation covered more than 2,000 counties of China, accounting for about 95% of the total territory, only excluding Taiwan, Shanghai municipality and a few farming counties located in the eastern plain of Jiangsu and Hebei provinces.

On the basis of this detailed grassland investigation *The Atlas of Rangeland Resources of China* (*1:1M*) was compiled in 1992 (CISNR, 1995). *The Map of Grassland in China* at the scale of 1:4M was recently completed based on *The Atlas of Rangeland Resources of China* (*1:1M*) and with reference to Landsat MSS image maps at the scale of 1:2.5M and 1:4M, compiled by the Institute of Remote Sensing Applications of the Chinese Academy of Sciences (CAS) in 1991, and *The Land-Use Map of China* at the scale of 1:1M compiled by Institute of Geography of CAS in 1991 (Su, 1997).

2. Description of China's georeferenced grassland database

2.1 Digitizing method

The digitizing of the *Map of Grassland in China* (1:4M) was carried out by ARCSCAN, one of the modules in the ARC/INFO geographical information system

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1) For counties in agricultural regions, the topographic map at 1: 50,000 scale was used in the survey and one yield-sampling plot was designed for each area of 5,000 ha.

2) For mixed agricultural counties, with ranching, ranching-farming or forestry, the topographic maps at scale 1:100,000 was used in the survey and one yield-sampling plot was designed for each area of 8,000 ha.

3) For counties in pure ranching areas with vast extents of rangeland, the topographic maps at scale 1:200,000 was used in the survey and one yield-sampling plot was designed for each area of 10,000 ha.

after scanning a clean analogue of the map (Chen, 1995). After entering into the GIS, some further processing was necessary such as correction of geometry and transformation of projection. The digitized polygons were also corrected in accordance with information on coastal lines, water bodies and rivers, etc., obtained from the *Digital Chart of World* at the scale of 1:1M (ESRI, 1993). Finally, the mapping units were encoded. The code of each polygon is composed of three parts. The first part of encoding expresses the type of grassland, numbered from 1 to 17 (see Table 1 and Section 2.3.1). The second part indicates the quality class of grassland, numbered from 1 to 3 and assigned to the third position of the polygon 4-digit attribute code (see Table 2 and Section 2.3.2). The third part of the encoding expresses the yield grade of each grassland polygon, also numbered from 1 to 3 and assigned to the last position of the code (see Table 3 and Section 2.3.3). The 4-digit label of each polygon formed according to the above encoding procedure was entered manually into GIS through interaction by AML programming.

Table 1. The encoding of grassland types in China

Grassland types	Code
Temperate meadow-steppe	1
Temperate steppe	2
Temperate desert-steppe	3
High-cold meadow steppe	4
High-cold steppe	5
High-cold desert-steppe	6
Temperate steppe-desert	7
Temperate desert	8
High-cold desert	9
Tropical herbosa	10
Tropical shrub herbosa	11
Warm-temperate herbosa	12
Warm-temperate shrub herbosa	13
Lowland meadow	14
Temperate montane meadow	15
Alpine meadow	16
Marsh	17

Table 2. The encoding of quality classes of grassland types

Quality classes	Code
Good quality: The weight percentage of excellent and good herbage is ≥ 60%	1
Fair quality: The weight percentage of fair (or better) herbage is ≥ 60%	2
Inferior quality: The weight percentage of low and poor quality herbage is > 40%	3

Table 3. The encoding of yield grades of grassland types

Yield grades (dry matter)	Code
High yield: > 2000 kg/ha/yr	1
Fair yield: 1000 – 2000 kg/ha/yr	2
Low yield: < 1000 kg/ha/yr	3

2.2 Projection parameters

The parameters of a cartographic projection are essential pieces of information for transferring paper maps into a GIS or transforming one kind of data format to another one in GIS. As in many other countries, China has its own traditions and preferences in using cartographic projections. Widely used nowadays is a conic equal-area projection with two standard parallels, also called *Albers* projection. The parameters of the *Albers* projection are listed below:

1st standard parallel:	25º N
2nd standard parallel:	47º N
Central meridian:	110º N
Latitude of projection origin:	0º N

A generalized version of the grassland map in Albers projection is shown in Figure 1.

Legend

- Temperate meadow-steppe
- Temperate steppe
- Temperate desert-steppe
- High-cold meadow-steppe
- High-cold steppe
- High-cold desert-steppe
- Temperate steppe-desert
- Temperate desert
- High-cold desert
- Tropical herbosa
- Tropical shrub herbosa
- Warm-temperate hearbosa
- Warm-temperate shrub herbosa
- Lowland meadow
- Temperate montane meadow
- Alpine meadow
- Marsh

Total area of grassland in China
361,134 (1000 ha)

