Country Pasture/Forage Resource Profiles

CHINA

by

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CONTENTS

1. INTRODUCTION

The People's Republic of China (see Figure 1) in eastern Asia, on the west coast of the Pacific Ocean, has a land area of around 9 600 000 km^2; the area of its territorial waters is 4 730 000 km^2. It has land borders with fourteen countries: Democratic People's Republic of Korea, Russian Federation, Mongolia, Kazakhstan, Kyrgyzstan, Tajikistan, Afghanistan, Pakistan, India, Nepal, Bhutan, Myanmar, Lao People's Democratic Republic and Viet Nam; it has sea borders with P.O. Korea, Japan, Philippines, Malaysia and Brunei. It is the most populous country, 1 295 000 000 with 22% of the world's population. According to the World Factbook the July 2006 population was 1 313 973 713 with a growth rate of 0.59%. There are 56 ethnic groups but Han account for 94%; Chinese is spoken all over the country. Beijing, with a population of 12 570 000, is the capital and the hub of politics, culture and economy. Population distribution is shown in Figure 2.

There are 34 provinces (or municipality, autonomous region and special administrative region) and 668 cities. Based on economic development and geography, China is divided into three parts: west, central and east. The east includes Liaoning, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Hainan, Taiwan, Hongkong and Macao. The centre includes Heilongjiang, Jilin, Shanxi, Henan, Anhui, Hubei, Jiangxi and Hunan. The west includes Guangxi, Sichuan, Chongqing, Guizhou, Yunnan, Shaanxi, Gansu, Ningxia, Qinghai, Xinjiang, Inner Mongolia and Tibet (see Figure 3).

Agricultural Land Use Agricultural land includes cultivated land, forests, inland water, grassland and others (see Figure 4). Cultivated land and forests are mainly in the east and centre, and grassland in the west (see Figure 5). The east is dominated by farming and the west by grassland husbandry. Inner Mongolia, Xinjiang, Tibet, Qinghai, Sichuan and Gansu are the six main pastoral areas.

Table 1. Agricultural land use characteristics

Land use	Area (1000 ha)	% of total
Cultivated land	120 040	13.53
Forest	158 940	16.56
Inland water	17 470	1.82
Grassland	400 000	41.67
Useable grassland	313330	32.64
Others	253 550	26.41

Source: National Bureau of Statistics (2000a)

Plant and Animal Resources. China has abundant plant and animal resources: there are more than 30 000 plant species, which puts it in third place after Brazil and Colombia and accounts for 13.1% of the world total; it has many species of cultivated plants, domesticated livestock and their wild relatives. Its agricultural history dates back for 7 000 years. It is

Figure 1. Map of Peoples Republic of China

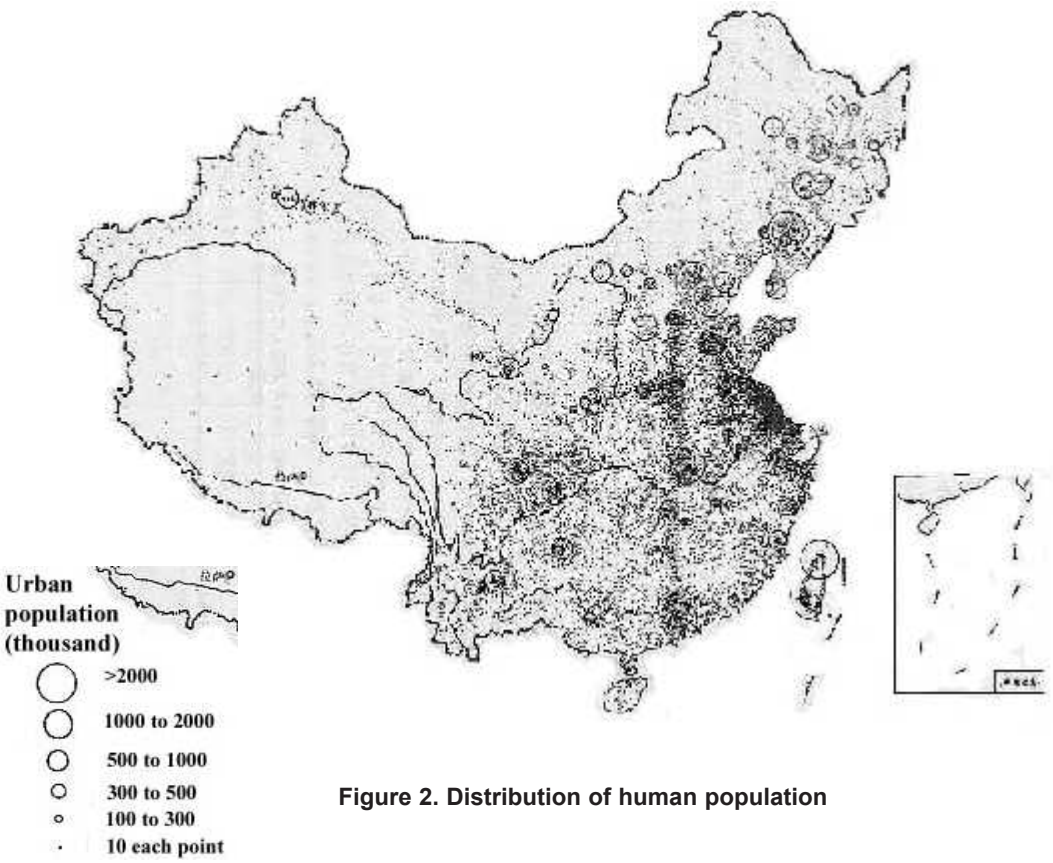


Figure 2. Distribution of human population

Figure 3. East, Central and West Parts of China

the main area and centre of diversity of many fruits and the birthplace of soybean; the number of local crop cultivars exceeds 20 000 (National Biodiversity Situation Research Report, 1998).

Economic Development. The national economy has improved greatly since the founding of the People's Republic. Since the beginning of the Reform and Opening in 1978, the average annual growth rate of

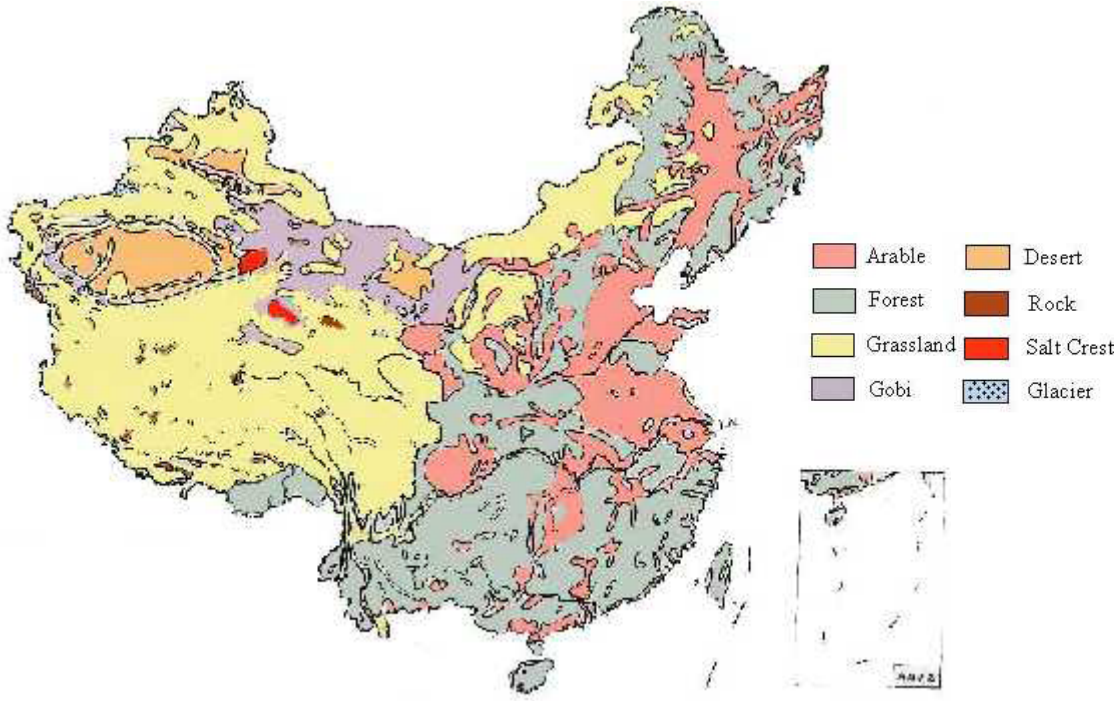


Figure 4. Map of land use

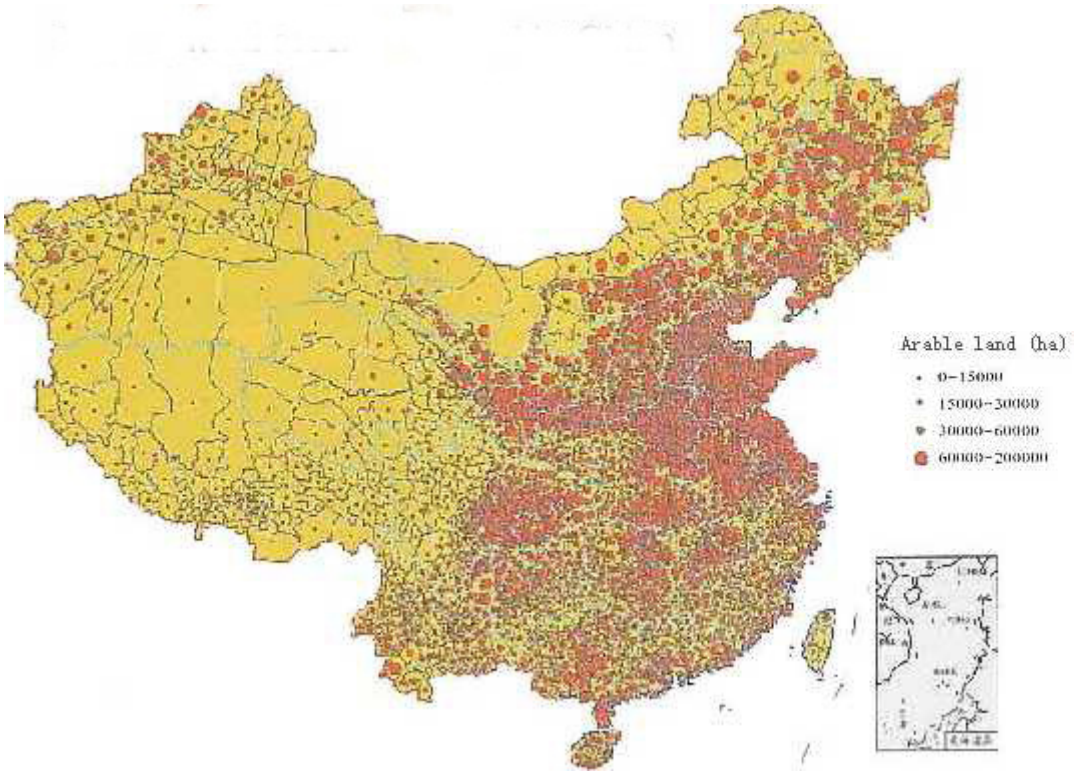


Figure 5. Distribution of arable land in China

the gross domestic product (GDP) is 9.8% at fixed prices, and the goal of quadrupling GDP over 1980 was achieved in 1995, five years ahead of the plan. China's economic gross product is now the seventh largest in the world.

National agricultural gross output value in 1999 was 2451.91 billion RMB Yuan (USD1 was worth 8.2 ¥ in 1999), of which, agriculture was 1410.62, forestry 88.63, animal husbandry 699.76 (28.53%

of the total), and fisheries 252.90. The number of domestic herbivores in China was 429 506 000 head (at December 1999), of which, cattle, buffalo and yak were 126 983 000, horses 8 914 000, donkeys 9 348 000, mules 4 673 000, camels 330 000, sheep 131 095 000, and goats 148 163 000. FAOSTAT (2005) figures for 2004 give: cattle, buffalo and yak 134.8M, horses 7.9 M, donkeys 8.2 M, mules 4.0 M, camels 265 000; sheep 157.3 M and goats 183.4 M.

In 1999, 5 054 000 tonnes of beef, 2 513 000 tonnes of mutton, 8 069 000 tonnes of milk (cow milk 7 176 000 tonnes), 283 152 tonnes of sheep wool (fine wool 11 410 tonnes and semi-fine wool 73 700 tonnes), 31 849 tonnes of goat wool and 10 180 tonnes of cashmere were produced. 2004 production data were: beef and veal 6.5 M mt (2005–6.8M); mutton and lamb 2.2 M mt (2005–2.4 M); total milk 27.0 M mt (of which cow milk was 22.9 M mt) (2005–28.7 M and cow milk 24.5 M); total wool 373 902 mt (2005–400 000 mt) and goat meat 1.8 M mt (2005–1.9 M). It should be noted that milk production more than doubled between 2000 and 2004. In 1997, 65 700 beef cattle, 4 585 sheep, and 9 882 goats were exported; 479 beef cattle, 84 sheep, 1 543 goats, 244 horses were imported. Imported stock was for breeding. In 2004 some 59 009 cattle, 8 637 goats and 145 269 sheep were exported (as well as 2.0 M pigs). Imports included 132 446 cattle, 2 950 sheep, 0.5 M mt of meat and 3.2 M mt of milk equivalents.

2. SOILS AND TOPOGRAPHY

Topography

China's topography is characterized by high land in the west, lower land in the east, and hilly, varied terrain (see Figure 6):

- the first terrace is the Qinghai-Tibet Plateau, with an average altitude over 4 000 m;
- the second terrace starts from the north and east edges of the Qinghai-Tibet Plateau and ends in Daxinanlin Mountain, Taihang Mountain, Wushan Mountain, Xuefengshan Mountain; its landform is highland with basins at altitudes between 1 000 to 2 000 m.
- the third terrace is east of the above area and extends to the eastern continental shelf, its landform is mainly plains and hills.

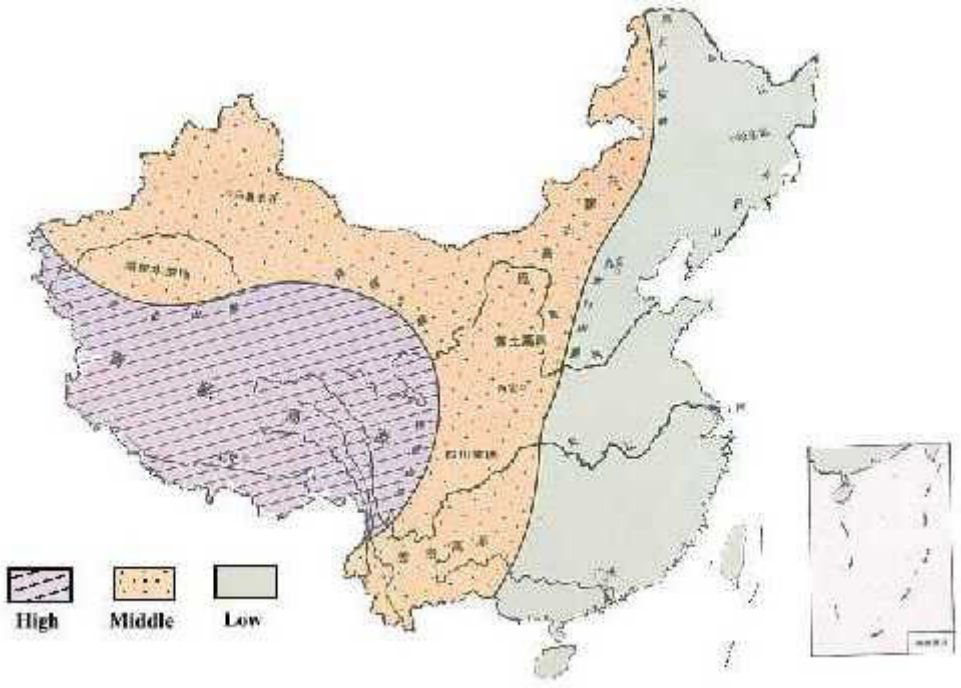


Figure 6. Three terraces of China [Sun He, 1994]

Figure 7. Topography of China

The natural conditions and agriculture of the three terraces are very different. This topography (see Figure 7) makes most water systems run from west to east and drain to the Pacific Ocean; except for those rising on the southern Qinghai-Tibet Plateau which run from north to south and drain into either the Pacific Ocean or the Indian Ocean from the barrier of the Hengduanshan Mountains.

China is hilly, it is one of the countries with the highest mean altitude; 33% is mountainous and only 12% plains. The area below 500 m almost equals that above 3 000 m, both of them around a quarter of the total (Table 2).

Table 2. Land characteristics of China

Item	Area (1 000 km²)	%of total
Total land area	**9 600**	**100.00**
By topographic feature		
Mountains	3 200	33.33
Plateaux	2 500	26.04
Basins	1 800	18.75
Plains	1 150	11.98
Hills	950	9.90
By altitude		
Under 500 m	2 417	25.18
500 to 1000 m	1 625	16.93
1000 to 2000 m	2,399	24.99
2000 to 3000 m	677	7.04
Above 3000 m	2 483	25.86

National Bureau of Statistics, 2000

Soils

Based on the complex influence of climate, topography, vegetation and human development, China's soil types are complex (see Figure 8). A simplified map of soil-vegetation distribution in China is shown in Figure 9.The zonal soil types in the East Monsoon Zone are latosol, lateritic red soil, red soil and yellow soil, yellow-brown soil, burozem and drab soil, dark brown forest soil, podzolic soil from south to north. The zonal soil types from northeast to northwest are chernozem, chestnut soil, brown soil, sierozem, grey brown desert soil, brown desert soil. On the Qinghai-Tibet Plateau, the soil types from east to west are alpine meadow soil, alpine steppe soil, alpine desert soil and alpine frozen soil. Because there are plenty of mountains, the vertical zonal pedigree of soil type appears widely. There are different soil pedigrees on the different mountains. Influenced by the long history of cultivation, agricultural soil types are also many, such as paddy soil, oasis soil and lou soil (stratified old manurial loessial soil).