80000
70000
60000
50000
40000
30000
20000
10000
0

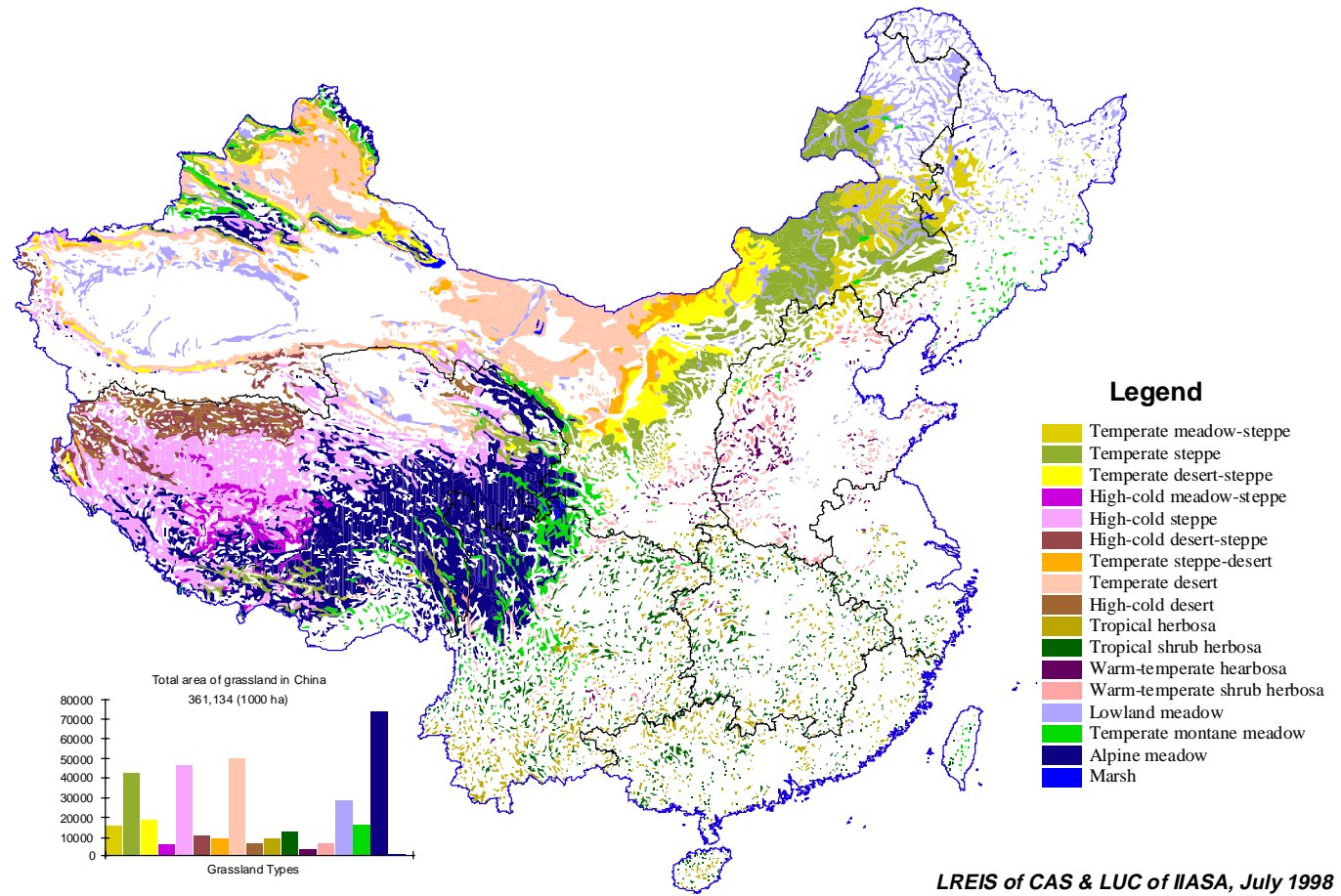Grassland Types

LREIS of CAS & LUC of IIASA, July 1998

Figure 1. The distribution of main grassland types in China

2.3 Definition of attributes

2.3.1 Grassland types

Based on climatic zonation, humidity index, vegetation type of grassland and its importance in livestock husbandry, China's grasslands were classified into 17 types as follows:

(1)　　Temperate meadow-steppe

This type is composed of four formation groups including meadow-steppe of *Leymus chinensis*, meadow-steppe of *Stipa baicalensis*, meadow-steppe of *Filifolium sibiricum*, and meadow-steppe of *Festuca spp.*

(2)　　*Temperate steppe*

This type includes six formation groups such as steppe of *Stipa grandis*, steppe of *Stipa krylovii*, steppe of *Stipa bungeana*, steppe of *Festuca spp.*, steppe of semi-brush *Artemisia*, Grass steppe with shrubs.

(3)　　*Temperate desert-steppe*

Composed of five formation groups, this type includes desert-steppe of *Stipa klemenziiI,* desert-steppe of *Stipa breviflora*, desert-steppe of *Stipa glareosa*, desert-steppe of *Stipa gobica*, desert-steppe of semi-brush *Artemisia*.

(4)　　*High-cold meadow-steppe*

Two formation groups are included, namely meadow-steppe of *Stipa capillacea*, and meadow-steppe of small *Carex spp.*, *Stipa purpurea*.

(5)　　*High-cold steppe*

This type comprises of three formation groups such as steppe of *Stipa purpurea*, steppe of small *Stipa spp.*, steppe of semi-brush *Artemisia*.

(6)　　*High-cold desert-steppe*

Two formation groups contribute to this type such as desert-steppe of small *Stipa spp.*, desert-steppe of *Carex moorcroftii*, *Ceratodies compacta*.

(7)   *Temperate steppe-desert*

This type is composed of three formation groups such as steppe-desert of *Seriphidium spp.*, small *Stipa spp.*, steppe-desert of small semi-shrub, small grasses, and steppe-desert of small *Stipa spp.* with shrubs.

(8)   *Temperate desert*

Five formation groups were included in this grassland type, comprising of desert of semi-brush *Artemisia*, desert of *Reaumuria soongorica*, desert of saline semi-brush, desert of shrub, and desert of small-tree *Haloxylon ammodendron*.

(9)   *High-cold desert*

This grassland type includes only one formation, i.e., desert of *Ceratoides compacta*.

(10)   *Tropical herbosa*

This grassland type is composed of six formation groups including herbosa of *Imperata cylindrica* var. *major*, herbosa of *Arundinella hirta*, herbosa of *Heteropogon contortus*, herbosa of *Ischaemum ciliare*, herbosa of *Miscanthus floridulus*, *Miscanthus sinensis*, and herbosa of *Dicranopteris dichotoma*, middle grasses.

(11)   *Tropical shrub herbosa*

The six formation groups this grassland type is composed of include shrub herbosa of *Imperata cylindrica* var. *major* with trees, shrub herbosa of *Arundinella hirta* with trees, shrub herbosa of *Heteropogon conrortus* with trees, shrub herbosa of *Ischaemum ciliare* with trees, shrub herbosa of *Eulalia speciosa* with trees, and shrub herbosa of *Miscanthus floridulus*, *Miscanthus sinensis* with trees.

(12)   *Warm-temperate herbosa*

Three formation groups - herbosa of *Bothriochloa ischaemum*, herbosa of *Themeda japonica*, and herbosa of *Eulalia pallens* - constitute this grassland type.

(13)   *Warm-temperate shrub herbosa*

Three formation groups contribute to this type, such as shrub herbosa of *Bothriochloa ischaemum*, shrub herbosa of *Themeda japonica*, and shrub herbosa of *Miscanthus sinensis*.

(14)   *Lowland meadow*

This type is composed of six formation groups including marsh-meadow of *Phragmites australis*, marsh-meadow of *Calamagrostis angustifolia*, lowland meadow of *Achnatherum splendens*, march-meadow of big *Carex spp.*, saline meadow of saline forbs, and beach meadow of *Spartina anglica.*

(15)   *Temperate montane meadow*

This type is composed of five formation groups represented by meadow of *Festuca ovina*, meadow of *Deyeuxia arundinacea*, meadow of *Arundinella chenii*, meadow of grasses with trees and shrubs, meadow of grasses, forbs.

(16)   *Alpine meadow*

This widespread grassland type is composed of nine formation groups. It includes meadow of *Kobresia pygmaea*, meadow of *Kobresia humilis*, meadow of *Kobresia capillifolia*, meadow of small *Kobresia spp.* with shrubs, meadow of *Festuca rubra*, meadow of *Polygonum macrophyllum*, *Polygonum viviparum*, meadow of small *Carex spp.*, marsh-meadow of *Kobresia schoenoides*, and marsh-meadow of *Kobresia littledalei*.

(17)   *Marsh*

Composed of three formation groups this type includes marsh of *Phragmites australis*, marsh of *Carex muliensis*, and marsh of big *Carex spp.*, *Scirpus triqueter*.

2.3.2 Quality classes of grassland

In the detailed grassland survey, the herbage of grassland in China has been divided into five quality classes according to palatability, nutritive value and usability (OINP, 1986; Su, 1997). The classes were termed excellent, good, fair, low, and poor quality.

The *excellent* herbage quality: where available, livestock chooses it first from the herbage mass in every season; the nutritive value is high, with a crude protein content exceeding 10%, and a crude fiber proportion lower than 30%. The grazing tolerance and utilization rate are generally high.

The *good* herbage quality: livestock likes graze this herbage class in all seasons, but does not choose it particularly. The crude protein content is more than 8%, the crude

fiber share is less than 35%, with good grazing tolerance, high preservation ratio and utilization in the cold season.

The *fair* herbage quality: ruminants feed on this herbage class but do not prefer it as they do the previous two kinds. When withered and turning yellow, the texture of herbage becomes hard and rough. When green, some of the herbage is odorous, and unpalatable to the animals. The crude protein content of this class is generally less than 10%, the crude fiber content higher than 30%, with good grazing tolerance and medium utilization ratio.

The *low* herbage quality: except for camels and goats, most animals avoid herbage of this class unless the better qualities in the plant mass is fully grazed and finished. The contents of the nutritive materials is similar to those of the fair herbage quality, but the grazing tolerance is not as good and the preservation and utilization ratios are low in the cold season.

The *poor* herbage quality: livestock seldom feeds on herbage of this quality except when the animals are very hungry. Seasonally, some of the herbage can be slightly poisonous. The nutritive materials are not very different from those of the fair herbage but are low in grazing tolerance and utilization ratio.