Soil degradation is the most important constraint for China's ecological conservation and economic development. The area of desertified (i.e. soil degradation in the arid, semi-arid and non-humid areas) soil accounts for 27.32% of the land area (see Figure 10 and Table 3). Of this, 61.3% was caused by wind,

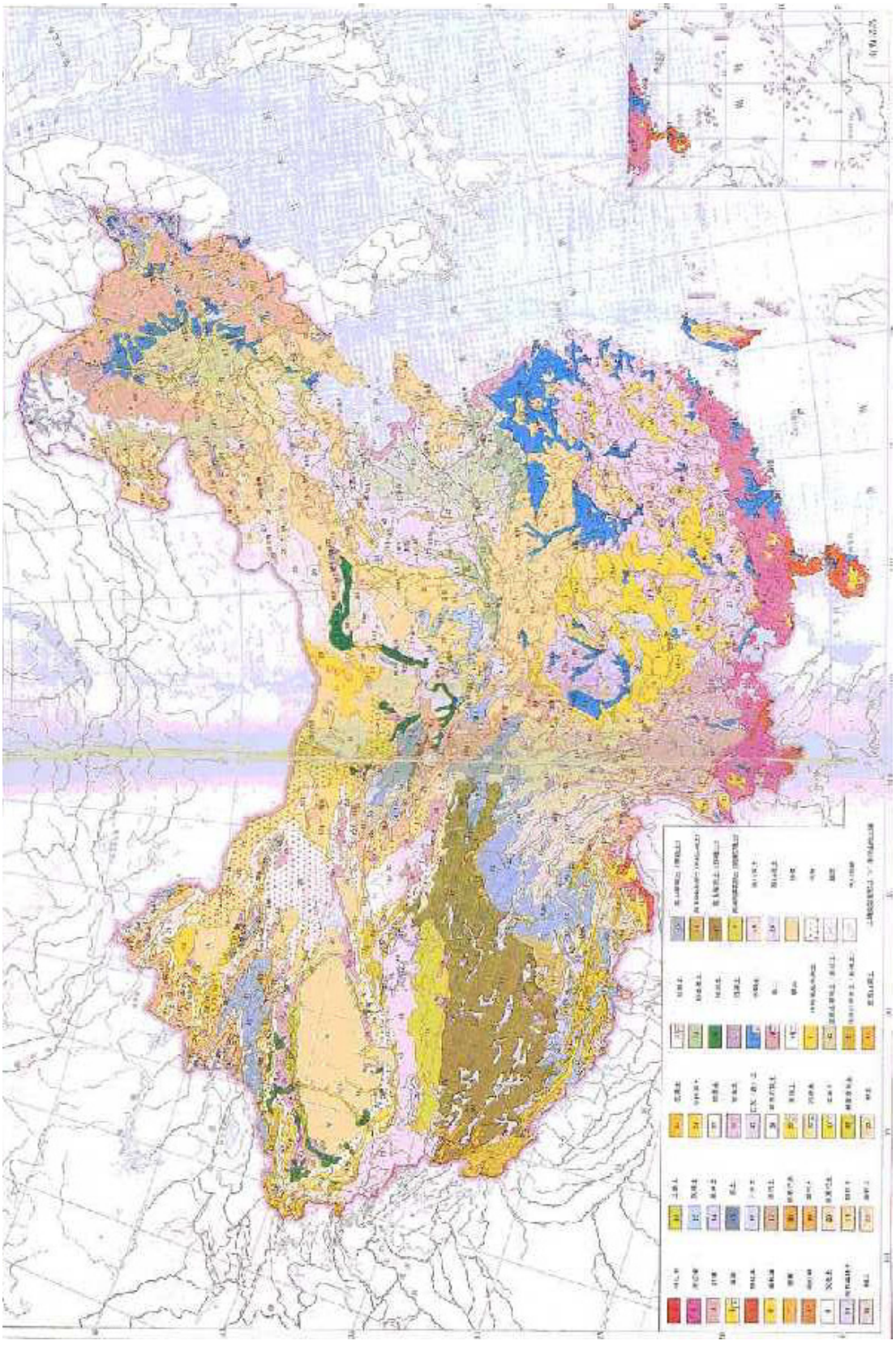
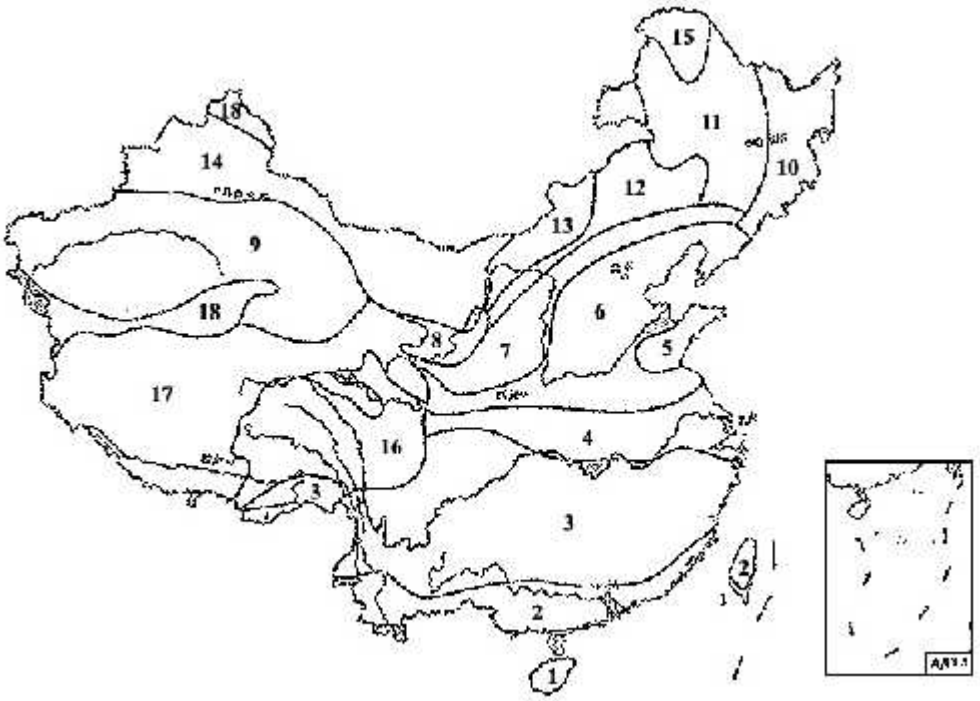


Figure 8. Soil distribution

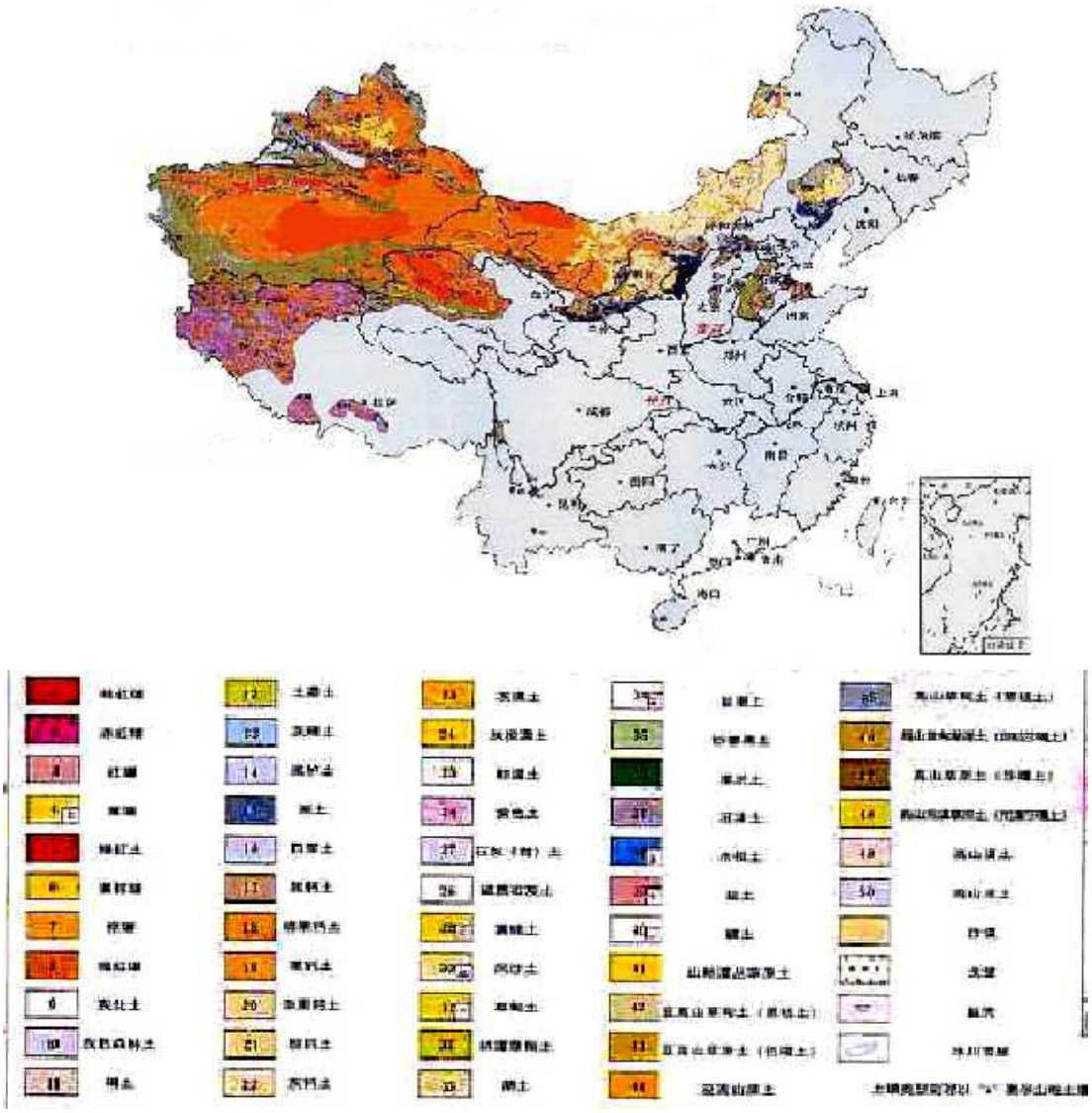
Key to Figure 8

1	Latosol	12	Stratified old manural loessial soil (Lou soil)	23	Gray desert soil	34	Salinized chao soil	45	Alpine meadow soil
2	Lateritic red soil	13	Gray-drab forest soil	24	Gray brown soil	35	Sajong black soil	46	Alpine meadow-steppe soil
3	Red soil	14	Dark loessial soil	25	Brown desert soil	36	Warp soil	47	Alpine steppe soil
4	Yellow soil	15	Black soil	26	Purplish soil	37	Bog soil	48	Alpine desert-steppe soil
5	Dry red soil	16	Planosol	27	Limestone soil	38	Paddy soil	49	Alpine desert soil
6	Yellow-brown soil	17	Chernozem	28	Phospho-calcic soil	39	Solonchak	50	Alpine frozen soil
7	Burozem	18	Dark chestnut soil	29	Yellow mein soil	40	Solonetz	51	Desert
8	Dark red soil	19	Chestnut soil	30	Aeolian sandy soil	41	Moutain scrubby steppe soil	52	Gobi
9	Podsolic soil	20	Light chestnut soil	31	Meadow soil	42	Subalpine meadow soil	53	Salt crust
10	Gray forest soil	21	Brown soil	32	Scrubby meadow soil	43	Subalpine steppe soil	54	Glacier and snow
11	Drab soil	22	Sierozem	33	Cultivated fluviogenic soil (Chao soil)	44	Subalpine desert soil		



1. Latosol-Tropical Forest
2. Lateritic red soil-Monsoon evergreen forest
3. Red or yellow soil-evergreen forest
4. Yellow-brown soil-evergreen forest or Aestisilve
5. Burozem-Aestisilve
6. Drab soil-Xerophytic Aestisilve
7. Dark loessial soil-Steppe
8. Sierozem-Desert Steppe
9. Gobi or Solonchak-Desert
10. Dark brown forest soil or Planosol-Theropencedrymion
11. Black soil or Chernozem-Forest-steppe
12. Chestnut soil-Steppe
13. Brown soil-Desert Steppe
14. Brown desert soil-Desert
15. Podzolic soil-Needle Forest
16. Alpine meadow soil or Subalpine meadow soil-Alpine Meadow
17. Alpine steppe soil or Subalpine steppe soil-Alpine Steppe
18. Alpine desert soil-Alpine Desert

Figure 9. Soil - vegetation distribution



Key: Factors of desertification

Water erosion		Wind erosion		Other factors	
1	Light	9	Light	17	Light
2	Medium	10	Medium	18	Medium
3	Heavy	11	Heavy	19	Heavy
Freeze thawing		Salination			
4	Light	12	Light	20	Non-desertificated land
5	Medium	13	Medium	21	Extreme dry area
6	Heavy	14	Heavy	22	Wet area
7	Water	15	National boundary	23	Unfixed national boundary
8	Province boundary	16		24	City

Figure 10. Distribution of desertified land in Northern China

7.80% by water, 8.89% by salinization, 13.85% by frost and 8.16% by other factors. The area of degraded grassland is 1 052 300 ha, and it is increasing at an annual rate of two%. At the same time, the area of degraded arable land in the arid, semi-arid and non-humid regions is 7 744 900 ha, or 40.6% of total arable land.

Table 3. Desertification in Northern China by cause

Factor	%
Over cultivated grassland	23.3
Overgrazing	29.4
Excessive deforestation	32.4
Improper water use	8.6
Communication construction	0.8
Sand dune drift driven by wind	5.5

Cai Yunlong, 2000

Vegetation

China has one of the widest ranges of vegetation types in the world. According to the classification system used in "Vegetation of China" (Wu Zhengyi, 1980), there are ten vegetation type groups covering 29 types and 560 formations (see Figure 11: 1) Coniferous

forest, 2) Broad-leaf forest, 3) Shrubs and shrub-meadow, 4) Steppe and savanna, 5) Desert, 6) Tundra 7) Alpine sparse vegetation 8) Meadow, 9) Marshes 10) Aquatic vegetation.

With obvious latitudinal zonal distribution, the vegetation types in the East Monsoon Zone from south to north are as follows: tropical rain forest and monsoon forest, subtropical evergreen broad-leaf forest, warm-temperate deciduous broad-leaf forest, temperate broad-leaf and coniferous mixed forest, sub-temperate coniferous forest.

With obvious longitude zonal distribution, the vegetation types in northern China from east to west are as follows: forest, steppe and desert.

On the Qinghai-Tibet Plateau, vegetation type distribution is characterized by both horizontal and vertical zonal features. With increasing altitude and decreasing rainfall from southeast to northwest, vegetation types are: mountain forest, alpine shrub, alpine meadow, alpine steppe and alpine desert.

Vegetation distribution in China can be summarized as: 1) all types (whatever forest or steppe and desert) are present; 2) subtropical evergreen broad-leaf forest widely distributed through the impact of monsoon; 3) a complete and unique vertical distribution spectrum of alpine vegetation on the Qinghai-Tibet Plateau. For a general idea of the main vegetation types see Figure 9.

Wildlife groups

Based on the distribution of dominant and common species and their related natural eco-geographic conditions, there are nine eco-graphic wildlife groups (Hu Zizhi, 1997):

1) Tropical forest, shrub, grassland-cropland group: the components in this group are complex, including many families, genera and species. The main hoofed animals are *Cervus unicolor*, *Cervus eldi*, *Elaphodus cephalophus*, *Muntiacus reevsii*, *Muntiacus manta*, *Capricornis sumatraensis*, and *Sus scrofa*.
2) Subtropical forest, shrub, grassland-cropland group: Main hoofed animals are *Muntiacus reevisi*, *Elaphodus cephalophus*, *Hydropotes inermis*, *Moschus chysogaster*, and *Sus scrofa*. *Lepus sinensis* and *Lepus capensis* are common in shrub and grassland.
3) Warm-temperate broad-leaf forest, forest-steppe, cropland wildlife group: Main hoofed animals are *Capreolus capreolus*, *Moschus moschiferus*, *Cervus nippon*, *Cervus elaphus*, *Naemorhedus goral*, and *Elaphurus davidianus.*
4) Temperate steppe: rodents dominate here and ungulates take second place: *Microtus brandti* and *Microtus gregariuis* take the first place in population and *Cittellu dauricus*, *Myospalax aspalax*, *Marmota bobac*, and *Ochotona daurica* take second place in the east. Hoofed animals: *Procapra gutturosa* is the representative in this group, its distribution ambit is consonant with steppe. The population is low at present, but once there were flocks of more than a thousand. *Gazella subgutturosa* is representative of the desert-steppe.
5) Temperate desert wildlife is the same as in the temperate steppe group, hoofed animal and rodents dominate. Hoofed animals: *Gazella subgutturosa* is dominant with groups of 3 or 5 head on desert or gobi. *Camelus bactrianus* is a special species, but now quite rare. *Equus hemionus* also exists. Rodents: *Meriones unguiculatus*, *Meriones meridianus*, *Meriones libycus*, *Rhombomys opimus*, *Dipus sagitta*, and *Allactaga sibirica*.
6) Sub-temperate coniferous forest wildlife group: Hoofed animals: *Alces alces*, with large body size, browsing the leaf of broad-leaf trees in-group, is the representative in this group and called "forest giant". *Moschus moschiferous*, *Capreolus capreolus*, *Cervus elaphus*, *Sus scrofa* are also in this group.
7) Alpine forest-shrub wildlife group: This group is distributed in the southeast of Qinghai-Tibet Plateau with altitude between 3 500 to 5 000 m. Since three vegetation types (mountain forest, alpine shrub and alpine meadow) are interlaced, the animals are distributed accordingly and the dominant ones are those living on alpine shrubs. Hoofed animals: *Cervus albirostris*, *Cervus elaphus, Moschus sifanicus* and *Capricornis sumatrensis*. Rodents: Same as alpine meadow and alpine steppe.
8) Alpine shrub-meadow group: This group is in the middle of the Qinghai-Tibet Plateau at an altitude between 3 800 to 4 500 m and the hypsography is smooth. Shrubs are on the north-facing slopes and meadow is on the plain and south-facing slope. Hoofed animals: *Cervus albirostris*, *Cervus*