On the basis of the above herbage quality classes and their weight proportion in the pasture composition, the grassland polygons were encoded as three broad categories (see Figure 2).

(1)   The *good quality*: the weight percentage of *excellent* and *good* herbage is ≥ 60%;
(2)   The *fair quality*: the weight percentage of *fair (or better)* herbage is ≥ 60%;
(3)   The *inferior quality*: the weight percentage of *low* and *poor* herbage is > 40%.

2.3.3 Yield grades of grassland

The criteria for grassland productivity grading are based on the dry matter yield of grassland per hectare per year. The grasslands in China are consequently divided into *high*, *fair*, and *low yield* grades (see Figure 3):

(1)   The *high yield*: > 2000 kg dry matter per ha per year;
(2)   The *fair yield*: 1000 – 2000 kg dry matter per ha per year;
(3)   The *low yield*: < 1000 kg dry matter per ha per year.

Quality class

Good quality ---
The weight percentage of
excellent and good herbages:
equal and more than 60%

Fair Quality ---
The weight percentage of
herbages better than
average ones:
equal and more than 60%

Inferior Quality ---
The weight percentage of
low and poor herbages:
more than 40%

LREIS of CAS & LUC of IIASA, July 1998
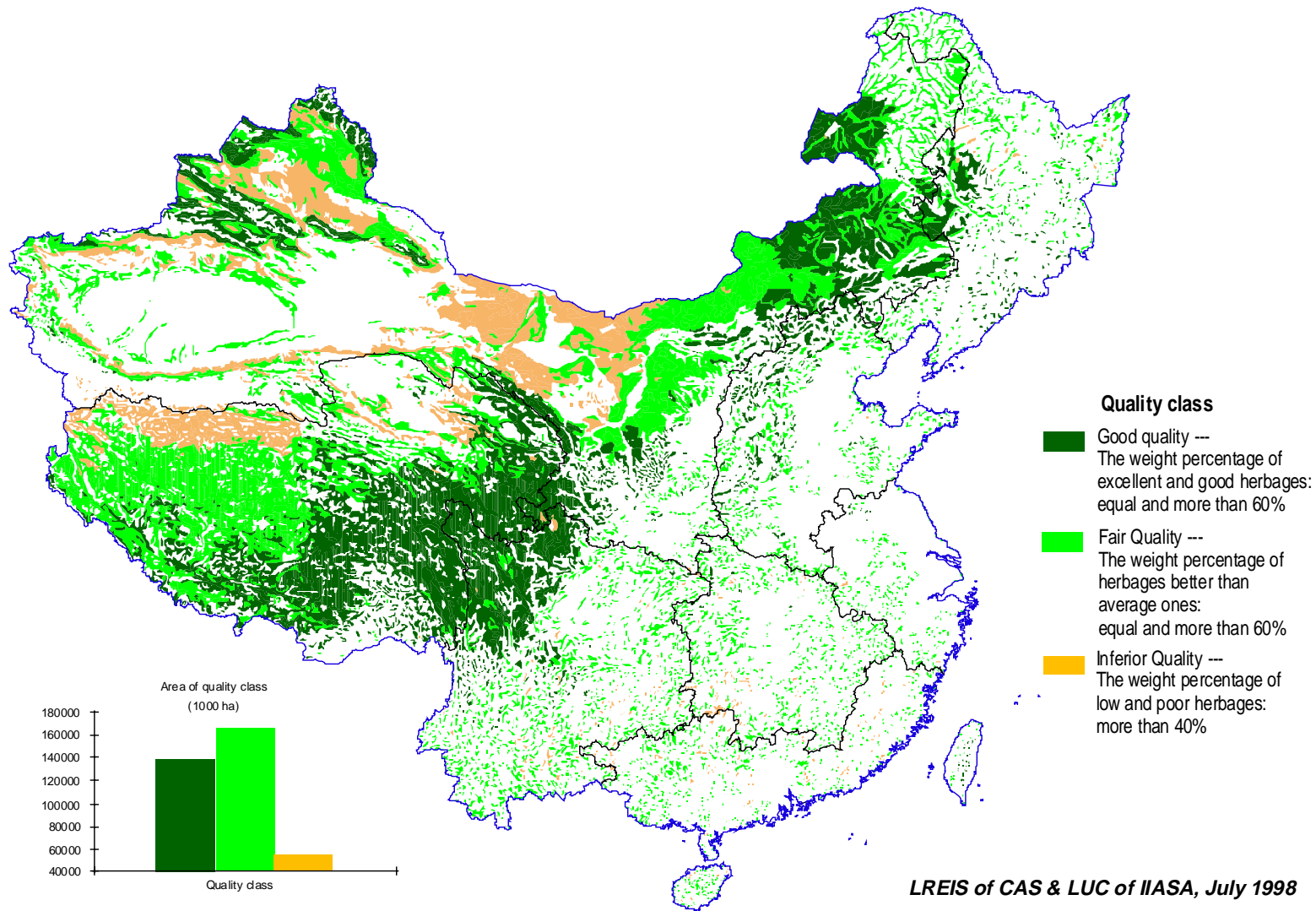
Figure 2. The distribution of quality classes of grasslands in China

Yield grade

High yield:
> 2000 kg/ha.yr

Fair yield:
1000 - 2000 kg/ha.yr

Low yield:
< 1000 kg/ha.yr

LREIS of CAS & LUC of IIASA, July 1998

Area of yield grade
(1000 ha)

280000
240000
200000
160000
120000
80000
40000
0

Yield grade

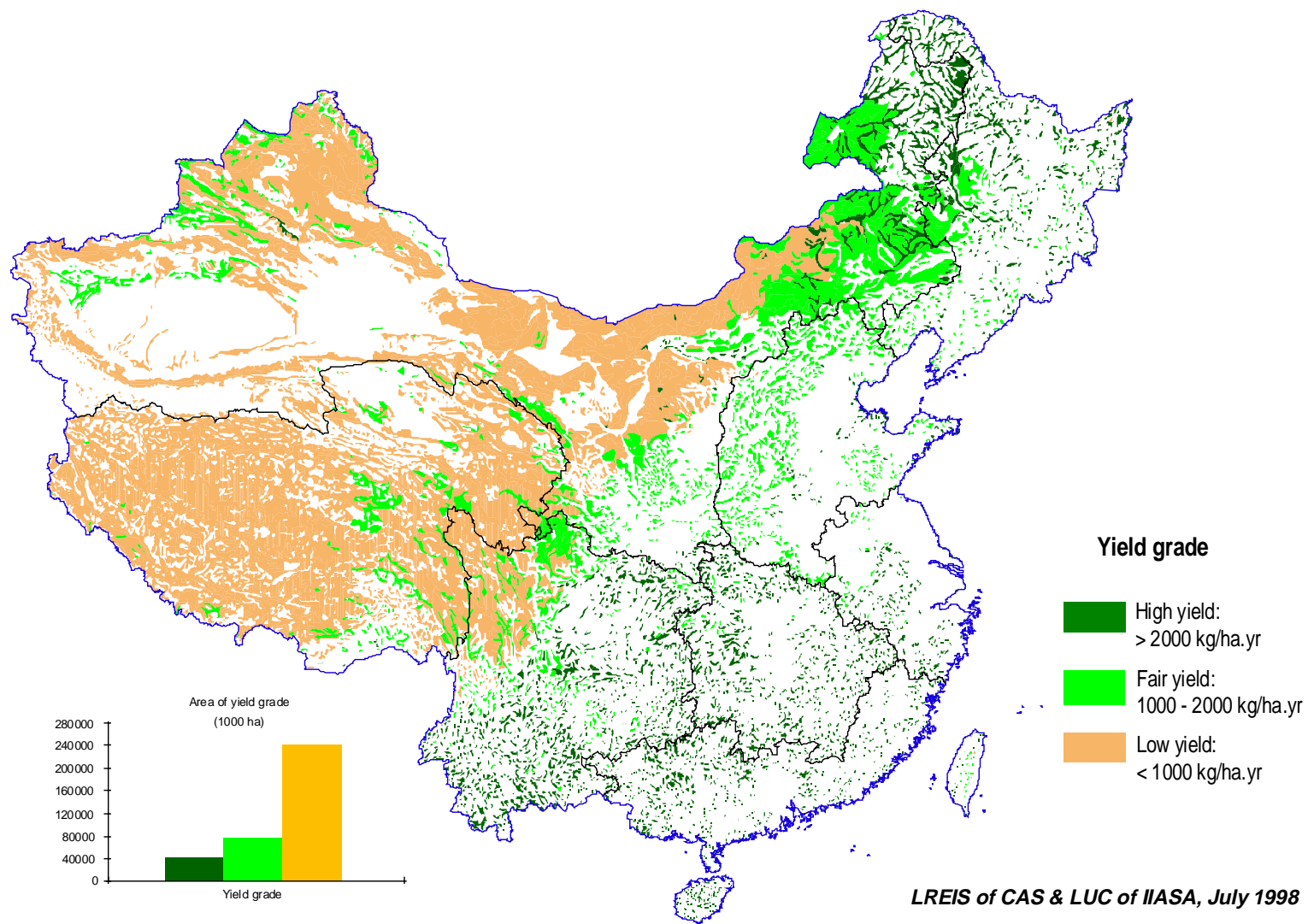**Figure 3. The distribution of yield grades of grasslands in China**

3. Geographic distribution of grassland types and their productive levels

3.1 Extents and distribution of grassland types in China

There are three recent data sources available at the national level that can be used to estimate the distribution and extents of grassland types in China. First, the results of the detailed grassland resources survey, conducted in the 1980s and compiled at county level, can be aggregated to the national level (DAHV and GSAHV, 1996).

According to this assessment, the total area of grassland in China amounts to 398.9 million hectares, comprising of 6.1 million hectares of improved/sown grassland and 392.8 million hectares of natural grassland. The latter estimate includes 354.4 million hectares of natural grasslands according to the major 17 grassland types, some 36.6 million hectares of scattered grassland, 863 thousand hectares of dry-tropical sparse shrub herbosa grassland (in Hainan island), and 933 thousand hectares grassland of unknown type (located in the center of Xizang autonomous region).