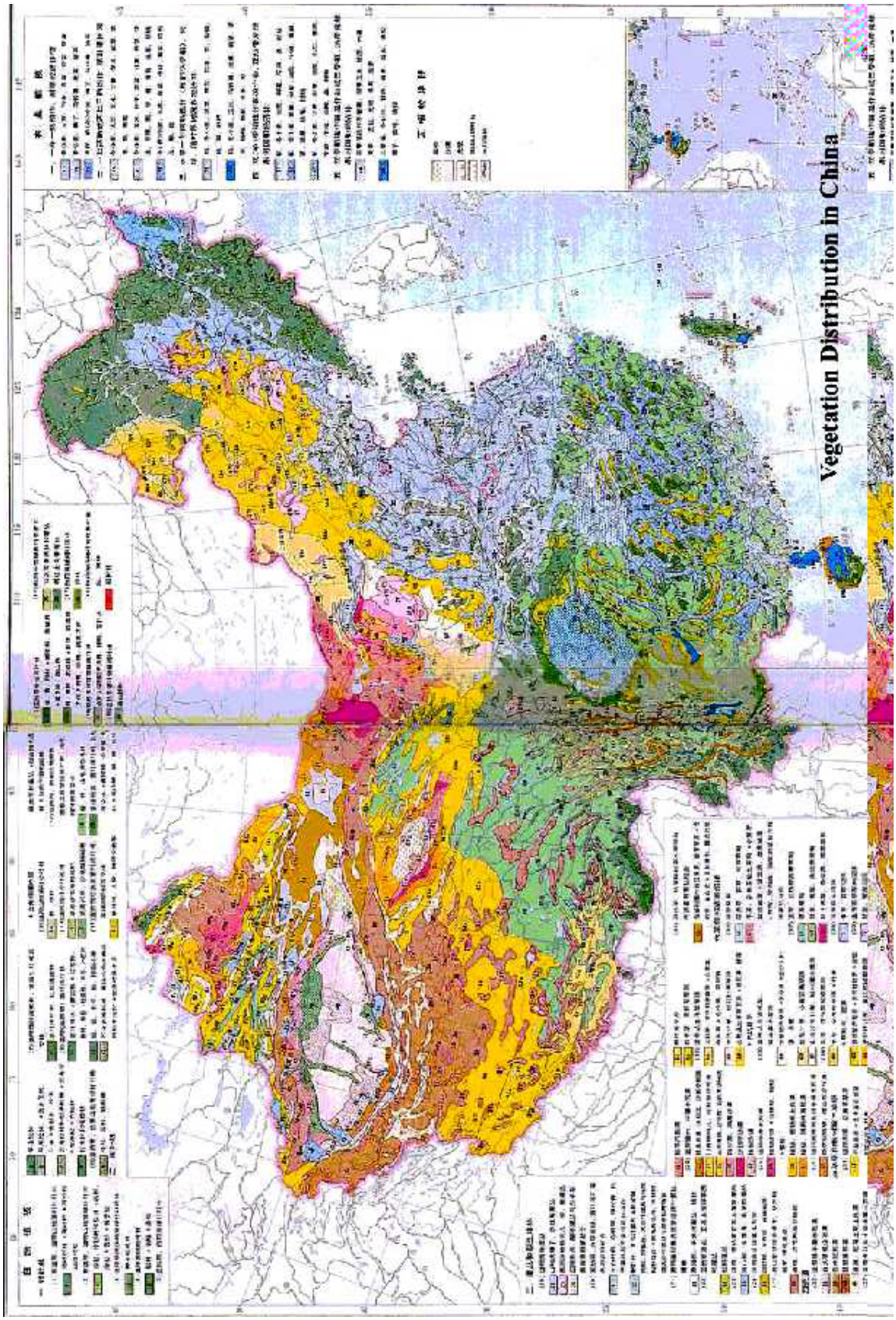


Figure 11. Vegetation distribution of China
(Wu Zhengyi, 1980)

Key to Figure 11

Native vegetation

I. Coniferous Forest

(1) Subtemperate zone, temperate zone mountain deciduous coniferous forest

1. *Larix* forest

a. *Larix*

b. *Larix sibirica*

(2) Subtemperate zone, temperate zone mountain evergreen coniferous forest

2. *Picea, Abies* forest, *Pinus* forest

a. *Picea, Abies*

b. *Picea*

c. *Pinus sylvestris* var. *mongolia*

(3) Temperate zone sand steppe evergreen coniferous open forest

3. *Pinus sylvestris* var. *mongolia* open forest

(4) Temperate zone evergreen coniferous forest

4. *Pinus* forest – *Pinus tabulaeformis; Pinus densiflora*

(5) Subtropical, tropical evergreen coniferous forest

5. *Pinus armandii* forest

6. *Pinus massoniana* forest

a. contain *Quercus serrate, Symplocos paniculata*

b. contain *Cuninghamia lanceolata, Eurya japonica*

7. *Pinus yunnanensis* and *P. khasya* forest

a. *Pinus yunnanensis*

b. *Pinus khasya*

c. *Pinus grrifithi*

8. *Cuningghamia lanceolata* forest and *Phyllostachys pubescens* forest

(6) Subtropical,tropical mountain evergreen coniferous forest

9. *Abies, Picea,Tsuga* forest

II. Broad-leaf Forest

(7) Temperate zone deciduous broad-leaf, evergreen coniferous mixed forest

10. Deciduous broad-leaf, *Pinus koraiensis* mixed forest

(8) Temperate zone (subtropical) deciduous broad-leaf forest

11. Deciduous *Quercus* forest

a. *Quercus mongolicus*

b. *Quercus liaotungensis, Q.dentata, Q.aliena*

c. *Quercus variabilis, Q.acutissima, Q.serrata*

12. *Acer, Tilia, Fraxinus, Ulmus, Betula* miscellaneous forest

13. *Lime Ulmacea, Pistacia chinensis*, miscellaneous forest combine *Platycladus orentalis*

a. contain deciduous bush layer

b. contain evergreen bush layer

(9) Temperate zone mountain deciduous micro-leaf forest

14. *Betula, Populus* forest

(10) Temperate zone deciduous micro-leal open forest

15. Steppe sand *Ulmus* open forest

16. Desert bank,sandland *Populus euphratica* (diversifolia) open forest mixed forest

(11) Tropical lime deciduous and evergreen broad-leaf forest

17. *Ulmaceae, Platycarya strobilicea, Castanopsis* mixed forest and lianes thorny shrubs

a. combine *Cupressus* open forest

b. combine *Sabina* open forest

(12) Subtropical,tropical mountain acid yellow-brown soil evergreen and deciduous broad-leaf mixed forest

18. *Castanopsis, Fagus sylvatica* miscellaneous forest

19. Evergreen *Quercus*, deciduous broad-leaf, *Tsuga chinensis* mixed forest

a. *Cyclobalunopsis glauca, Fagus sylvatica, Tsuga chinensis*

b. High mountain *Quercus, Acer, Betula, Tsuga chinensis*

(13) Subtropical evergreen broad-leaf forest

20. *Castanopsis, Cyclobalabopsis* forest

a. *Castanopsis glauca, Castanopsis eyrei*

b. *Castanopsis glaucoides, Castanopsis delavari*

21. *Castanopsis, Cinnamomum, Schima* forest

a. *Castanopsis hystrix, C. tordii, Schima superba*

b. *Castanopsis hystrix, C. indica, Schima noranhac*

(14) Tropical evergreen broad-leaf forest like rain forest

22. *Castanopsis bornnensis, Lauracea, Teaceae* forest contain *Podocarpaceae*

(15) Subtropical sclerophyllous evergreen broad-leaf forest

23. High mountain *Quercus* forest

(16) Tropical semi-evergreen broad-leaf seasonal rain forest

24. Lime seasonal rain forest and shrubs

25. Lotosol seasonal rain forest

(17) Tropical evergreen broad-leaf rain forest

26. Rain forest

(18) Tropical littoral sclerphyllous evergreen broad-leaf shrubs, brake

27. Mangrove

III. Shrubs and Coppice

(19) Temperate deciduous shrubs

28. Mountain *Ostryopsis davidiana, Spiraea shrubs*

29. Steppe sand Caragana, *Salix, Artemisia* shrubs

30. Hilly *Vitex negunda* var. *heterophylla, Zizyphus jujube* shrubs combine *Bothrichloa ischaemum, Themeda triandra* var.*japonica* community

(20) Subtropical, tropical evergreen, deciduous broad- leaf shrubs combine farmland

31. *Rhododendron decorum, Vaccinium fragile, Tesrstrocmia gymnanthera, Myrsine africana* shrubs combine *Pinus yunnanensis* open forest

32. *Melastoma candidum, Aporosa chinensis* shrubs

a. *Rhodomyrtus tomentosa, Bacckea frutescens, Melastoma candidum, Aporosa chinensis* shrubs combine *Pinus massoniana* forest

b. *Melastoma normale, Wendlandia uvaariifolia* subsp. *chinensis* shrubs combine *Pinus khasya* forest

(21) Tropical coral island succulent evergreen broadleaf shrubs, coppice

33. *Scaevola sericea* shrubs, coppice

(22) Subtropical alpine, subtropical evergreen leathery shrubs

34. Rhododendron shrubs

(23) Temperate zone, subtropical subalpine deciduous shrubs

35. *Salix cupularis, Dasiphora fruticosa, Caragana jubata* shrubs

(24) Temperate zone alpine short-bush tundra

36. *Salix rotundifolia, Vaccinium vitis-idaea,* moss tundra

(25) Alpine cashion short semibush, herbaceous vegetation and sparse vegetation

37. *Arenaria, Androsae* cushion vegetation

IV. Desert

(26) Temperate zone short semibush desert

38. *Sympegma regelii* rock desert

39. *Anabasis* gobi

40. *Reaumuria soogorica*

41. *Artemisia*, ephemental herbaceous clay desert

(**27) Temperate zone succulent saline short semibush desert**

42. Kalidium saline desert

(**28) Temperate zone bush, semibush desert**

43. *Ephedra przewalskii, Zygophyllum xanthoxylon, Calligonum mongolicum gob*i

44. *Caragana tibetica, Ceratoides lateens* sand-rock desert

45. *Potaninia mongolica, Ammopiptantus mongolicus, Tetraena mongolica*, sand-rock desert

46. *Artemisia arenaria, A.spaerocephala* sand desert

47. *Calligonum* sand desert

48. *Tamarix* sand desert

(29) Temperate semi-tree desert

49. *Haloxylon* desert

a. *Haloxylon persicum, H.ammodendron*

b. *H. ammodendron*

50. *Haloxylon ammodendron, Reaumuria soongorica* clay desert

51. *Haloxylon ammodendron, Ephedra przewalskii* gravel desert

(30) Temperate zone alpine creeping short semi-bush desert

52. *Ceratoides compacta, Ajania tibetica* sand-gravel desert

V. Steppe and Bush Savanna

(31) Temperate grass, forbs steppe

53. *Leymus chinense* steppe

a. contain rich forbs

b. contain *Stipa baicalensis*

54. *Filifolium sibiricum* steppe

55. *Bothriochloa ischaemum, Themeda triandra* var. *japonica* steppe

(32) Temperate bunch-grass steppe

56. *Stipa grandis, S.krylovii* steppe

a. contain *Leymus chinense,* forbs

b. contain A*rtemisia frigida, Thymus mongolicus*

57. *Stipa bungeana, S.breviflora* steppe

58. Mountain bunch-grass steppe

a. *Festuca sulcata, Stipa capilata*

b. *Stipa krylovii*

(**33) Temperate short bunch-grass, short semi-bush steppe**

59. *Stipa gobica* stepe

a. contain *Artemisia frigida*

b. contain *Stipa glareosa, Artemisia xerophytica*

60. *Stipa brevifolia, Ajania achilleoides* steppe

61. Mountain *Stipa glareosa,* short semi-bush steppe

(34) Temperate zone, subtropical alpine steppe

62. Grass, forbs steppe

a. *Stipa*

b. *Poa, Festuca*

63. *Stipa purpurea* steppe

a. contain *Stipa subsessiliflora* var.*basiplumosa*

b. contain *Festuca*

64. *Stipa subsessiliflora* var. *basiplumosa, Ceratoides compacta* steppe

(35) Subtropical, tropical bush savanna combine succulent thorny shrub

65. *Heteropogon contortus,Themeda hookeri* savanna

a. contain *Zyzyphus mauritiana, Acacia farnesiana*

b. contain *Flacourtia indica, Pandanus tectorius*

VI. Meadow and marsh

(36) Temperate meadow

66. Forbs, Carex, grass meadow

67. Grass, forbs saline meadow

a. *Aeluropus littoralis, Suaeda* spp.

b. *Achnanthrum splendens, Suaeda physophora*

c. *Phragmetis communis,Trachomitum lancifolium,Alhagi sparsifolia* meadow combine *Tamarix chinenese* shrub

(37) Temperate, subtropical alpine meadow

68. *Kobresia* meadow

69. *Carex, Kobresia*, forbs meadow

70. Saline grass, forbs, *Kobresia* meadow

(38) Temperate marsh

71. Grass, *Carex* marsh

(39) Temperate alpine marsh

72.Carex, Kobresia marsh

Agricultural vegetation

I. One crop per annual grain, hardy economic crop

73. Spring wheat, soybean, corn, sorghum, sugar beet, flax

74. Spring wheat, millet, potato, sugar beet, flax

75. Barley, wheat, pea, potato, rapa

II.Two crop per annual or three crop per biennial continuous cropping. Deciduous fruit orchard

76. Winter wheat, soybean, corn, sweet potato, peanut, tobacco, apple, pear, grape

77. Winter wheat, corn, millet, sorghum, sweet potato, cotton, peanut, apple, pear, Chinese date, Chinese fig, grape, Chinese chestnut, walnut

78. Wheat, corn, sorghum, cotton, grape, Hami melon, pear, apricot

III.Irrigation-rain fed two crops per annual continuous cropping (local double cropping rice). Evergreen, deciduous fruit orchard and economic forest

79. Rice, winter wheat, rape, cotton, peanut, pomegranate, tea, peach, pear, loquat

80. Rice, winter wheat, corn, potato, rape, tobacco, tea, red bayberry, chestnut, apple, pear

IV. Double (single) rice continuous cropping cold season crop. Subtropical evergreen fruit orchard and economic forest

81. Rice, winter wheat, rape, cotton, mulberry, China grass, orange

82. Rice, winter wheat, sweet potato, coarse grain, tea, rape, China grass, jute, red bayberry, orange

83. Rice, winter wheat, sweet potato, China grass, coarse grain, sugar cane, peanut, orange, tung oil tree, hemp palm, mulberry

V. Double cropping rice continuous warm season crop or three cropping rice. Tropical evergreen fruit orchard and economic forest

84. Double cropping rice continuous winter sweet potato. Double cropping corn, sweet potato, cassava, jute, litchi, longan, banana, pineapple

85.T hree cropping rice, winter peanut, sugar cane, lemongrass, sisal hemp, rubber tree, coconut, cafe, oil palm

Non-vegetation area

Saline incrustation

Sand desert

Gobi

Alpine top gravel

Glacier and snow cover

elaphus, Procapra picticaudata, and *Pantholopus hodgsonii*. Rodents: *Marmota himalayana, Ochotona tibetica, Ochotona gloverii, Myospalax fontanieri,* and *Lepus oiostolus*.

9) Alpine steppe and alpine desert group: This group is in the western cold and dry area of the Qinghai-Tibet Plateau, centred around Qiangtang, at altitudes between 4 000 to 5 000 m. Animals in this area live under natural conditions since there are no people in most of the area. Hoofed animals: *Equus hemonius*, *Bos grunniens*, *Pantholops hodgsonii*, and *Procapra picticaudata* are dominant on alpine steppe and alpine desert. *Ovis ammon* and *Pseudois nayaur* live in hilly areas. Rodents: same as alpine shrub-meadow.

3. CLIMATE AND AGRO-ECOLOGICAL ZONES

Climate

With its vast territory and the effects of topography and surrounding atmosphere, China has three climatic zones: East Monsoon Zone, Northwest Arid and Semi-arid Zone and the Qinghai-Tibet Alpine Zone (Sun, He, 1994).

The East Monsoon Zone occupies 45% of the land, with prevailing wind directions: northwest, north and northwest winds are common in winter and southeast, south and southwest winds in summer. Rainfall varies seasonally according to wind and coincides with high solar radiation, which gives good conditions for plant growth. Drought, waterlogging, wind disaster and cold snaps are frequent in the east because of the protean monsoon, typhoon and cold wave.

Eastern China can be divided into three climate zones from south to north:

– Tropical Zone
– Subtropical Zone and
– Temperate Zone.

Temperature differences between zones are quite large in winter, but small in summer. Winter temperatures are lower than other areas at the same latitude, but higher in summer. The major vegetation in the east monsoon area is different types of forest.

The **Northwest arid and semiarid area** is in inner Eurasia and is controlled by a continental climate all year round. Precipitation decreases gradually from east to west from 400 mm to less than 100 mm. Steppe and desert dominate the landscape. Vertical variation of climate on the **Qinghai-Tibet alpine area** is very significant, which is characterized by low temperature, strong solar radiation, wind, and uneven rainfall. Precipitation declines from southeast to northwest on the plain of the plateau and the natural landscape varies accordingly from forest, alpine shrub and alpine steppe to alpine desert. Temperature and rainfall details for various cities are given in Tables 4 and 5.

Features of agricultural zones

The most important difference of agricultural zonation is between the east and west. This is due to geography and ecological environment, in which water is the prominent factor. Based on the zonal and azonal differences, China may be divided into three natural zones (similar to the areas shown in Figure 6), i.e., the monsoon zone in the east, which accounts for 45% of all land; the arid inland zone in the northwest, 30% of total land; Qinghai-Tibet Plateau inland zone in the southwest, 25% of total land. There are intrinsic differences in agricultural features between the zones. The eastern monsoon zone is an agricultural area, the northwest and southwest are pastoral areas.

Character and developing trends of nine first class agriculture zones

China can be devided into nine main agricultural zones (see Figure 12):

The Northeast As a vast plain, this zone has fertile land for agriculture and forest and plenty of water, but relatively low solar radiation. Industry and communications are developed, the population engaged

Table 4. Temperature of main cities (1961 to 1990)

City	Average temperature (ºC)			Frost-free period (days)
	Coldest month	Hottest month	Annual average	
Beijing	-4.3	25.9	11.8	179
Tianjin	-3.6	26.4	12.5	194
Shijiazhaung	-2.7	26.6	13.0	198
Taiyuan	-6.0	23.3	9.6	161
Huhhot	-12.5	22.2	6.2	117
Shenyang	-11.5	24.5	8.1	150
Changchun	-15.9	22.8	5.2	135
Haerbin	-19.1	22.6	3.8	136
Shanghai	3.7	27.8	15.8	236
Nanjing	2.1	27.9	15.3	223
Hangzhou	4.0	28.5	16.2	248
Hefei	2.4	28.1	15.7	235
Fuzhou	10.6	28.8	19.7	312
Nanchang	5.1	29.5	17.5	277
Jinan	-1.0	27.4	14.4	202
Zhengzhou	-0.1	27.1	14.2	214
Wuhan	3.3	28.6	16.3	253
Changsha	4.8	29.1	17.2	271
Guangzhou	13.3	28.5	21.8	350
Nanning	12.7	28.4	21.6	340
Haikou	17.2	28.4	23.8	305
Chengdu	5.5	25.2	16.0	293
Chongqing	7.2	28.0	17.7	335
Guiyang	5.1	24.0	15.3	274
Kunming	7.6	19.7	14.6	245
Lhasa	-2.1	15.3	7.5	135
Xi'an	-0.5	26.3	13.4	208
Lanzhou	-6.1	22.1	9.3	159
Xining	-7.7	17.2	5.9	128
Yinchuan	-8.4	23.3	8.7	152
Urumchi	-12.7	23.7	6.6	161

Table 5. Rainfall of main cities (1961 to 1990)

City	Annual rainfall (mm)	Maximum daily rainfall (mm)	Maximum snow thickness (cm)
Beijing	577.0	212.2	24
Tianjin	559.5	158.1	20
Shijiazhaung	527.6	200.2	19
Taiyuan	456.8	183.5	16
Huhhot	401.6	127.2	30
Shenyang	684.4	215.5	28
Changchun	576.3	130.4	22
Haerbin	519.6	94.8	21
Shanghai	1 110.9	204.4	14
Nanjing	1 034.1	179.3	36
Hangzhou	1 374.7	189.3	29
Hefei	975.2	238.4	44
Fuzhou	1 348.3	167.6	-
Nanchang	1 521.2	289.0	24
Jinan	674.1	298.4	19
Zhengzhou	645.2	189.4	23
Wuhan	1 222.5	298.5	25
Changsha	1 376.6	192.5	20
Guangzhou	1 681.9	253.6	-
Nanning	1 320.6	198.6	-
Haikou	1 625.0	283.0	-
Chengdu	921.1	201.3	5
Chongqing	1 138.6	195.3	5
Guiyang	1 107.8	113.5	16
Kunming	1 006.6	165.4	36
Lhasa	426.1	41.6	12
Xi'an	573.0	97.0	14
Lanzhou	316.0	96.8	10
Xining	367.5	62.2	14
Yinchuan	193.8	66.8	11
Urumchi	276.1	57.7	44

in agriculture is low and the agriculture is quite large-scale. It is the most important production base for cereals, soybean and sugar beet. Forestry is also developed and it has the largest natural wood production. The development of animal husbandry is slow; it is dominated by stall feeding and grazing is subordinate.

Inner Mongolia and Along the Great Wall With a temperate climate, low precipitation and shortage of water, there is less arable and forest, but vast grasslands. The agricultural environment is very vulnerable because of frequent drought, windy weather and increasing desertification. The main agricultural sector is livestock: crop and animal husbandry are mixed. Animal production is still traditional nomadic or semi-nomadic (herders live in fixed houses in winter and early spring but travel at other seasons), but its commercial economy is undeveloped.

Yellow River, Huai River and Hai River The climate is temperate monsoon with simultaneous rainfall and solar radiation. Water is relatively scarce. With vast plains, well-equipped agricultural machinery, good communications, a long history of cultivation and a high proportion of arable land, it is an important base for wheat, cotton, maize, groundnuts and fruit. The development of animal husbandry and aquaculture is relatively high.

Figure 12. Ecological zonation of agriculture
(Sun He, 1994)

Loess Plateau The topography is characterized by plateaux and hills covered by loess; soil erosion is very severe. Solar radiation is plentiful, but water scarce. Agricultural structure is unitary with rainfed grain production. The commodity economy is weakly developed, however the potential for developing grassland farming and fruit culture is high.

Middle and Lower Reaches of Yangtse River Water and solar radiation are abundant. Solar radiation, temperatures and water are all favourable. The arable area is large and fertile. City density is quite high and industry is well developed. Agriculture is highly developed with a high total yield of agricultural products and a high commodity rate. It is the main integrated agricultural production area and the base for rice, cotton, oil crop, tea, silk, pigs and fish.

The Southwest The climate is warm and humid. The terrain is dominated by hills, with little flat land. There is plenty of biodiversity and rare species. Agriculture is poor with extensive systems and low productivity. Grain production is for subsistence. It is the production base for tobacco, rape seed, silk, tea and fruit. The dominance of commercial pig production is remarkable. There are many forest and speciality products.

South China The topography is characterized by hills, scarce arable land and a long coastline. Most of the area is subtropical with plenty of precipitation; it is the only area suitable for tropical crops. The land is superior and favours export-oriented industries. The rural economy is well developed. The staple agricultural products are vegetables, fish, pigs and poultry. Grain production exceeds local needs. The difference in development between coastal and hill areas is very obvious.

Gansu and Xinjiang Land resources are typified by vast areas and low quality; there is much natural grassland but little forest and arable. Solar radiation and thermal resources are abundant, but water is very scarce. Desertification and salinization are very severe and the agricultural environment is very fragile. Energy and mineral resources are abundant. Communications are poor. Scattered oases are the main agricultural production mode. Grain and oil resources per capita are high. The yield of cotton, sugar beet, fruit and melon is high. Grassland husbandry is well developed. There is animal production in both crop and pastoral areas, but its output is quite low.

Qinghai-Tibet This zone is characterized by rarefied air, high altitude, strong solar radiation and low temperatures. The area of natural grassland takes first place and forest takes second. Arable land is very rare and distributed in patches. Water is plentiful but unevenly distributed. It is a sparsely populated vast land in a remarkable landscape. Communications are very difficult. Agriculture, forestry and animal husbandry have features common to all alpine areas. Animals, crops and trees are adapted to low temperature and low oxygen concentration, and their potential for productivity is quite high. Livestock herding on natural pasture is the major agricultural sector. Grain production per capita is only half of the national average. The management of agriculture and animal production is extensive and production levels low. The commodity economy is undeveloped and backward.

4. RUMINANT LIVESTOCK PRODUCTION SYSTEMS

Since 1949, animal husbandry has developed rapidly. The livestock population reached 833.7 M by the end of 1999 (and 954 M by 2004). Pigs take first place with 422.6 M and account for nearly 50% of the total. Among the herbivores, around 70% of sheep, all camels, 25% of cattle and goats, 44% of horses and 39% of donkeys are raised in six provinces or regions where the pastoral industry of China is concentrated (see Table 6). Of the total livestock, 2 461 300 are kept by state owned farms - 3.67% of the total (2.54% of pigs). Meanwhile, the yields of meat and milk increased greatly (see Table 7) especially in the period 2000–2004 when for example the production of cow milk more than doubled. Average annual growth rates of meat and dairy output from 1980 to 1998 are 8.7% and 9.9% respectively. National total yields of meat and sheep wool took first place and second place in the world in 1999. Meat availability per capita is 47.3 kg, which exceeds the average world level. But the availability per capita of milk and wool is still quite low. The proportion of animal product value in total agricultural production has increased from 12.4% in 1949 to 28.5% in 1999.

There were 56 575 technical extension posts servicing livestock production and veterinary medicine with around 400 000 staff in 1999. There are 1 852 breeding farms (83 are national key farms), of which, 104 are for cattle, 187 for sheep, 23 for rabbits, 585 for pigs and 491 are integrated breeding farms. The coverage of high quality breeds of cattle, sheep and pigs are 35%, 55% and 90% respectively (Source: National Bureau of Statistics, 2000a).

The degree of commercial livestock production used to be very low and the supply of animal products insufficient. Now, the proportion of animal products consumed domestically is very small and their commercialisation has increased greatly. Animal husbandry has moved from the subsistence to the commercial economy.

Farm size (National Bureau of Statistics, 2000a)

There are two types of holdings: private family farms and state-owned farms. The pasture of family farms still belongs to the state and families pay according to a Long-term Grassland Use Contract with the government, but the livestock belong to the family. State-owned farms are mainly for breeding and their size varies greatly. Those in crop growing areas, for pigs and poultry, are usually small. Those in pastoral areas are normally larger with 30 000 to 50 000 ha of pasture and 20 000 to 30 000 head of animals (in sheep units). The largest state-owned farm covers 150 000 ha These farms are mainly for breeding sheep and cattle, a very few for horses and goats. The state-owned ranches of ancient China were for providing war-horses for the army. In the late 1970s, most military ranches switched to sheep, cattle or integrated farming.

In pastoral areas, a family farm usually has 5 to 6 people, 40 to 80 ha of pasture and 100 to 150 sheep units of livestock.

In the eastern agricultural areas animal production at family level is quite small due to land scarcity. According to the sample survey on rural households in 1999, a family had only 1.48 pigs, 0.47 sheep and 0.05 cattle on average and the output of beef, milk and wool was 0.40 kg, 12.74 kg and 0.73 kg respectively. Some family farms specialize in pig raising, sheep raising or cattle raising and their scale is much larger than common family farms. Some of them could sell more than 100 fat beef cattle.

Table. 6 Livestock population (in thousand head)

Year/Region	Cattle and buffalo	Horses	Donkeys	Mules	Camels	Pigs (NBS data Year end)	Goats (NBS data year end)	Sheep (NBS data year end)
1996	110 318	8 715	9 444	4 780	349	362 836	123 158	114 125
1997	121 757	8 912	9 528	4 806	350	400 348	134 801	120 956
1998	124 419	8 981	9 558	4 739	335	422 563	141 683	127 352
1999	126 983	8 914	9 348	4 673	330	430 198	148 163	131 095
2000*	127 149	8 916	9 348	4 673	330	437 541	148 401	131 095
2004*	134 824	7 902	8 207	3 957	265	472 895	183 363	157 330
2005*	137 975	7 641	7 919	3 740	262	488 810	195 759	170 882
Six pastoral provinces and regions (1999)	29 608	3 907	3 637	1 502	329	63 952	38 032	91 454
Proportion of pastoral provinces in total (%, 1999)	23.32	43.83	38.91	32.14	99.70	14.87	25.67	69.76

Note: the pastoral provinces and regions include Inner Mongolia Autonomous Region, Xinjiang Uigur Autonomous Region, Tibet Autonomous Region, Qinghai Province, Sichuan Province and Gansu Province. Source: National Bureau of Statistics [NBS] (2000a)
**2000/2004/2005 data from FAOSTAT, 2006*

Table 7. Output of livestock products of China

Year/Region	Meat (1000 tonnes)			Milk (1000 tonnes)		Sheep wool (tonne)			Goat Wool (tonne)	Cash-mere (tonne)
	Pork	Beef	Sheep & goat meat	Cow & sheep milk	Cow Milk	Total	Fine Wool	Semi-fine Wool		
1996	31 580	3 557	1 810	7 358	6 294	298 102	121 020	74 099	35 255	9 585
1997	35 963	4 009	2 128	6 811	6 011	255 059	116 054	55 683	25 865	8 626
1998	38 837	4 799	2 346	7 454	6 629	277 545	115 752	68 775	31 417	9 799
1999	38 907	5 054	2 513	8 069	7 176	283 152	114 103	73 700	31 849	10 180
2000*	41 406	4 991	2 754	9 479	8 632	292 502	n.r.	n.r.	n.r.	n.r.
2004*	47 210	6 803	3 951	19 550	18 500	325 000	n.r.	n.r.	n.r.	n.r.
2005*	50 095	6 800	4 349	25 650	24 530	400 000	n.r.	n.r.	n.r.	n.r.
Six pastoral provinces and regions (1999)	5 476	814	959	2 228	2 084	172 336	71 694	33 629	9 914	5 971
Proportion of pastoral provinces in total (%, 1999)	13.67	16.11	38.16	27.61	29.04	60.86	62.83	45.63	31.13	58.65

Note: the pastoral provinces and regions include Inner Mongolia Autonomous Region, Xinjiang Uigur Autonomous Region, Tibet Autonomous Region, Qinghai Province, Sichuan Province and Gansu Province. Source: National Bureau of Statistics (2000a)
**2000/2004/2005 data from FAOSTAT, 2006*
n.r.= no record

Livestock species and breeds

Based on origin and distribution, livestock in China may be classified into four lineages. They are Mongolia lineage (horse, cattle, sheep and goat) in the north, Kazakh lineage (horse, cattle, sheep and goat) in the west, Tibetan lineage in the western Qinghai-Tibet Plateau and Central Plains lineage in the central and southeast.

China has a great range of livestock breed resources; its breeds are famous for their prolificity, flavour and adaptation to extensive management, cold tolerance, load tolerance and adaptation to specific regions. There are special excellent breeds in each typical grassland type.

Cattle (Bos taurus) (Editorial Board of Cattle Breeds of China, 1998)

"Cattle" is the general name for *Bos taurus* and *Bos indicus* which are called "Huang Niu" (Yellow Cattle) in Chinese. Cattle are found in all areas below 3 000 m. There are 55 breeds. Based on their

adaptation to ecological conditions, cattle may be sorted into three ecological-geographic groups: Northern Cattle, Central Plains Cattle and South China Cattle.

- The representative breed of Northern Cattle are the Mongolian Cattle which are adapted to grazing in the Temperate Zone Steppe and Temperate Zone Meadow. Excellent native breeds are Wuzhumuqin Cattle, Kazakh Cattle and Sanhe Cattle, all of them are meat and milk dual breeds.
- Central Plains Cattle are mainly in the flat agricultural tracts of the Temperate Zone Deciduous Broad-leaf Forest and are mainly stall fed with some grazing. There are many excellent native breeds such as Qinchuan Cattle, Nanyang Cattle, Luxi Cattle, Bohai Black Cattle etc. These native breeds are famous draught animals and their raising depends, historically, on lucerne cultivation.
- South China Cattle are in the hilly tropical subtropical zones, such as Hainan Cattle, Guangxi Cattle and Yunnan Cattle, etc.

Yak (Bos grunniens)

Yak, regarded as the "ship of the plateau", lives on anoxic plateaux at 3 000 to 5 000 m and are mainly kept on the Qinghai-Tibet Plateau. There are 15 000 000 yaks in China (Qinghai, Tibet, Sichuan, Gansu, Xinjiang and Yunnan), around 90% of the world total. It is believed that they were domesticated from the wild *Bos grunniens mutus*, which is still found in remote mountains of Tibet (Zhang Rongchang, 1989). The habitat of yak is limited to the mountains and plateaux of the Asian highlands, inter-connected chain areas of the Himalayas, Pamir, Kunlun, Tianshan and Altai Mountains and parts of Mongolia.

Yak are raised for draught and meat; milk, hide and hair are also important products (Hu Zizhi, 1997). As "green food" (from less polluted plateaux), yak meat is very popular in cities. Nomadism is the main raising style for yak and nomads have been herding yak them on the Qinghai-Tibetan Plateau for probably 4 000 years. Herders drive their yak from low valley (cold season pasture) to high mountains (warm season pasture).

Yaks in China can be classified into two groups; Plateau Type and Valley type and seven native strains or types.

- **Yaks of the Plateau Type** are mainly found in the centre of the Qinghai-Tibet Plateau which covers most of Qinghai Province, the Tibet Autonomous Region and parts of Sichuan and Gansu Provinces. The habitat of the Plateau Type is mountainous and difficult of access. There are many marshes, semi-marshes and hilly grasslands with broad valleys, open topography and gentle slopes. So yaks of the Plateau Type have a wide range of geographical types, hair-coat, high proportion of polled animals, and different horn shapes. The weather is cold, the annual average temperature is below 0 ^{0}C and annual precipitation less than 600 mm. The growing period is about 120 to 150 days. Because of differences of microclimate and level of feeding and grazing, the different breeds and populations of yaks show various body sizes. Milk and meat of yak are the staple food of local herdsmen. Generally, yaks of the Plateau Type are good milkers with high fat content milk.
- **Yaks of the Valley Type** are mainly found in the alpine region of the Hengduan Mountain range of the south-eastern Qinghai-Tibet Plateau, including the eastern part of Tibet, the southern part of Qinghai, the south-western part of Sichuan and north-eastern Yunnan. The altitude is 4 000 to 5 000 m. Annual precipitation is more than 600 mm and the climate is frigid and sub-humid. Grassland in this region is mainly alpine shrub meadow and the growing period is about 150 to 180 days. Yak of this type have big body size, good tolerance, strong constitution, high meat productivity and high yield of hair and undercoat. Both sexes have wide and rough horns. The seven native strains are Jiulong Yak (big body size with male liveweight of 470 kg), Maiwa Yak (413 kg of male liveweight, good at loading), Tianzhu White Yak (distributed in Gansu and small body size with male liveweight of 260 kg, its white hair is valuable for stage property and its tail is also important for religious uses), Qinghai Alpine Yak (the most numerous, male liveweight is 440 kg), Tibetan Mountain Yak (found in Tibet and the male liveweight is 290 kg), Xinjiang Bazhou Yak (found in Xinjiang and the male liveweight is 360 kg) and Zhongdian Yak (found in Yunnan with male liveweight of 230 kg).

Buffalo (Bubalus bubalis)

Buffalos are of the swamp type and kept in the humid tropical and subtropical areas. There are three types and 18 subtypes. Buffalo are stall-fed and mainly kept for draught and meat. The milk and hide are also important products (Editorial Board of Cattle Breeds of China, 1998).

Sheep (Ovis aries) (Editorial Board of Sheep Breeds of China, 1989)

Sheep, the major grazing livestock in China, are kept in temperate areas within N 30º to 50º and E 75º to 135º. There are four lineages (Mongolia, Kazakh, Tibetan and Central) with many excellent breeds. Inner Mongolia Fine Wool Sheep, Aohan Fine Wool Sheep and Northeast Fine Wool Sheep are excellent breeds bred with the Mongolian Sheep as female parent.

Kazakh Sheep is an ancient coarse wool breed in the desert areas of Xinjiang, it was used as the female parent of Xinjiang Fine Wool Sheep. Xinjiang Fine Wool Sheep has strong adaptability and has been successfully introduced into many places.

Tibetan Sheep is an ancient breed which can adapt to extreme alpine climates, but can not adapt to warm areas. Gansu Alpine Fine Wool Sheep and Qinghai Fine Wool Sheep are excellent breeds bred with Tibet Sheep as female parent.

Central Plains Sheep are kept in warm temperate and subtropical areas under semi stall feeding; they have some special features. For example, Hu Sheep can live under subtropical humid conditions and is the southernmost sheep breed. Xiaoweihanyang Sheep and Hu Sheep are very prolific, each lambing could give 2 to 6 young (artificial feeding always needed). Daweihanyang Sheep have an exceptionally fat tail.

Tan Sheep famous for their fur with long curled hair, are raised in desert and semi-desert areas.

Goat (Capra hircus)

Goats are the most widely distributed livestock in China, since they can adapt to many climates and pastures. There are 35 breeds. The most special breed is Zhongwei Goat; its fur is like the famous "Tan Sheep". The Tibetan Turi Goat is famous for its cashmere. Since 1999, the Government has requested farmers to switch goat management pattern from grazing to stall feeding. This is for recovering the ecological condition of grassland.

Horse (Equus caballus)

Horses are the ancient draught animals of China in areas below 4 000 m. There are four major ecological-geographic groups (North Grassland Horse, Xinjiang Mountain Grassland Horse, Qinghai-Tibet Plateau Horse and Southwest Mountain Horse) and 70 breeds. In pastoral areas, horses are used for riding and grazed on natural grassland. Herders in Inner Mongolia and Xinjiang also drink mares' milk. In agricultural areas horse are pack and draught animals, mainly for ploughing, and are kept in stables or even the farmers' yard. Normally Chinese do not eat horsemeat. The special breeds are Haomeng Horse (natural ambler), Chinese Mini Debao Pony, Erlunchun Forest Horse, anoxic tolerant Tibetan Horse and Yunnan Horse (adapted to stony mountain terrain).