As a second data source, we can rely on the digital grassland database, described in this paper, based on the detailed grassland field survey and derived from the 1:4M scale *Map of Grassland in China* compiled by CISNR (1997). The surface area of the respective grassland polygons, measured by GIS, results in a total grassland extent of 360.3 million hectares (excluding Hong Kong and Taiwan).

The third way is to measure the extent of grassland from the *Map of Land Use in China* (1:4M) compiled by Institute of Geography of Chinese Academy of Sciences (1991), with a total grassland area of 348.9 million hectares. In the *Map of Land Use in China,* available in the LUC-GIS (http://www.iiasa.ac.at), grasslands are classified into only three types according to use, namely of a natural grassland type, an improved grassland type, and a swamp type. It is therefore difficult to compare this source with the 17 types of grassland in both the county-level surveyed data and the *Map of Grassland in China* compiled by CISNR.

A summary of grassland extents, compiled for each of the eight LUC economic regions and the country total, are shown in Table 4. Though the discrepancy in the aggregate extents of grassland at the national level is only 1.7 percent, Table 4

illustrates that there are also major differences between the *Map* and the *Survey*, both for some grassland types (e.g., types 9, 12, 13, and 17) as also some LUC regions. For instance, the grassland areas derived from the two sources for the North, Central and South regions are fairly different (though relatively small compared to the national total). Obviously in these regions, which crop agriculture and other features dominate rather than extended grasslands, the considerations on mapping scale given in Section 1.2 apply and several factors listed may have limited the accuracy of map compilation and cartographic integration. Hence, the polygons of the Map in these specific regions cannot indicate the exact extent of grassland extents but rather show the approximate spatial distribution of grassland types. On the other hand, in regions dominated by grassland (e.g., Plateau and Northwest region) the Map tends, for the same reasons of mapping accuracy, to somewhat overstate the extent of grassland and to neglect the presence of other land covers of minor importance.

Table 4. Comparison between the Map and Survey of grassland (in 1000 ha)

Types		North	North-east	East	Central	South	South-west	Plateau	North-west	Total
1	G	1568	3800	0	0	0	0	260	9924	15552
	S	355	2774	0	0	0	0	210	11180	14519
2	G	1312	385	0	0	0	0	4765	35754	42216
	S	1011	775	0	0	0	0	3833	35477	41097
3	G	0	0	0	0	0	0	437	18794	19230
	S	0	0	0	0	0	0	968	17954	18922
4	G	0	0	0	0	0	0	6315	6	6321
	S	0	0	0	0	0	0	5626	1240	6866
5	G	0	0	0	0	0	0	41095	5732	46827
	S	0	0	0	0	0	0	37762	3861	41623
6	G	0	0	0	0	0	0	9342	1499	10841
	S	0	0	0	0	0	0	8679	887	9566
7	G	0	0	0	0	0	0	171	9405	9576
	S	0	0	0	0	0	0	107	10566	10673
8	G	0	0	0	0	0	0	2645	47268	49913
	S	0	0	0	0	0	0	2084	42977	45061
9	G	0	0	0	0	0	0	5259	1228	6488
	S	0	0	0	0	0	0	5967	1561	7528
10	G	65	0	411	2160	2166	5014	5	187	10008
	S	294	0	334	2821	3700	6929	9	150	14237
11	G	87	0	830	3742	2112	6028	83	135	13018
	S	273	0	971	4358	4526	7394	28	1	17551
12	G	2405	239	135	100	0	262	92	437	3670
	S	3539	660	65	610	0	1418	11	354	6657
13	G	3542	355	143	89	0	1309	203	869	6510
	S	5034	645	9	951	0	3739	140	1099	11616
14	G	598	6219	114	73	36	0	1418	20313	28771
	S	886	5481	164	427	30	229	1168	16834	25220
15	G	246	949	0	105	0	5805	2979	6397	16481
	S	760	1576	0	20	0	4047	2040	8276	16719
16	G	0	0	0	0	0	13316	53434	7054	73804
	S	0	0	0	0	0	10101	48551	5069	63723
17	G	4	466	0	4	6	177	62	393	1113
	S	49	1264	3	0	6	432	21	1098	2874
S	G	9826	12412	1634	6274	4320	31912	128566	165395	360339
U	S	12203	13175	1545	9187	8262	34290	117203	158584	354449
M	%	-19.5	-5.8	5.8	-31.7	-47.7	-6.9	9.7	4.3	1.7

Remarks:

- Estimates exclude areas of grassland in Taiwan and Hong Kong.
- The definition of grassland types 1,...,17 is explained in Table 1 and Section 2.3.1.
- *G* refers to data from the *Map of Grassland in China, S* denotes data compiled from the detailed grassland resources survey.
- *% = (G-S)/S*; i.e., percent difference between grassland extents derived from *Map of Grassland in China* and the results of the detailed grassland survey.
- The estimate of 354.4 million hectares according to the detailed grassland survey in Table 4 used for comparison with the Map excludes improved/sown grassland (6.1 mill. ha), scattered natural grasslands (36.6 mill. ha), and minor grasslands of dry-tropical sparse shrub herbosa (0.9 mill. ha) and of unknown type (0.9 mill. ha).

3.2 Extent and distribution of productive levels of grassland

Based on polygon attributes of quality "*class*" and yield "*grade*" described in Section 2.3 above, the grasslands can be grouped into nine productive levels, such as *good quality & high yield*, *fair quality & fair yield*, *inferior quality & low yield*, etc. These classes show various combinations of quality and yield of grassland (see Table 5).

Table 5. The encoding of productive levels of grassland

Codes	High yield: > 2000 kg/ha/yr	Fair yield: 1000 – 2000 kg/ha/yr	Low yield: < 1000 kg/ha/yr
Good quality: The weight percentage of excellent and good herbage is ≥ 60%	11	12	13
Fair quality: The weight percentage of fair (or better) herbage is ≥ 60%	21	22	23
Inferior quality: The weight percentage of low and poor herbage is > 40%	31	32	33

The regional and national summary listed in Table 6 and the class distribution shown in Figure 4 point to the fact that *low* yield and *fair* to *good* quality are the main characteristics of grassland types in China. The area of grassland with an annual dry matter production of less than 1000 kg/ha (i.e., the low yield classes) accounts for about two-thirds of the total. High yields, i.e., areas with an annual dry matter production of more than 2000 kg/ha (classes 11, 21, and 31) occur on just over 10 percent of the grasslands. On the other hand, good and fair herbage quality is attributed, respectively, to 39 and 46 percent of the grassland areas. The four classes ranking highest in terms of area occupied account for more than four-fifths of the grassland. They are:

    (i)   28.8 percent fair quality - low yield (class 23),

    (ii)   23.3 percent good quality - low yield (class 13),

    (iii)   15.0 percent good quality - fair yield (class 12), and

    (iv)   14.8 percent inferior quality - low yield (class 33).

As to the geographical distribution, the Northwest economic region of LUC (Xinjiang, Nei Mongol, Ningxia, Gansu, Shaanxi) accounts for 45.9 percent of grassland areas, followed by the Plateau region (Qinghai, Xizang) with its share of 35.7 percent in total grassland. About half of the remaining one fifth, some 8.9 percent of total grasslands, is located in the Southwest region (Sichuan, Guizhou, Yunnan). The other five LUC economic regions are relatively unimportant with regard to pastures, contributing between 0.5 to 3.5 percent of national grassland areas. However, despite this overall grassland distribution, almost 60 percent of the best pasture productivity class, good quality - high yield (class 11), scatters in the Northeast economic region (Heilongjiang, Jilin, Liaoning).

Table 6. Extents of productive classes of grassland at the level of LUC economic regions (1000 ha)

Class	North	North-east	East	Central	South	South-west	Plateau	North-west	Total	%
11	0	874	0	11	0	351	0	273	1510	0.4
12	4582	4218	52	120	0	6077	6885	32186	54121	15.0
13	0	17	0	0	0	12138	54152	17458	83764	23.3
21	886	6236	1328	5438	3707	10025	36	11084	38740	10.8
22	4311	792	218	175	9	1950	1715	13491	22661	6.3
23	27	0	0	0	0	539	52373	50825	103764	28.8
31	11	275	12	524	604	535	0	18	1979	0.6
32	0	0	25	6	0	297	67	245	639	0.2
33	0	0	0	0	0	0	13338	39814	53152	14.8
Total	9817	12412	1635	6274	4320	31912	128566	165394	360330	
%	2.7	3.4	0.5	1.7	1.2	8.9	35.7	45.9		

*   The meaning of class codes 11,..., 33 is explained in Table 5.
**   Estimates exclude grassland areas in Taiwan and Hong Kong.