Camel (Camelus bactrianus)

Camels are important in temperate deserts. There are some single humped camels in south Xinjiang but the great majority are two-humped Bactrian camels. There are three breeds in China, Xinjiang Camel, Alashan Camel and Sunite Camel, the latter lives in the steppe and its body size is the largest since the forage is better. The major purpose of camel raising is as pack animals and for wool. Camel are raised on natural grassland with supplementation in winter.

Pigs (Sus scrofa domestica)

There are breeds of 60 pigs in China, most are stall-fed. The Tibetan Pig is a grazing breed, usually grazing on natural grassland as a mixed flock of 60 to 80 heads (adult and young, male and female are

all mixed). It grows slowly because of poor forage; its adult liveweight is around 35 kg. However, its meat is very lean and is superior material for preserved pork and roast suckling pig. Xinjiang Yili White Pig is another grazing breed, but its numbers are quite small. It grazes on grassland along rivers or in woodland, but is kept in sheds during winter with supplementation.

Animal units

For convenience of management, an Animal Unit is defined, based on the grazing pressure on grassland or grass consumption of certain specific animal, as the standard so other animals can be converted into Animal Units by comparing the same items. The Animal Unit is also called "Animal Equivalent" or "Animal Index". Sheep is used as the standard unit in China; a Sheep Unit is defined as a ewe of 40-kg liveweight and its nursing lamb(s) and the daily forage consumption is 5 to 7.5 kg. The conversion coefficients of Sheep Unit to other grazing animals are given in Table 8.

Feeding systems

Extensive Grazing System: Feeding systems in the north and west differ because of the ecological conditions. Steppe is the dominant grassland type of Inner Mongolia where the pasture is flat and the environment is simple. Land can be grazed at any season so long as water is available; there are no seasonal restrictions to grazing. Animals are moved rotationally following a predetermined range and routine.

In Xinjiang desert areas, there are two seasonal grazing belts: basins and mountains. Animals graze in the basins in winter, move in transhumance to the mountains in spring and to the high mountains in summer, returning to the basins in late autumn. It is a strict seasonal grazing system and animals spend 1 to 2 months travelling from winter to summer pasture. This system is adopted commonly in Central Asia.

In the Qinghai-Tibet Plateau, although animals graze where the elevation is above 3 000 m, grassland is still divided into two grazing seasonal belts: lower cold season pasture and higher warm season pasture. Summer pasture can be used for only 1 to 2 months. This system composed of frigid alpine grassland and resistance to anoxia makes Tibetan livestock unique. Now, this system has switched to one in which animals are supplemented in winter.

Tethered System: Animals are tethered so they are strictly controlled and the grass can be completely utilized. It is used for saddle horses and high yielding milk cows in pastoral areas and for small pieces of grassland in crop areas.

Uncontrolled Grazing: Pasture use is not planned and animals are herded from place to place over a large area. This system existed when the grazing rights were not defined and the grassland was sufficient. After the Long-term Grassland Use Contract System was completed, this system has been gradually replaced by rotational grazing and only exists in remote summer pastures or open pasture. However, some researchers consider that the fact that nomads still follow this system is proof of the rationality and efficacy of many aspects of traditional pastoral production as a means to convert forage from cold, arid rangelands into valuable animal products in an environment where cultivated agriculture is not possible. The survival of pastoral nomads indicates that many of the strategies of animal husbandry and grassland management developed centuries ago are well-adapted responses to the spectrum of environment conditions (Miller and Craig, 1996).

Table 8 Stock units

Species	Description	Stock unit
Sheep	Breeding ewe and its nursing lamb	1
	Adult ram	1
	One-year old lamb hogg	0.5
Goat	Breeding doe and its nursing kid	0.9
	Adult buck	0.9
	One-year old goat hogg	0.4
Pigs	Mixed herd on average	0.8
Cattle	Adult cow	5
	Draught bull, medium working strength	5
	Fattened beef cattle	5
	6 to 12 month old cattle	2.5
	12 to 18 month old cattle	3.5
	18 to 24 month old cattle	4.5
Yak	Mixed herd on average	3
	Breeding yak cow and its nursing calf	4
Horse or mule	Adult horse or mule, medium strength	5
	Breeding mare and its nursing foal	5
	1 year old horse or mule	2.5
	2 year old horse or mule	3.5
	3 year old horse or mule	4.5
Camel:	Adult camel	7

Integration of livestock into farming systems

In the two past decades, developing animal husbandry through integrating livestock into farming systems has been successfully introduced with the development of science and technology, improvement of production and management levels and increasing shortage of natural grassland. The approach for integrating livestock into the farming system is as follows. Since agricultural holdings are small grazed sown pasture is not practicable so stall feeding with cut and carry is usual for ruminants combining crop residues, wild herbage and cultivated fodder.

Growing Grass and Fodder for Livestock: Since 1983, the central government has encouraged farmers to grow fodder and raise livestock. Agricultural experts and extension services are extending the "three components growing" model (cereals, cash crops and forage crops grown in rotation). Both farming structure and production efficiency were improved under this model. Practices vary according to region.

1. In pastoral areas, government encourages and assists farmers to establish some artificial grassland for hay.
2. In northern warm temperate agricultural areas, farmers are encouraged to use some of, or even all, arable land to grow high quality forages such as lucerne, or to grow *Vicia sativa* after wheat harvest for high quality hay and then to raise pigs and poultry.
3. In southern subtropical paddy areas, farmers use the fallow paddy field to grow *Lolium multiflorum* for pigs, dairy cows and rabbits. This is a rotation of rice and ryegrass. Annual ryegrass is sown in November and cut once every 10 days from November to next March (in total 8 to 10 times). The yield of fresh grass is 60 to 70 tonnes per ha and its content of crude protein is 20 to 26%. This farming system is called "Rice-Annual Ryegrass System" and is greatly supported by government. It has been extended to more than 2 000 000 ha in southern subtropical paddy areas

Develop Beef Production with Maize Silage: In the Central Plains (including Henan, Hebei, Shandong and Anhui Provinces), maize stover was used as fuel or thrown away. Since the mid nineteen-eighties, maize silage technology has been the subject of an extension campaign. With help from the Livestock Technique Extension Service, farmers can easily get beef cattle through artificial insemination using imported frozen semen. Farmers feed beef cattle with maize silage supplemented with some concentrates. This is a high profile initiative. The central government, starting in 1992, established demonstration counties at national level for cattle fattening using maize stover; their number was increased to 268 and the number of local demonstration counties became 187 (including counties for sheep raising with ammoniated straw). At present, there are many large-scale beef cattle farms in this area. The Central Plains is now the most important beef production base and produces around 50% of national beef output. This trend is advancing rapidly for cereals are relatively abundant and the demand for beef is rising.

Sheep Production with Ammoniated Straw: In northern agricultural areas, wheat straw was used as fodder for draught animals. However, more and more farmers use machines instead of draught animals and a huge amount of straw was not used. Farmers burnt it in the field which threatened the environment. In the last decade, ammoniated straw technology was extended to increase the nitrogen content in straw, improve palatability and feeding value. Animal production in this area was greatly improved. This technology can also reduce environmental pollution. From 1995 the central government started to establish demonstration counties at national level and it strongly promotes roughage utilization and animal production. Sheep are given ammoniated wheat straw and supplemented with concentrates so that the wheat straw is fully used.

Socio-economic conditions

Legislation: Since the open door and reform policy in 1979, law creation in the animal husbandry sector has made great strides. It began with the "Byelaw of Livestock and Poultry Epidemic Prevention" in 1985 and 13 laws relating to grassland and animal production have been passed up to now, including the "Law of Grassland", "Law of Animal Epidemic Prevention", "Byelaw of Animal Remedy Management", "Byelaw of Breeding Animal and Poultry", "Law of Quarantine Inspection of Imported and Exported Plants and Animals" and "Byelaw of Fodder and Fodder Additive Management". At the same time,

over 100 detailed rules and regulations have been made and local government made local regulations accordingly. Usually the local Grassland Station or Animal Production Station is the law enforcer.

Social Services: As mentioned above, China has a complete animal husbandry technical extension network (including grassland technical services). The network has four levels: National, Provincial, Prefecture and County. There are more than 50 000 services in the country and more than 400 000 staff are employed. Additionally, around 500 000 village extension workers are involved in this network. Some extension workers at grass roots level were lost around 1990 since the fund was reduced. In 1998, 46 249 Animal Husbandry and Veterinary Medicine Stations (or Grassland Stations) at township level were determined as government-sponsored institutions, and out of them, 30 989 stations are totally sponsored, occupying 67% of the total. 295 407 staff are employed by these institutions (China Agricultural Yearbook Editorial Committee, 2000). This network provides strong backing for animal production.

Market Constraints: Animal products had a seller's market before the 1990s and supply was insufficient. Thereafter, animal production was dramatically promoted and farmers have to face furious competition in a buyer's market. So as to make market mechanisms more active and favour animal production, government strengthens the information exchange between producers and consumers. Government also set-up the "Milk Plan for Students" and "Breakfast Revolution" to enhance milk consumption. To improve fine wool production, a Society of Fine Wool Producers has been set-up in Xinjiang Uigur Autonomous Region. Meanwhile, show, sale and auction of breeding sheep and wool was held in Inner Mongolia Autonomous Region. These two regions produce most of the sheep wool in China.

5. THE PASTURE RESOURCE

Grassland is defined, in China, as land mainly covered by herbaceous vegetation, or with sparse shrubs or trees concurrently present in the community. It can provide food for livestock and wildlife; it is also a kind of land-organism resource that can provide a graceful environment, organic products and other functions for the human population (Hu Zizhi, 1997). Land sown to grazeable forages is defined as artificial grassland.

Area and distribution of grassland

China is one of the countries with the most plentiful grassland resources in the world. The total area (see Table 9) is 392 832 633 ha (1994), which accounts for 11.82% of the world's grassland - and takes third place after Australia and Russia. The area of usable grassland is 330 995 458 ha (excluding Hongkong, Macao and Taiwan); 34.49% of the national land area. Most of China's grassland is in the northern arid and cold areas. For grassland area and number of livestock the six major pastoral areas are, Tibet, Inner Mongolia, Xinjiang, Qinghai, Sichuan and Gansu. The grassland of these regions accounts for 74.68% of the national total and the grazing herbivorous livestock accounts for around 70% (see Table 10).

[References: Animal Husbandry and Veterinary Medicine Division of Agriculture Ministry of China, 1994, 1996; China Resource Information Editorial Committee, 2000)

Grassland classification

Because of the huge territory, complex terrain, diverse climate and long history of grassland utilization, there are many grassland types in China and this led to in-depth research on grassland classification. Currently, there are two systems of grassland classification with more than 40 years' research behind them.

The Vegetation-habitat Classification System This was created by Prof. Liao Guofan, Prof. Su Daxue, Prof. Xu Peng, Prof. Liu Qi, and Prof. Zhang Zutong. It is a compendious and non-numerical system based on the subjective judgement of the surveyor. It was used for the national survey of grassland

resources from 1980 to 1990 (Rangeland Resources of China, 1996). Most of the data cited in this document are from that investigation. The system has four grades.

- First grade: Class, grassland is classified into 9 Classes based on thermal and vegetation features (see Table 13).
- Second grade: Subclass, is the further division after Class based on the features of climate or vegetation. Some Classes, such as marshes, are not further divided (see Table 13).
- Third grade: Group, is divided according to the economic groups of grasses based on the grassland Type, for example, Tall Herbaceous Group, Medium Herbaceous Group, Short Herbaceous Group.
- Fourth grade: Type, it is the basic unit and divided according to the features of the dominant species in community and habitat. Types are named with the name of the dominant species. Grassland in China is divided into 276 Types.

The Comprehensive and Sequential Classification System (see Figure 13) This was created by Prof. Ren Jizhou, Prof. Hu Zizhi, Prof. Zhang Degang, Prof. Long Ruijun and Dr. Gao Caixia, etc. Its features are:

- the basic unit, Class, is divided through humidity grade and thermal grade. This method enables quantitative classification and computer retrieval;
- the Classification index chart can visually indicate the different classes, sort order of classes, the grassland development relation and zonal features among classes;
- it can be used for grassland classification all over the world within a unified system.

There are four grades in this system.

- First grade: Class Group, after the Class is determined the Classes can be merged into Class Groups according to cumulative temperature or humidity.
- Second grade: Class, is divided in terms of thermal and moisture conditions. Thermal grade is determined with >0 ºC accumulative temperature (see Table 11). Humidity grade is determined with humidity (see Table 12). Class is named with thermal grade, humidity grade and representative zonal vegetation climax consecutively.

Table 9. Grassland area in China

Province	Total grassland area		Usable grassland area		
	Area (ha)	% of total land	Area (ha)	%	Per capita (ha)
Beijing	394 846	24.07	336 310	0.10	0.03
Tianjin	146 604	12.97	135 402	0.04	0.02
Hebei	4 712 140	25.06	4 085 324	1.23	0.06
Shanxi	4 552 000	29.03	4 552 000	1.38	0.15
Inner Mongolia	78 804 480	68.81	63 592 092	19.21	2.84
Liaoning	3 388 848	23.23	3 239 293	0.98	0.08
Jilin	5 842 182	30.60	4 378 993	1.32	0.17
Heilongjiang	7 531 767	16.57	6 081 653	1.96	0.17
Shanghai	73 333	11.64	37 333	0.0002	0.0029
Jiangsu	412 700	4.08	325 673	0.10	0.0049
Zhejiang	3 169 853	30.57	2 075 176	0.63	0.05
Anhui	1 663 179	11.89	1 485 176	0.45	0.02
Fujian	2 047 957	16.54	1 957 060	0.59	0.06
Jiangxi	4 442 334	26.58	3 847 562	1.16	0.09
Shandong	1 637 974	10.45	1 329 157	0.04	0.02
Henan	4 433 788	26.76	4 043 253	1.22	0.04
Hubei	6 352 215	34.23	5 071 537	1.53	0.09
Hunan	6 372 668	30.07	5 666 309	1.71	0.09
Guangdong	3 266 241	18.34	2 677 239	0.81	0.04
Guangxi	8 698 342	36.75	6 500 346	1.84	0.14
Hainan	949 773	27.93	843 273	0.25	0.12
Sichuan	20 964 932	42.16	18 230 281	5.51	0.22
Chongqing	1 537 844	24.07	1 390 021	0.41	0.05
Guizhou	4 287 257	24.40	3 759 735	1.14	0.11
Yunnan	15 308 433	40.11	11 925 587	3.61	0.31
Xizang (Tibet)	82 051 942	68.10	70 846 781	21.41	30.1
Shaanxi	5 206 183	25.32	4 349 218	1.31	0.13
Gansu	17 904 206	42.07	16 071 608	4.86	0.67
Qinghai	36 369 746	51.36	31 530 670	9.53	6.91
Ningxia	3 014 067	58.19	2 625 556	0.80	0.51
Xinjiang	57 258 767	34.68	48 006 840	14.51	2.93
China	392 832 633*	41.41**	330 995 458	100.00	0.28

** Hongkong and Taiwan are not included. **%age of grassland to total inland area. Source: China Resource Information Editorial Committee (2000)*

Table 10. Grassland area in different economic zones (ha)

Zone	Grassland area	%	Provinces covered
Pastoral	193 158 693	49.17	Inner Mongolia, Jilin, Heilongjiang, Xinjiang, Sichuan, Xizang (Tibet), Gansu, Qinghai, Ningxia
Agro-pastoral	58 525 674	14.90	Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Sichuan, Xizang (Tibet), Gansu, Qinghai, Yunnan, Xinjiang
Agricultural	141 148 266	35.93	All provinces
Total	392 832 633	100.00	

Source: Animal Husbandry and Veterinary Medicine Division of Agriculture Ministry of China, 1994

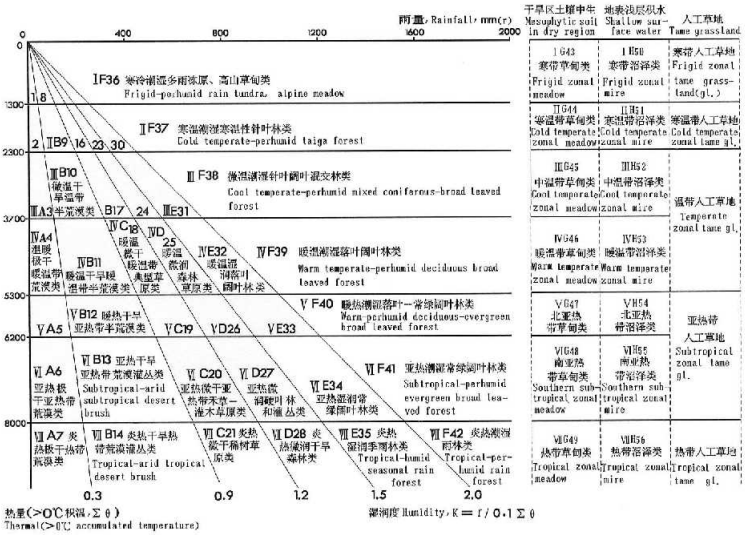


Figure 13. Index Chart of Class of Comprehensive and Sequential Classification System

- Third grade: Subclass, is divided according to land condition, including soil and terrain. Soil type is used in flat area and terrain type in hilly area. Subclass is named with the name of soil or terrain.
- Fourth grade: Type, is divided and named with the dominant species in the plant community.

Grassland types and area

According to the Vegetation-habitat Classification System, grassland in China can be divided into nine classes and 276 types. The names of classes and subclasses and their areas are shown in Table 13. There are 69 types in Temperate Steppe Class, 39 types in Temperate Desert Class, 25 types in Warm Shrubby Tussock Class, 39 types in Tropical Shrubby Tussock Class, 51 types in Temperate Meadow Class, 24 types in Alpine Meadow Class, 17 types in

Table 11. Thermal grades and their thermal zones

Thermal grade	Accumulated temperature>0 ºC	Thermal zone
Frigid	< 1 300 ºC	(Alpine) Frigid Zone
Cold Temperate	1 300 to 2 300 ºC	Cold Temperate Zone
Cool Temperate	2 300 to 3 700 ºC	Cool Temperate Zone
Warm Temperate	3 700 to 5 300 ºC	Warm Temperate Zone
Warm	5 300 to 6 200 ºC	North Subtropics
Subtropical	6 200 to 8 000 ºC	South Subtropics
Tropical	> 8 000 ºC	Tropics

Table 12. Precipitation grades and their associated natural landscapes

Humidity grade	K value	Suitable natural landscape
Hyper arid	<0.3	Desert
Arid	0.3 to 0.9	Semi desert (Desert steppe, Steppe desert)
Semi-arid	0.9 to 1.2	Typical Steppe, Xerophytic Forest, Savanna
Subhumid	1.2 to 1.5	Forest, Forest Steppe, Meadow Steppe, Savanna, Meadow
Humid	1.5 to 2.0	Forest, Tundra, Meadow
Per-humid	>2.0	Forest, Tundra, Meadow

Note: K= r/(0.1 sum theta) where K is humidity, r is annual rainfall (mm), sum theta is >0 ºC annual accumulative temperature.

Table 13. Area of different grassland classes

Grassland class and subclass	Total grassland area		Usable grassland area		Rank*
	Area (ha)	%	Area (ha)	%	
Temperate Steppe Class	74 537 509	18.98	66 247 465	20.01	1
Temperate Meadow-steppe	14 519 331	3.7	12 827 411		[8]
Temperate Typical Steppe	41 096 571	10.46	36 367 633		[1]
Temperate Desert-steppe	18 921 607	4.82	1 705 421		[5]
Temperate Desert Class	55 734 229	14.19	39 745 057	12.00	4
Temperate Typical Desert	45 060 811	11.47	30 604 131		[3]
Temperate Desert Steppe	10 673 418	2.72	9 140 926		[11]
Warm Shrubby Tussock Class	18 273 058	4.65	15 627 185	4.72	7
Warm Tussock	6 657 148	1.69	5 853 667		[14]
Warm Typical Tussock	11 615 910	2.96	9 773 518		[10]
Tropical Shrubby Tussock Class	32 651 615	8.31	25 506 997	7.71	6
Tropical Tussock	14 237 196	3.62	1 141 999		[9]
Tropical Typical Shrub Tussock	17 551 276	4.47	13 447 569		[7]
Tropical Savanna	863 144	0.22	639 429		[15]
Temperate Meadow Class	41 900 414	10.68	35 942 515	10.87	5
Lowland Meadow	25 219 621	6.42	21 038 409		[4]
Mountain Meadow	16 718 926	4.26	14 923 439		[6]
Alpine Meadow Class	63 720 549	16.22	58 834 182	17.75	2
Alpine Steppe Class	58 054 911	14.77	149 202 826	14.87	3
Alpine Meadow-steppe	6 865 734	1.75	6 011 528		[13]
Alpine Typical Steppe	41 623 171	10.59	35 439 220		[2]
Alpine Desert Steppe	9 566 006	2.43	7 752 078		[12]
Alpine Desert Class	7 527 763	1.92	5 592 765	1.69	8
Marsh Class	2 873 812	0.73	2 253 714	0.68	9
Total	392 832 633	100.00	330 995 458	100.00	

** Numbers in brackets mean rank of subclass*
Source: China Resource Information Editorial Committee (2000)

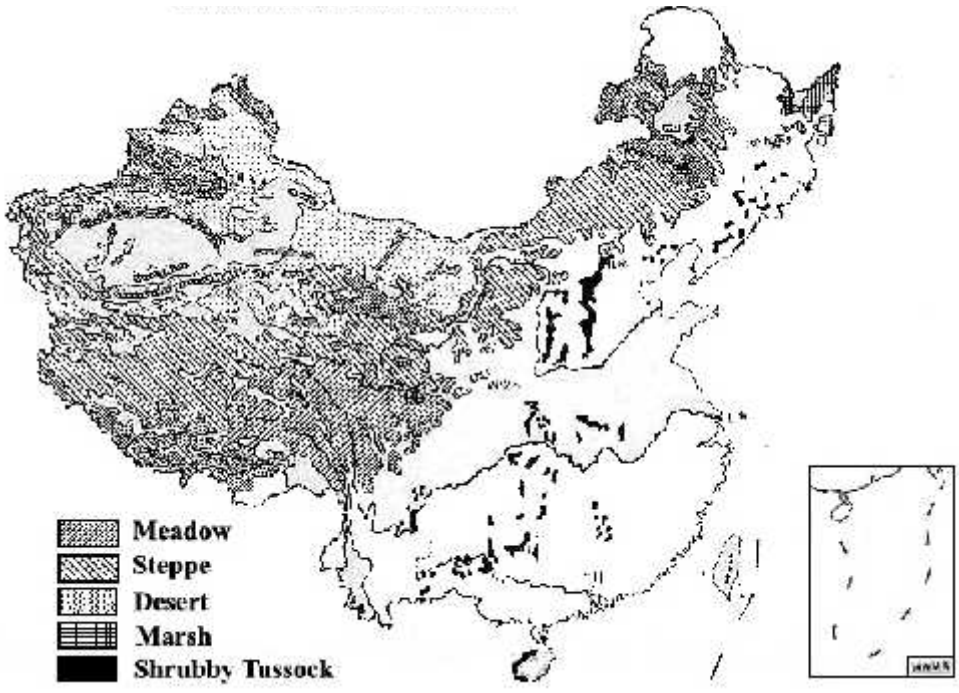


Figure 14. Grassland distribution and classes

Alpine Steppe Class, 4 types in Alpine Desert Class and 8 types in the Marshes Class. See Figure 14 for broad grassland distribution and Figure 15 for photographs of some grassland types.

Grassland productivity

Because grassland is used for livestock production, its productivity may be measured by three indexes:

15a) Alpine steppe type, Tibet

15b) Alpine desert type, Tibet

15c) Temperate steppe type, Inner Mongolia

15d) Alpine meadow steppe type, Quinghai

15e) Temperate meadow steppe type, Inner Mongolia

15f) Temperate desert steppe type, Quinghai

Figure 15. Landscape (photographs) of different grassland classes

1. dry herbage yield, indicates the essential productivity of grassland;
2. carrying capacity, indicates the intermediate productivity of grassland;
3. animal product units, indicates the end productivity of grassland.

Index of Grass Yield Herbage yield varies greatly among different classes and types since most grassland is in arid and alpine areas with low productivity. The dry grass yield is 911 kg/ha on average, the highest is 2 544 kg/ha from Tropical Shrubby Tussock Class and the

Table 14. Dry herbage yield of different grassland classes

Grassland class	Yield (kg/ha)	Rank	Total yield (kg)	% of total
Temperate Steppe Class	888.9	5	5 888x107	19.55
Alpine Steppe Class	272.5	8	1 006x107	4.45
Temperate Desert Class	360.3	7	1 432x107	4.75
Alpine Desert Class	117.0	9	65x107	0.22
Warm Shrubby Tussock Class	1 740	3	2 718x107	9.02
Tropical Shrubby Tussock Class	2 544	1	6 490x107	21.56
Temperate Meadow Class	1 697	4	6 090x107	20.26
Alpine Meadow Class	882	6	5 189x107	17.24
Marshes Class	2 183	2	492x107	1.63
National Average	911		3 009x107	100.00

Source: China Resource Information Editorial Committee (2000)

lowest is 117 kg/ha from Alpine Desert Class (see Table 14).

Carrying Capacity Index Carrying capacity is the number of animals and the time of grazing that a specified class can support per unit, it can be expressed in animal units, time units or grassland units. The theoretical carrying capacity of the national total grassland is 448 920 000 sheep units (the sheep unit is defined as one 40-kg ewe with lamb, the daily intake is 5 to 7.5 kg of fresh grass); a sheep unit needs 0.93 ha of grassland. The carrying capacity of Tropical Shrubby Tussock Class is the highest with 0.33 ha per sheep unit per year and Alpine Desert Class is the lowest with 9.27 ha, which is around 10 times the average (see Tables 15 and 16).

Animal product unit index

An animal product unit (APU) is defined as the output of standard animal product unit per unit grassland area in a specified time. All animal products from grassland should be converted into standard animal product units (Ren Jizhou *et al*., 1985 and Hu Zizhi, 1979).

One APU equals 1 kg of liveweight of grazing beef cattle with medium nutrition condition; it contains approximately 26.5 MJ of digestible energy or 22.5 MJ of metabolisable energy or 13.9 MJ of net energy for liveweight gain. The following rules should be followed when converting animal products into APU:

1. liveweight is carcass of cattle and sheep with medium fatness;
2. milk is standard milk with 4% fat and 8.9% solid-not-fat matter;
3. wool is scoured wool;
4. draught animal is an adult of medium body weight;
5. work output of draught animal is low-grade;
6. hides should meet common processing requirements;
7. lamb-wool should meet common requirements.

The norms used for converting animal products into APU are based on comparing energy requirement with

Table 15. Carrying capacity of natural grassland in different regions

Province	Carrying capacity (ha/sheep unit/year)	Theoretical carrying capacity (sheep unit)	%age of total carrying capacity	Rank
Beijing	0.66	510 304	0.11	28
Tianjin	0.28	489 657	0.11	29
Hebei	0.35	11 738 689	2.61	13
Shanxi	0.41	10 991 092	2.45	17
Inner Mongolia	1.44	44 201 516	9.85	2
Liaoning	0.61	5 324 729	1.19	24
Jilin	0.39	11 106 669	2.47	15
Heilongjiang	0.32	19 263 730	4.29	9
Shanghai	0.29	130 945	0.03	30
Jiangsu	0.35	918 290	0.20	27
Zhejiang	0.26	7 937 405	1.77	23
Anhui	0.18	8 172 337	1.82	21
Fujian	0.23	8 520 105	1.90	20
Jiangxi	0.32	11 972 715	2.67	12
Shandong	0.50	2 639 334	0.59	26
Henan	0.45	8 976 660	2.00	19
Hubei	0.28	18 061 219	4.02	10
Hunan	0.24	23 233 666	5.18	8
Guangdong	0.15	18 066 020	4.02	11
Guangxi	0.25	25 719 535	5.73	7
Hainan	0.22	3 901 690	0.87	25
Sichuan	0.39	46 351 755	10.33	1
Chongqing	0.19	7 999 175	1.78	22
Guizhou	0.32	11 734 636	2.61	14
Yunnan	0.38	31 080 500	6.92	4
Xizang (Tibet)	2.63	27 082 473	6.03	6
Shaanxi	0.48	9 029 582	2.01	18
Gansu	1.46	11 040 546	2.46	16
Qinghai	1.09	29 003 611	6.46	5
Ningxia	1.78	1 471 186	0.33	27
Xinjiang	1.49	32 248 600	7.18	3
China	0.74	448 915 416	100.00	

Source: Animal Husbandry and Veterinary Medicine Division of Agriculture Ministry of China (1994)

Table 16 Carrying capacity of different grassland classes

Grassland class	Carrying capacity (ha/ sheep unit/ year)	Theoretical carrying capacity (million sheep unit)	% of total	Rank
Temperate Steppe	1.42	46.734	14.6	4
Alpine Steppe	3.73	13.259	4.1	6
Temperate Desert	3.67	10.016	3.3	7
Alpine Desert	9.27	0.603	0.3	9
Warm Shrubby Tussock	0.45	34.682	10.8	5
Tropical Shrubby Tussock	0.33	77.401	24.2	1
Temperate Meadow	0.51	70.350	22.0	2
Alpine Meadow	0.98	60.132	18.8	3
Marsh Class	0.39	5.730	1.8	8
Total	0.93	318.907*	100.0	

** 13 000 000 sheep units on fragmentary grassland are not included.*
Source: Animal Husbandry and Veterinary Medicine Division of Agriculture Ministry of China (1994)

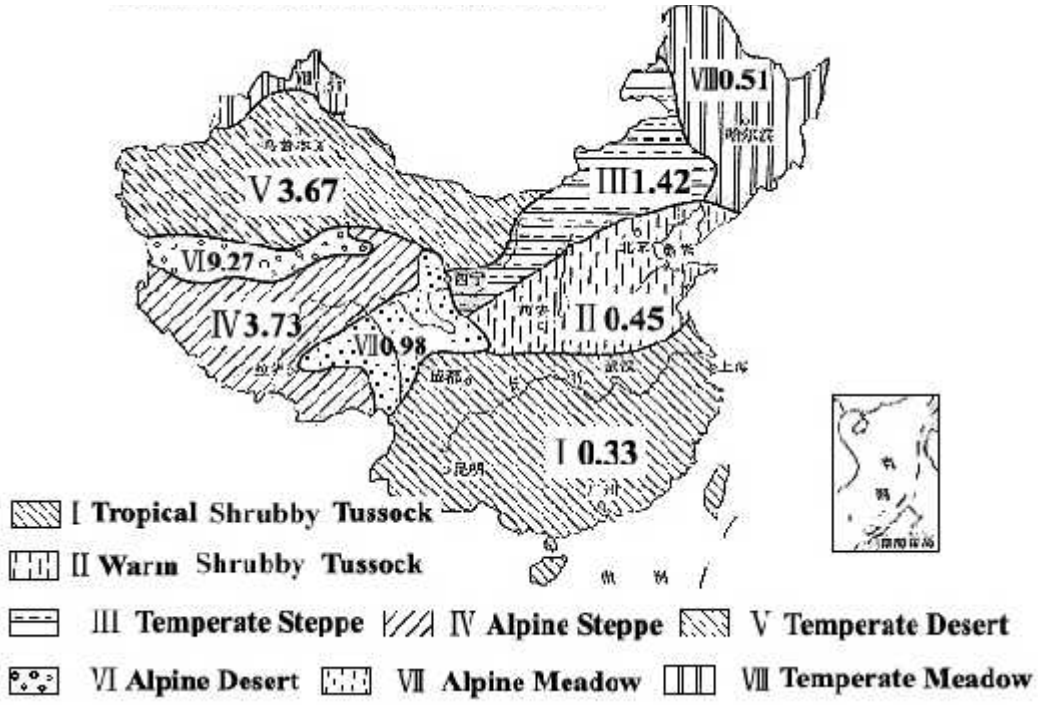


Figure 16. Carrying capacity pattern chart of different grassland classes

APU. For convenience, the conversion rates for different animal products are shown in Table 18. These rates are determined according to the proportion of different parts of slaughtered beef cattle or mutton sheep of at least medium size (Table 17).

Table 17. Proportion of parts of cattle or sheep of at least medium fatness

	Cattle	Sheep
Number	79	105
Average liveweight	276	50
Carcase %	50	45
Head and feet %	7	8
Intestines %	13	15
Blood %	4	4
Hide %	7	9
Gut contents %	10	19

This can truly show the amount of animal products which a unit of grassland could provide for humans in a specified period when APU is used to evaluate grassland productivity. Moreover, it avoids the inaccuracy caused by carrying capacity and it is convenient to compare grassland productivity among different regions or countries. According to the statistics, the average grassland productivity of China is 7.02 APUs per ha, which is 7.02 kg carcass or 0.45 kg net wool or 70.2 kg milk if converted into sole animal product. This productivity is very low compared with developed countries.

Grassland protection

There are many factors which can ruin grass growth and grassland ecology. Apart from over-grazing, these include grassland rodents, pests, diseases, toxic plants, harmful plants and fire. Of these rodents and pests are most important. The area of grassland destroyed by rodents ranges from 1 700 000 to 2 000 000 ha (see Table 19) and pests damage 6 500 000 to 7 500 000 annually. The economic loss caused by rodents and pests is 1 300 000 to 1 400 000 RMB Yuan (equivalent to 160 to 170 million US dollars). In some areas, farmers have to move to other places or even become ecological refugees because the grassland has been totally destroyed by rodents and no forage remains.

China has set up a remote sensing grassland disaster monitoring system for grassland (mainly for fire and snow). This system can estimate the area of snow-covered grassland and depth of snow.

Grassland rodents

Species of harmful grassland rodents. There are more than 80 species distributed in different grassland types.

Temperate Steppe: *Microtus arvajis*, *M. brandtii*, *M. gregalis*, *Myospalax aspalax*, *M. fontanieri*, *M. psiluris*, *Allactaga sibirica*, *Lepus capensis*, *L. mandschurica*, *Ochotona daurica*, *Citellus daurica*, *Marmota sibirica*, *Cricelulus barobensis*, *Meriones unguiculatus*, and *M. meridiaus*

Temperate Desert: *Lepus yarkandensis*, *Ochotona pallasi*, *Citellus dauricus*, *Citellus erythrogenys*, *Citellus Pygmaeus*, *Rhombomys opimus*, *Meriones unguiculatus*, *M. meridianus*, *Lagurus sagitta*, and *Stylodpus telum*

Alpine Grassland: *Lepus oiostolus*, *Ochotona curzoniae*, *O. Tibetana*, *O. Thomasii*, *O. cansus*, *Marmota himalayana*, *Pitymys irene*, *P. lencurus*, *P. oeconomus*, *Myospalax fontanieri*, and *Allactaga sibirica*

Table 18. APU Conversion rates for different animal products

Animal products	Conversion rate (APU)
1 kg liveweight of beef cattle	1.0
1 carcass of a 50 kg sheep	22.5 (45% dressing%)
1 carcass of a 280 kg cattle	140.0 (50% dressing%)
1 kg edible intestines	1.0
1 kg standard milk	0.1
1 kg net wool	13.0
1 three year old draught horse	500.0
1 three year old draught cattle	400.0
1 four year old draught camel	750.0
1 three year old draught donkey	200.0
1 year work of a draught horse	200.0
1 year work of a draught cattle	160.0
1 year work of a draught camel	300.0
1 year work of a draught donkey	80.0
1 cow hide	13.0
1 lamb skin	15.0
1 cow hide	20.0 (or 7% of liveweight)
1 horse hide	15.0 (or 5% of liveweight)
1 sheep skin	4.5 (or 9% of liveweight)
1 sheep (medium fat or more, 50 kg liveweight)	34.5 (or 69% of liveweight)
1 ox (medium fat or more, 280 kg liveweight)	196.0 (or 70% of liveweight)

Measures for rodent control. The guidelines for rodent control in China are "To make a full-scale plan and focus on the key regions, to strengthen the monitoring and comprehensively control in safe and efficient ways". The measures are as follows:

(1) **Trapping.** This involves catching rodents manually with simple tools. It is safe for people and animals and the skin and bone of captured rodents could be utilized, but it is time and labour costly and cannot be carried out on a large scale at the same time.

(2) **Poisoning.** This is a simple, easy and efficient method to kill rodents and can be done on a large scale at the same time. But it is costly and causes environmental pollution. Attention must be paid to safety of people and animals when toxic chemicals are used.

(3) **Biological measures**
- **Attracting eagles**: Set up wooden or cement poles on the grassland at intervals of 500 m as perches and attract eagles. This method has been used in China since the 1980s.
- **Biotoxins:** Botulinal toxin produced by microorganism metabolite has been used on a large scale to control rodents since 1985. Biotoxin features are highly efficient, residue-free, no secondary nor environmental pollution and safe for people and animals.