Legend

- Good quality & High yield
- Good quality & Fair yield
- Good quality & Low yield
- Fair quality & High yield
- Fair quality & Fair yield
- Fair quality & Low yield
- Inferior quality & High yield
- Inferior quality & Fair yield
- Inferior quality & Low yield
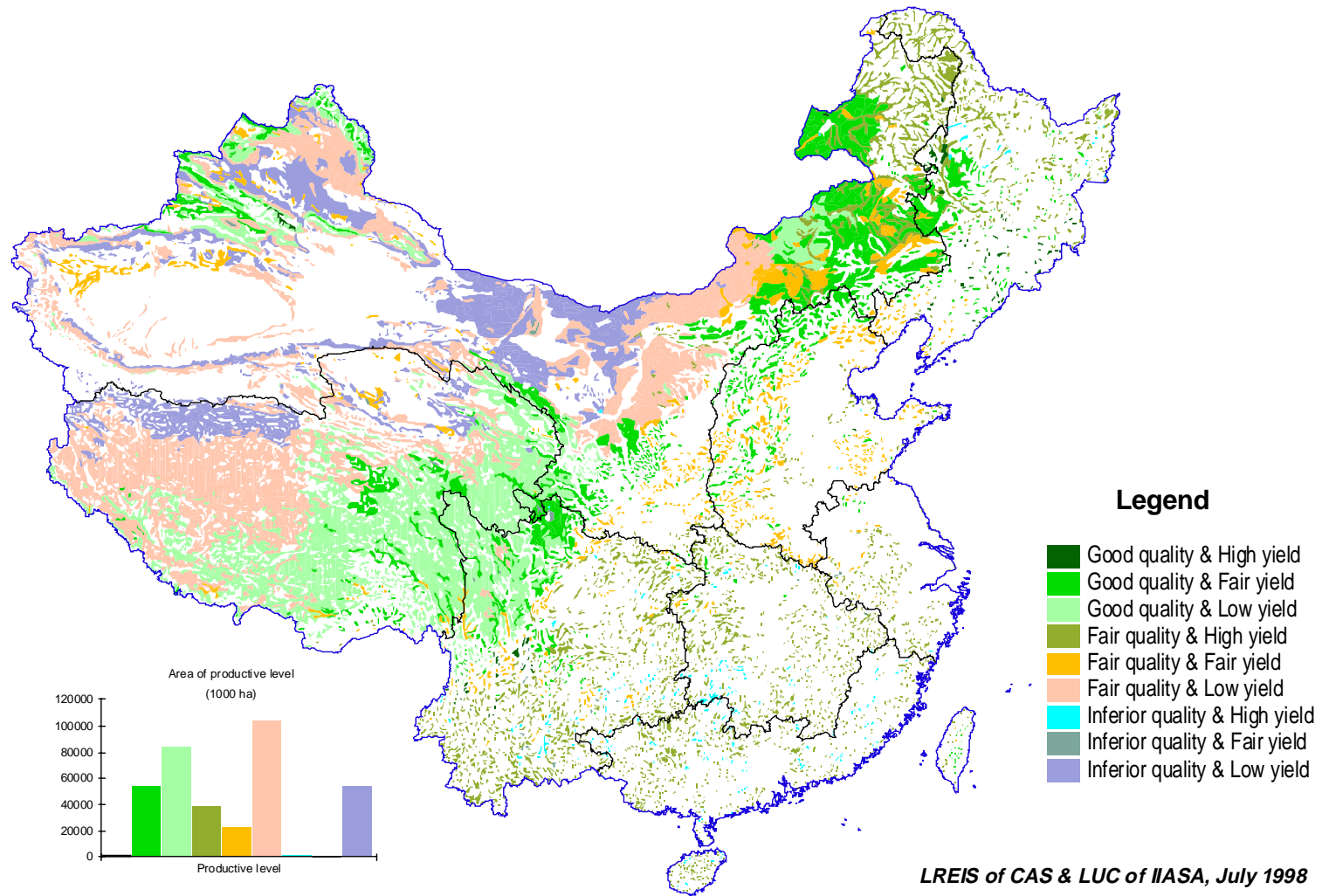
LREIS of CAS & LUC of IIASA, July 1998

Figure 4. The distribution of productive levels of grasslands in China

4. Summary

The main objective of this work was to update the datasets available in the LUC-GIS at IIASA with new authoritative information regarding the distribution of grassland types in China. This paper relies on the latest published grassland map of China (CISNR, 1997), focusing on the extents and geographical distribution of seventeen major grassland types and their productive levels. It is worth noting that the materials used are consistent with and complementary to the recent efforts of China's State Land Administration to accurately estimate extents of cultivated land and conversion of land from and to crop agriculture (Fischer et al., 1998).

Due to limitations in cartographic integration at the chosen mapping scale (1:4M), the relatively small and dispersed areas of improved grassland and sown grassland have been excluded in the compilation of the Map, and minor areas of natural grassland in the South and Central region have been exaggerated to some extent. Nevertheless, the total area of natural grassland from the digitized georeferenced database is very close to the result of the detailed survey conducted by the authorized departments of the Central Government. Therefore, it is believed that the distribution of the main natural grasslands in China has been fairly accurately expressed in the database.

China has a vast area of grassland, about 40 percent of its total territory. According to a report jointly edited by the World Resources Institute and major UN organizations (1998), China is second only to Australia, being the leading country in the world with regard to extent of grassland. However, our study concludes that the productivity level of grasslands in China is much lower than in other parts of the World, as for instance, also estimated by Oak Ridge National Laboratory (1997). This situation severely limits further progress of China's ruminant livestock industry, which still operates at a low level of development compared to that in developed countries.

The productive level as used in the grassland database, integrating both fodder quality and yield level, is an important index to express suitability of various grassland types to support the needs of the livestock sector and the pastoral societies in China. Understanding better the relationships between grassland productivity and the underlying ecological factors (e.g., terrain, soil, climate, etc.) is critical to the LUC

project of IIASA (Fischer et al., 1996) for improved quantitative modeling of future land-use changes especially with regard to livestock development, but also of fragile environments prone to desertification. The database can as well be helpful in estimating greenhouse gas emissions from grassland areas, or to quantify the scope for grassland bioenergy uses in China[4].

Thus the newly established grassland database of China, based on detailed recent survey information and remotely sensed images, provides important geographical detail and sufficiently differentiated qualitative aspects of grassland to be of great value to global change research.

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[4] Private communication with Dr. Leo Schrattenholzer of IIASA.

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