Table 19. Area of rodents and pest damaged grassland and controlled areas in some provinces

Region	Damaged area by rodents (1,000 ha)		Damaged area by pests (1,000 ha)		Economic loss (million RMB Yuan)
	Damaged	Controlled	Damaged	Controlled	
Hebei	486.7	62.0	456.7	217.3	7 075.0
Inner Mongolia	5 036.0	1 173.3	2 926.3	382.7	4 8740.0
Liaoning	79.7	16.1	51.1	17.2	4 157.6
Jilin	573.3	347.3	173.3	166.7	440.0
Heilongjiang	213.3	54.7	420.0	90.0	5 700.0
Sichuan	2 692.0	200.0	220.0	33.3	20 000.0
Shaanxi	420.0	84.0	260.0	35.3	2 550.0
Gansu	2 198.7	162.0	566.4	41.3	16 590.0
Qinghai	6 807.2	1 524.3	948.0	146.2	29 089.4
Ningxia	200.0	46.7	166.7	6.7	990.0
Xinjiang	82.1	664.3	739.9	531.3	-
Total	18 789.0	4 334.7	6 928.4	1 668.0	135 332.0

Source: China Resource Information Editorial Committee (2000)

(4) **Ecological measures** The rodent population could be reduced dramatically by establishing perennial artificial grassland since forbs (favourite food of rodents) could be eliminated from the community. This is very efficient where the grassland is completely damaged and has become bare ground. *Ochotona curzoniae* and *Myospalax fontanieri* on the Qinghai-Tibet Plateau could be effectively controlled thus.

Insect pests

Many pest insects threaten natural grassland, such as locusts, meadow caterpillar, meadow moth, leaf beetle, long-horned grasshopper, and carabid beetle.

Locusts There are more than 50 species of locust on natural grassland, the important ones are *Locusta migratoria, Myrmeleotettix palpalis, Calliptamus italicus, Ghorthippus fallax, Comphocerus sibiricus sibiricus, Haplotropis brunneriana, Oedaleus infernalis, Epacromius coerulipes, Chorthippus dubius, Bryodema gebleri* etc.

Both chemical and biological techniques are used to control locust in practice.

(1) Chemical control. A suitable pesticide is applied by air when locusts occur on a large scale.
(2) Biological control.
   a. Chickens: Locusts can be predated by chicken that graze on grassland.
   b. *Sturnus* (starling): The distribution of *Sturnus* is closely related with locusts, they can be attracted by setting up artificial nests and a bird can eat 120 to 180 locusts daily.
   c. *Microsporidium* of locusts is a protozoon of the Sporozoa which parasitises locusts and causes the host insects to kill each other. This protozoon affects the offspring of the host. Microsporidia of locust can be commercially produced for large scale locust control.

Meadow Caterpillar. Meadow caterpillar, of Lymantriidae family of Lepidoptera, only exists on the Qinghai-Tibet Plateau. The major species are *Gynaephora alpherekii*, *G. qinghaiensis*, *G. aureata*, *G. ruoergensis*, *G. minora* etc. Their larvae eat a large amount of grass and also can cause disease in the mouths of livestock. Apart from pesticide, a sex attractant, a parasitical fly and a virus are used to control them.

Meadow Moth. Meadow moth (*Loxostege sticticatis*), exists both in temperate and alpine grassland and often causes severe damage. It is important to eliminate the eggs by weeding, inter-cultivation in artificial grassland and crop fields.

Meadow Leaf Beetle Meadow leaf beetle (*Geina invenusta*), is found in hilly grassland. The adult eats the growing points of plants and the larva feeds on new leaves and young stems. Pesticide is usually used to control this pest.

Diseases

As with rodents and pest insects, diseases are a major factor limiting the development of animal husbandry in China. It is estimated that the economic loss of grassland caused by disease is around 2 600 000 RMB Yuan per year (Nan Zhibiao, 2000). Because they have been long ignored, damage from plant diseases have increased considerably in recent years and now require major attention from farmers and researchers.

The study of grass diseases in China and their control is quite underdeveloped because study only began in the 1970s. Along with the increasing development of artificial grassland, grass pathological research has made some progress. 1 200 fungal diseases of forage grasses and 1 240 pathogens have been reported.

Toxic and harmful plants of grassland

Research on the poisonous and harmful plants of grassland started in 1950 and a full-scale survey was carried out in 1990. The survey indicates that toxic and harmful plants propagate in large amounts where the grassland is severely degraded. Therefore, the control of these noxious plants is an important part of any programmes for grassland improvement.

1) **Toxic Plants** There are 49 families, 152 genera and 731 species of toxic plants in the grasslands of China. The major families are Ranunculaceae (13 genus and 186 species), Leguminoseae (22 genus and 153 species), Gentianaceae (7 genus and 100 species), Euphorbiaceae (11 genus and 59 species), Papaveraceae (3 genus and 45 species), Compositeae (11 genus and 40 species), Solanaceae (7 genus and 22 species) and Ericaceae (4 genus and 12 species). The most harmful plants are *Oxytropis glabra*, *Oxytropis gansuensis*, *Astragalus variabilis*, *Euphorbia helioscopia, Euphorbia lunulata*, *Euphorbia hirta*, *Solanum nigrum, Solanum septemlobum*, *Stellera chamaejasme*, *Achnatherum inerbrians* etc.
2) **Harmful Plants.** Plants which could be distinctly harmful to livestock and animal products and can be sorted into three groups.
   – Spiny shrubs: The spine of shrubs might hurt animals or contaminate wool and cashmere.
   – Awned grasses: The awns of seeds might hurt the skin and mouth or even pierce skin and hurt the internal organs. The quality of wool may be affected by the awn.
   – Prickly forbs: Similar to awned grasses.

There are 64 species of harmful grassland plants in 13 families and 23 genera. It should be noticed that harm by these plants is seasonal and relative. So, many harmful plants need not be cleared, the alternative practice being to open the grassland (with harmful plants) to livestock at a suitable time.

Grassland Fire. Hundreds or even thousands of grassland fire disasters occur annually, the grassland burnt may be hundreds or several millions of hectares (see Table 20). The frequency of fire is much higher in drought years. Its seasonal pattern is very significant: in arid Inner Mongolia, fire normally occurs in winter and spring. In the semiarid northeast and north China, it usually occurs in spring and autumn. In south China, it occurs in winter and spring.

Table 20. Grassland fire disaster in some provinces

Region	Times of fire disaster			Burnt area (ha)
	Total	Very serious	Serious	
Hebei	45			515.9
Shanxi	21			1 170.7
Inner Mongolia	35	5	6	258 800.0
Liaoning	91			117.2
Jilin	12			3 657.0
Heilongjiang	41			174.6
Sichuan	12			1 940.0
Shaanxi	23			160.0
Gansu	49			1 545.0
Qinghai	14			616.8
Ningxia	2			0.1
Xinjiang	38	2		5 172.0
Total	383	7	6	273 869.3

Source: China Agricultural Yearbook Editorial Committee (2000)

Grassland nature reserves

The establishment of grassland nature reserves began in the nineteen-eighties and 11 have already been set up with a total area of 2 068 968 ha, 0.5% of all grassland (see Table 21). Of them, the Xilingele Steppe Nature Reserve in Inner Mongolia has been approved by the United Nations as part of the International Biosphere Network. However,

Table 21. Grassland nature reserves

Name	Location	Area (ha)	Major objective
Inner Mongolia Xilingele Rangeland NR	Xilingele	1 078 600	Typical steppe ecosystem
Gansu Anxi Desert And Gobi Grassland NR	Anxi County	80 000	Wildlife in desert and gobi ecosystem
Heilongjiang Yueya Lake Grassland NR	Hulin County	1 533	*Deyeuxia angusifolia* meadow ecosystem
Ningxia Yunwu Mountain Rangeland NR	Guyuan County	4 000	*Stipa bungeana* rangeland ecosystem on Loess Plateau
Jilin Yaojinzi Rangeland NR	Changlin County	23 800	*Leymus chinensis* meadow ecosystem
Shanxi Wutai Mountain Grassland NR	Taihuai Township	3 333	Subalpine meadow ecosystem
Liaoning Namusilai Rangeland NR	Zhangwu County	7 103	Sandy grassland ecosystem
Shandong Yellow River Delta Grassland NR	Kengli County	58 000	*Glycine soja* and wet grassland ecosystem
Xinjiang Middle Tianshan Dongnaisi Alpine Meadow NR	Xinyuan County	66 667	Mountain meadow ecosystem
Xinjiang Qitai Desert And Semi-desert Grassland NR	Qitai County	12 600	Plain desert ecosystem and forage resource
Xinjiang Fuhai Jintasi Mountain Grassland NR	Fuhai County	9 733	Forage resource and mountain rangeland ecosystem

Note: NR means Nature Reserve
Source: Editorial Committee of Environmental protection in China (2000)

the number of grassland reserves is very low compared with 85 forest nature reserves; the central government plans to create another 17 grassland nature reserves in the near future, of which five are under construction.

Zonation of flora

There are 6 352 species, 29 subspecies, 303 varieties, 13 variant types and 7 cultivars of forage plants in China. These belong to 1 545 genera of 246 families (Tables 22 and 23).

Of all families, nine have more than 100 species: Leguminoseae, Gramineae, Compositeae, Cyperaceae, Rosaceae, Chenopodiaceae, Liliaceae, Polygonaceae, and Salicaceae. Both Leguminoseae and Gramineae have over 1 000 species. There are in all 3 873 species, 26 subspecies, 219 varieties and 10 variant types in these 9 families, which account for 61.67% of the total of China. 43 families have less than 100 species, covering 1,568 species, 1 subspecies, 67 varieties and 3 variant types, which accounts for 24.45%. 30 families have 10 to 20 species, covering 430 species, 12 subspecies, which accounts for 6.59%. 105 families have 2 to 9 species, covering 422 species and 6 variant types, which accounts for 6.38%. Some families only have 1 species, covering 59 species, which accounts for 0.88% (see Table 23).

Out of all genera, *Astragalus* and *Oxytropis* of Leguminoseae and *Carex* of Cyperaceae contain more than 100 species, covering 581 species, 2 subspecies, 18 varieties and 1 variant types, which accounts for 8.99%. 784 genera only have 1 species, totally covering 757 species, 7 subspecies, 12 varieties, 3 variant types and 5 cultivated varieties, which accounts for 11.69% (see Table 24).

Species of unique forage plants (Animal Husbandry and Veterenary Medicine Division of Ministry of Agriculture, 1996)

With a vast territory, complex natural conditions and without Quaternary Glaciation, China has plenty of unique forage plants, including 10 species in 7 families of Pteridophyta, 35 species in 6 families of Gymnospermae, and 273 species in the following 24 families of Angiospermae.

Table 22. Grassland flora of China

Item	Families	Genera	Species	Subspecies	Variety	Variant type	Cultivars	% of total
Lichens	5	7	16	–	–	–	–	0.24
Bryophyta	14	17	31	–	–	–	–	0.46
Pteridophyta	40	103	291	-	3	–	–	4.39
Gymnospermae	10	27	88	-	12	–	–	1.49
Angiospermae	177	1 391	5 926	29	288	13	7	93.42
Total	246	1 545	6 352	29	303	13	7	100.00

Source: Animal Husbandry and Veterenary Medicine Division of Ministry of Agriculture (1996)

Table 23. Major families of forage plants of China

Family		Genera	Species	Subspecies	Variety	Variant type	Cultivar	% of total
Leguminoseae		125	1 157	6	69	4	3	18.48
Gramineae		210	1 028	15	98	3	4	17.12
Compositeae		136	532	1	5	-	-	8.03
Cyperaceae		24	350	1	7	-	-	5.34
Rosaceae		40	222	-	8	-	-	3.43
Chenopodiaceae		38	183	3	11	1	-	2.95
Liliaceae		20	150	-	5	-	-	2.31
Polygonaceae		11	135	-	8	-	-	2.13
Salicaceae		3	116	-	8	2	-	1.88
Others	237	938	2 479	3	84	3	-	38.32
Total	246	1 545	6 352	29	303	13	7	99.99

Source: Cheng Shan (1994)

Table 24. Major genera of forage plants of China

Genus		Species	Subspecies	Variety	Variant types	Cultivar	% of total
Astragalus		276	2	14	1	1	4.39
Carex		181	-	3	-	-	2.74
Oxytropis		124	-	1	-	-	1.86
Poa		96	-	3	-	-	1.48
Roegneria		74	-	16	2	-	1.37
Salix		80	-	3	2	-	1.27
Allium		73	-	2	-	-	1.12
Polygonum		68	-	7	-	-	1.12
Caragana		65	-	7	-	-	1.07
Artemisia		66	-	2	-	-	1.01
Indigofera		63	-	2	-	-	0.97
Desmodium		54	-	8	-	-	0.92
Saussurea		53	-	-	-	-	0.79
Hedysarum		48	-	3	-	-	0.76
Others	1 531	5 031	27	232	8	6	79.13
Total	1 545	6 352	29	303	13	7	100.00

Source: Cheng Shan, Resource of forage plant of China, 1994

Urticaceae (*Elatostema ichangense*, *Elatostema sinense*, *Urtica dioica* var. *kansuensis*, *Urtica tibetica*)

Polygonaceae (*Oxyria sinensis*, *Atraphaxis manshurica*, *Atraphaxis jrtyschensis*, *Rheum tanguticum*, *Calligonum alaschanicum*, *Rumex kaschgaricus*, *Polygonum songaricum*)

Chenopodiaceae (*Cornulaca alaschanica*, *Baolia bracteata*, *Ceratoides arborescens*, *Kalidium cuspidatum* var. *sinicum*, *Suaeda stellatiflora*, *Suaeda rigida*, *Corispermum candelabrum*, *Corispermum dilutum*, *Corispermum platypterum*, *Corispermum puberulum*, *Corispermum retortum*, *Corispermum stenolepis*, *Corispermum falcatum*, *Chenopodium gracilispicum*, *Chenopodium intramongolica*)

Amaranthaceae (*Aerva hainanensis*, *Cyathula officinalis*)

Caryophyllaceae (*Psammosilene tunicoides*, *Arenaria tapanshanensis*, *Arenaria yunnanensis*, *Arenaria kansuensis*, *Arenaria giraldii*, *Arenaria przewalskii*, *Arenaria formosa*, *Arenaria forrestii*, *Stellaria chinensis*)

Ceratophyllaceae (*Ceratophyllum manschuricum*)

Menispermaceae (*Tinospora stinensis*, *Stephania sinica*)

Magnoliaceae (*Michelia yunnanensis*)

Papaveraceae (*Corydalis yanhuzuo*)

Cruciferae (*Megadenia pygmaea*, *Hedinia tibetica*, *Lepidium alashanicum*, *Lepidium cuneiforme)*

Saxifragaceae (*Saxifraga tangutica*)

Rosaceae (*Neillia sinensis*, *Chaenomeles cathayensis*, *Chaenomeles sinensis*, *Crataegus kansuensis*, *Cotoneaster moupinensis*, *Spiraea chinensis*, *Potentilla chinensis*)

Leguminoseae (*Gymnocladus chinensis*, *Stracheya tibetica*, *Cercis chinensis*, *Calophaca sinica*, *Alysicarpus vaginalis* var. *diversifolius*, *Amphicarpaea linearis*, *Albizia bracteata*, *Acacia delavayi*, *Acacia yunnanensis*, *Melilotoides ruthenica* var. *oblongifolia*, *Melilotoides ruthenica* var. *inschanica*, *Melilotoides tibetica*, *Uraria sinensis*, *Trigonella schischkinii*, *Glycyrrhiza yunnanensis*, *Dunbaria henryi*,

Rhynchosia yunnanensis, *Shuteria sinensis*, *Tephrosia purpurea* var. *yunnanensis*, *Pueraria omeinsis*, *Pueraria yunnanensis. Mucuna hainanensis*, *Phaseolus yunnanensis*, *Gueldenstaedtia yunnanensis*, *Gueldenstaedtia yadongensis*, *Moghania yunnanensis*, *Millettia kweichouensis*, *Millettia heterocarpa*, *Dalbergia peishaensis*, *Dalbergia yunnanensis*, *Medicago alashanica*, *Bauhinia apertilobata*, *Bauhinia esquirolii*, *Lespedeza caraganae*, *Lespedeza hengduanshanensis*, *Lespedeza davurica* subsp. *huangheensis*, *Crotalaria hainanensis*, *Crotalaria heqingensis*, *Crotalaria yunnanensis*, *Campylotropis ichangensis*, *Campylotropis yajiangensis*, *Campylotropis yunnanensis*, *Vicia amurensis f. sanheensis*, *Vicia gigantea Vicia tibetica*, *Caragana jilungensis*, *Caragana tangutica*, *Caragana potanini*, *Caragana opulens*, *Caragana kansuensis*, *Caragana brevifolia*, *Indigofera ichangensis*, *Indigofera chuniana*, *Indigofera daochengensis*, *Indigofera hainanensis*, *Indigofera muliensis*, *Desmodium hainanensis*, *Desmodium yunnanensis*, *Hedysarum polybotrys*, *Hedysarum xizangensis*, *Oxytropis biflora*, *Oxytropis densifora*, *Oxytropis holanshanensis*, *Oxytropis inschanica*, *Astragalus taipaischanensis*, *Astragalus adsurgens* cv. *shandawang*, *Astragalus tsadaensis*, *Astragalus baotouensis*, *Astragalus geerwusuensis*, *Astragalus lasaensis*, *Astragalus sedaensis*, *Astragalus yumenensis*)

Zygophyllaceae (*Nitraria tangutorum*)

Tamaricaceae (*Tamarix chinensis*, *Reaumuria trigyna*)

Umbelliferae (*Ferula sinkiangensis*)

Primulaceae (*Androsace alashanica*)

Labiatae (*Mesona chinensis*)

Compositeae (*Hippolytia alashanica*, *Galatella songorica*, *Heteropappus meyendorffii*, *Seriphidium borotalense*, *Kalimeris mongolica*, *Scorzonera manshurica*, *Ajania alabasica*, *Ajania parviflora*, *Taraxacum heterolepis*, *Senecio atractylidifolius*, *Artemisia xigazeensis*, *Artemisia anethoides*, *Artemisia blepharolepis*, *Artemisia dalai-lamae*, *Artemisia eriopoda*, *Artemisia feddei*, *Artemisia giraldii*, *Artemisia igniaria*, *Artemisia oxycephala*, *Artemisia princeps*, *Artemisia subditgiata*, *Artemisia wudanica*, *Saussurea likiangensis*, *Saussurea maximowiczii*, *Saussurea pectinata*, *Saussurea sungpanensis*, *Saussurea tangutica*, *Saussurea graminea*, *Saussurea iodostegia*)

Gramineae (*Roegneria alaschanica*, *Roegneria intramongolica*, *Roegneria hirsuta*, *Roegneria kokonorica*, *Roegneria sinkiangensis*, *Roegneria tibetica*, *Roegneria barbicalla*, *Roegneria multiculmis*, *Poa pachyantha*, *Poa ianthina*, *Poa elanata*, *Poa hengshanica*, *Poa mongolica*, *Poa plurinodis*, *Poa shansiensis*, *Poa orinosa*, *Festuca sinensis*, *Festuca elata*, *Festuca changduensis*, *Stipa aliena*, *Stipa przewalskyi*, *Stipa roborowskyi*, *Deyeuxia kokonorica*, *Deyeuxia henryi*, *Deyeuxia hupehensis*, *Deyeuxia himalaica*, *Isachne guangxiensis*, *Isachne hainanensis*, *Melica tibetica*, *Helictotrichon delavayi*, *Digitaria chinensis*, *Puccinellia multiflora*, *Eragrostis alta*, *Eragrostis hainanensis*, *Eragrostis laxa*, *Bromus sinensis*, *Bromus pseudoramosus*, *Bromus magnus*, *Agrostis breviaristata*, *Agrostis morrisonensia*, *Cymbopogon tungmaiensis*, *Achnatherum chingii*, *Achnatherum inaequiglume*, *Trisetum tibeticum*, *Setaria arenaria*, *Calamagrostis kengii*, *Arundinella yunnanensis*, *Eulalia micrantha*, *Cleistogenes ramiflora*, *Cleistogenes foliosa*, *Oryzopsis grandispicula*, *Elymus purpuraristatus*, *Elymus tangutorum*, *Ischaemum crassipes* var. *hainanensis*, *Themeda hookeri*, *Sorghum hezicao*, *Glyceria chinensis*, *Pennisetum longissimum*, *Agropyron mongolicum*, *Andropogon girongensis*, *Orinus kokonorica*, *Trikeraia ramosa*, *Stephanachne monandra*, *Littledalea racemosus*, *Sinarundinaria chungii*, *Rottboellia laevispica*, *Hemarthria humilis*, *Erianthus rockii*, *Chloris anomala*, *Anthoxanthum formosanum*, *Arthraxon hainanensis*, *Tripogon multiflorus*, *Spodiopogon ramosus*, *Psathyrostachys huachanica*, *Brachypodium pratense*, *Microstegium biforme*, *Urochloa cordata*, *Pleioblastus amarus*, *Chimonocalamus tortuosus*, *Sasamorpha sinica*, *Setiacis diffusa*, *Sinochasea trigyna*, *Colposium tibeticum*, *Anisachne gracilis*, *Moliniopsis hui*, *Imperata flavida*, *Pseudosasa pubiflora*, *Neyraudia montana*, *Phragmites jeholensis*, *Orthoraphium grandifolium*, *Diandranthus szechuanensis*)

Cyperaceae (*Schoenus nudifructus*, *Eleocharis yunnanensis*, *Kobresia gracilis*, *Kobresia inflata*, *Kobresia minshanica*, *Kobresia pusilla*, *Carex kansuensis*, *Carex muliensis*, *Carex yunnanensis*, *Carex serreana*)

Commelinaceae (*Murdannia macrocarpa*)

Liliaceae (*Asparagus trichophyllus*, *Smilax vanchingshanensis*, *Allium anisopodium* var. *Zimmermannianum*, *Asparagus tenuissimus* var. *nalinianum*)

Dioscoreaceae (*Dioscorea exalata*)

Orchidaceae (*Bletilla formosana*, *Pholidota chinensis*, *Herminium alaschanicum*)

Wild species of cultivated forages

As a world region of crop origin, China has plenty of wild forage plants. There are wild species of many superior cultivated forages in China. Some are shown in Table 25 (Animal Husbandry and Veterinary Medicine Division of Ministry of Agriculture, 1996).

Special and rare forage species

(Animal Husbandry and Veterenary Medicine Division of Ministry of Agriculture, 1996)

The special and rare forage plants of China mainly belong to the Gramineae, Leguminoseae and Chenopodiaceae. Most of these plants are distributed in China and have high adaptability and feeding value.

Gramineae: *Sinarundinaria nitida, Aristida tsangpoensis, Roegneria kokonorica, Agropyron mongolium, Bromus sinensis, Elymus tangutorum, Festuca elata, Eragrostis hainanensis, Cleistogenes chinensis, Cleistogenes polyhylla, Arthraxon hainanensis, Arundinella barbinodis, Urochloa cordata,* etc.

Leguminoseae: *Medicago alashanica, Melilotoides ruthenica* var. *obolongifolia, Melilotoides ruthenica* var. *inschanica, Hedysarum laxum, Alysicarpus vaginalis* var. *diversifolia, Indigofera chuniana, Crotalaria hainanensis, Desmodium hainanensis, Mucuna hainanensis,* etc.

Cyperaceae: *Kobresia cuneata, Kobresia cercostachys, Kobresia kansuensis, etc.*

Chenopodiaceae: *Ceratoides arborescens, Ceratoides compacta* var. *longipilosa, Corispermum chinganicum* var. *stauntonii, Corispermum candelabrum, Corispermum stauntonii, Corispermum dilutum, Kochia prostrata* var. *canesdens, Salsola sinkiangensis, etc.*

Table 25. Wild forages and their distribution

Family - Species	Region of distribution
Gramineae	
Agropyron sibiricum	Northern China
Agrostis tenuis	Shanxi
Alopecurus arundinaceus	Northern China
Alopecurus pratensis	Northern China
Axonopus compressus	Tropical areas of Southern China
Bothriochloa ischaemum	All China
Bromus inermis	Northern China
Cynodon dactylon	Southern China and Xinjiang
Dactylis glomerata	Xinjiang and south-western China
Festuca arundinacea	Xinjiang
Festuca pratensis	Xinjiang
Festuca rubra	Northern and south-western China
Phalaris arundinacea	All China
Phleum pratense	Xinjiang
Poa pratensis	Northern China
Psathyrostachys juncea	Xinjiang
Leguminoseae	
Aeschynomene indica	Eastern China
Alysicarpus vaginalis	Tropical areas of Southern China
Desmodium heterocarpum	Tropical and subtropical areas of South China
Kummerowia striata	Northern China
Kummerowia stipulacea	Northern China
Lathyrus pratensis	Xinjiang
Lespedeza cyrtobotrya	Northern China
Lespedeza hedysaroides	Northern China
Lotus corniculatus	Xinjiang
Lotus tenuis	Inner Mongolia
Melilotus alba	Northern China
Melilotus officinalis	Northern China
Pueraria phaseoloides	Tropical and subtropical areas of South China
Trifolium fragiferum	Xinjiang
Trifolium pratense	Northern China and Xinjiang
Trifolium repens	Northern and south-western China
Trifolium incarnatum	Xinjiang
Amaranthaceae	
Amaranthus paniculatus	All China

Liliaceae: *Allium yanchiense, Allium tenuissimum, Allium anisopodium, Allium. songpanicum etc.*

Dominant plants of the main zones (Animal Husbandry and Veterinary Medicine Division of Ministry of Agriculture, 1996)

Many plants play an important role in forming a grassland community in terms of coverage and herbage yield in large grassland areas and various grassland types. According to their degree of dominance and distribution area, the most important species in different grassland classes are as follows:

Main Dominant Plants of the Temperate Steppe The dominant plants are mainly xerocole and fascicular grasses and sub-shrubs. They are listed as follows*: Leymus chinensis, Stipa baicalensis, Stipa grandis, Stipa krylovi, Stipa bungeana, Stipa breviflora, Stipa glareosa, Stipa klemenzii, Stipa capillata, Festuca ovina, Cleistogenes squarrosa, Filifolium sibiricum, Artemisia frigida, Artemisia halodendron, Artemisia ordosica, Artemisia intramongolica, Thymus serpyllum var. mongolium, Ajania fruticulosa.*

Main Dominant Plants of the Alpine Steppe The dominant species are cold resistant, mainly from *Gramineae* and *Compositeae.* The most important are *Stipa purpureum, Stipa subsessiflora, Festuca ovina ssp. sphagnicola, Orinus thoroldii, Carex moorcroftii, Artemisia stracheyi, Artemisia wellbyi,* etc.

Main Dominant Plants of the Temperate Desert The dominant plants are super-xerocole shrubs and sub-shrubs. The most important are *Seriphidium terrae-albae, Seriphidium borotalense, Artemisia soongarica, Salsola passerina, Salsola laricifolia, Sympegma regelii, Anabasis salsa, Reaumuria soongarica, Ceratoides latens, Kalidium schrenkianum, Potaninia mongolia, Nitraria sphaerocarpa, Ephedra przewalskii, Haloxylon erinaceum, Haloxylon persicum etc.*

Main Dominant Plants of the Alpine Desert The ecological environment of this class is the harshest. The dominant plants have a super ability to resist cold and drought. The most important species are *Rhodiola algida var. tangutica, Seriphidium rhodanthum, Ceratoides compacta etc.*

Main Dominant Plants of the Warm Shrubby Tussock The dominant plants are mainly grasses of medium height and some forbs. The most important are *Bothriochloa ischaemum, Themeda triandra var. japonica, Pennisetum centrasiaticum, Spodiopogon sibiricus, Imperata cylindrica* var. *major, Potentilla fulgens,* etc.

Main Dominant Plants of the Tropical Shrubby Tussock Almost all of the dominant plants in this class are hot season grasses. The most important are *Miscanthus floridulus, Miscanthus sinensis, Imperata cylindrica var. major, Heteropogon contortus, Arundinella setosa, Arundinella hirta, Eremopogon delavayi, Eragrostis pilosa, Eulalia phaeothrix, Eulalia quadrinervis, Dicranopteris dichotoma,* etc.

Main Dominant Plants of the Temperate Meadow These are mainly perennial temperate and medium-humid mesophytic grasses. Some are halophytes or forbs. The most important are *Achnatherum splendens, Arundinella hirta, Agrostis gigantea, Calamagrostis epigejos, Bromus inermis, Deyeuxia angustifolia, Deyeuxia arundinacea, Poa pratensis, Poa angustifolia, Miscanthus sacchariflorus, Phragmites communis, Brachypodium sylvaticum, Festuca ovina, Carex duriuscula, Potentilla anserina, Sanguisorba officinalis, Iris lactea var. chinensis, Suaeda* spp.*, Sophora alopecuroides.*

Main Dominant Plants of the Alpine Meadow The dominant forages are mainly cold resistant perennials. Most are *Kobresia* and forbs. The most important are *Kobresia pygmaea, Kobresia humilis, Kobresia capillifolia, Kobresia bellardii, Kobresia littledalei, Kobresia tibetica, Carex atrofusca, Carex nivalis, Carex stenocarpa, Blysmus sinocompressus, Poa alpina, Polygonum viviparum, Polygonum macrophyllum,* etc.

Main Dominant Species of the Marshes The dominant plants are mainly *Cyperaceae* and *Gramineae.* The most important are *Carex meyeriana, Carex muliensis, Carex appendiculata, Carex stenophylla, Scirpus yagara, Scirpus triqueter, Phragmites communis, Triglochin palustre,* etc.

6. OPPORTUNITIES FOR IMPROVEMENT OF FODDER RESOURCES

Grassland use

Most grassland in China is in the arid, semiarid or alpine areas where the climate is harsh, communications are poor and the economy backward. The grassland within agricultural and agro-pastoral areas is also scattered in remote places. In this case, the grassland utilization is extensive, mainly free grazing. Utilization methods are based on the natural geographic conditions and grassland productivity. Natural grassland may be divided into three types according to their use (see Table 26).

Table 26. Grassland types by use

Grassland type	Area (million ha)	Usable grassland (%)
Grazing pasture	264.2049	75.25
Warm season pasture	117.4606	33.45
Cold season pasture	64.1451	18.27
Year round pasture	82.5994	23.53
Grazing and haymaking dual purpose pasture	67.3293	19.18
Difficult usable grassland	19.5678	5.57
Total usable grassland	351.1020	100.00

Source: Animal Husbandry and Veterenary Medicine Division of Ministry of Agriculture (1996)

Grazing and Haymaking Dual Purpose Grassland. Grassland for dual purpose grazing and haymaking is generally on plains with a sward height of 50 cm, more than 50% of cover, less than 25º of slope and high quality. The aftermath is grazed.

Grassland suited to haymaking is mainly in northern and south-eastern China with >400 mm. of precipitation; it is scarce in the west temperate, arid and semiarid desert and steppe where it is only available in scattered patches on high mountains. Hay land is also available in lowland meadow areas along the rivers and by lakes; it is dominated by *Phragmites communis* (it is used for hay during early growth, i.e. before the six leaf stage). In spite of high coverage of grass communities on the Qinghai-Tibet Plateau hay land is still scarce since the grass is very short and is scattered in low altitude valleys. Dominant grasses in the valleys are *Leymus chinensis*, *Phragmites communis*, *Deyeuxia angustifolia*, *Deyeuxia langsdorffii*, *Deyeuxia arundinacea*, *Stipa grandis*, *Stipa baicalensis*, *Stipa capilata*, *Stipa bungeana*, *Spodiopogon sibiricus*, *Bothriochloa ischaemum*, *Themeda triandra* var. *japonica*, *Miscanthus sinensis*, *Miscanthus sacchariflorus*, *Achnatherum splendens*, *Elymus sibiricus*, *Elymus nutans,* etc.

According to the pattern of use, hay land can be divided into permanent and temporary types. Permanent haymaking land is used on the same patches, at the same time of year. Temporary haymaking land is used for hay or grazing, based on the precipitation and thermal conditions of the year and the grass height. Grass is mown once in late summer or early autumn in northern China and twice in summer and autumn in southern China. Harvested grass is mainly for hay and used as a supplement in winter and spring; a little is sold. Some high quality hay, such as *Leymus chinensis* is exported to Japan and Korea. It is not usual to make silage in pastoral areas.

Grazing. Grazing is the most important and essential method of using natural grassland. The area of grazed pasture is 264 204 900 ha, which accounts for 75.25% of national grassland. Grazed pasture has the following aspects: < 30 mm sward height or as for haymaking, but with an uneven surface, > 25º degree of slope, low quality grass and unsuitable for hay. Based on topography, seasons of use and water availability, the seasonal belts of grazing land may be divided into spring-autumn pasture, summer pasture and winter pasture or cold season (spring, autumn and winter) pasture and warm season (summer) pasture.

Seasonal bands of grassland in the plains of the northeast and Inner Mongolia are not clear and most grassland could be grazed at any time of year. However, seasonal belts of grassland in north-western arid desert areas are clearly defined since high mountains alternate with valleys. Animals graze desert pasture in basins in winter and on the semi-desert and steppe pasture in outlying hills and low mountains in spring and autumn and on the forest pasture and alpine meadows in summer. Stock and herders move as far as tens of kilometres, even 500 km, from winter to summer pasture. Although the grassland on the Qinghai-Tibet Plateau is in the alpine belt or above, it too is divided into warm pasture and cold season pasture. The former is in lower valleys and the latter in the remote higher mountains.

In the past decade, the government put the "**Long-term contract grassland use system"** into force with great effort. Under this system, grassland productivity is improved by sub-dividing pastures and allocating long-term grazing rights to individual families based on the number of family members, with fencing, establishing a homestead and barn, establishing artificial grassland and building infrastructure for water and electricity supply. This has been basically completed nationwide, but it is not totally applied on summer pastures because of their long distance from settlements, complex topography and difficulty of management. Most herders began to adopt extensive rotational grazing systems and use improved technology from the inception of the system. It also provides a good basis for managing grassland legally.

Grasslands which are difficult to use include areas which are:

- at high altitude, of harsh climate and in unpopulated areas
- where there is a shortage of drinking water for man and animals
- in the alpine belt where there is difficulty of access
- in swamp and bottomland difficult to access
- on small unpopulated islands
- > 35º degree of slope

The area of such land is 19 567 680 ha, or 5.57% of the total. Most water-scarce grassland is in Inner Mongolia, Xinjiang and Qinghai, unpopulated areas in north-western Tibet and south-western Qinghai, difficult swamps in Heilongjiang and Sichuan.

Grassland deterioration and control strategies

Grassland deterioration, a worldwide problem, is severe in China. According to data published in 1994 the national area of deteriorated grassland was 68 000 000 ha up to the end of 1980s, which is 27.5% of the total. It has increased remarkably in the past decade. Now 90% of national grassland is reported to show signs of deterioration, in which, moderately degraded grassland is 130 000 000 ha (32.5% of total) and it is accelerating by 20 000 000 ha per year (Liu Zixue, 2001). The current grassland deterioration in major pastoral regions is shown in Table 27.

Evidence of grassland deterioration is drifting sand, salinization, patch-like distribution and hammada. Its major causes are severe over-stocking caused by long-term uncontrolled grazing, improper land reclamation and abandonment, climate change, collecting firewood and herbal medicine.

Grassland deterioration not only results in decline of productivity, but also in environment damage, water and soil erosion, sand and dust storms, and desertification. The government is paying great attention to this situation. As one of its most important targets, ecological environment rebuilding has been covered in the West Development Plan by central government in 2000. In agricultural and agro-pastoral areas, this target will be achieved through returning arable land on slopes of >25º degree to forest and grassland and reducing the number of grazing livestock. Severely degraded pasture will be closed for vegetation recovery in pastoral areas. Simultaneously stock numbers will be reduced with yard feeding so that the vegetation and environment can recover rapidly.

Table 27. Current situation of over-grazing and grassland deterioration in major pastoral regions (%)

Region	1990		1999	
	Over-grazing rate	Deteriorated Grassland	Over-grazing	Deteriorated Grassland
Tibet	-	14	30	15
Inner Mongolia	-	40	32	60
Xinjiang	-	-	60-70	65
Qinghai	-	17	31	39
Sichuan	-	24	13	28
Gansu	-	40	35	50
Heilongjiang	-	30	124	65

Grassland improvement

The large area of degraded grassland has a severe negative influence on animal production and the environment and causes great concern to the government. According to the "Planning Program of National Ecological Environment Construction" and "Outline of Fifteenth Ten Years Plan", the following should be achieved by 2010:

– to increase artificial grassland and improved grassland by 50 000 000 ha;

– to improve 33 000 000 ha of degraded grassland and 20 000 000 ha of desertified land;
– to control of 600 000 ha of water and soil eroded land;
– to return 6 700 000 ha of arable land (on >25º degree slopes) to forest and grass.

These objectives show the resolve of the Chinese people and government to improve degraded grassland and the environment. There are temporary and permanent solutions for grassland improvement. The latter is to establish artificial grassland, which will be discussed below.

Closure Closure is to protect grassland from grazing or control grazing pressure strictly through fencing, so that it has a chance to recover. Herbage yield increases rapidly in the humid and subhumid areas but the effect declines over time; closure should not exceed three years. In western China, where the grassland is severely degraded, a large area has been closed to grazing since 2000 and many animals have been culled or are stall fed.

Reseeding Reseeding is over-sowing degraded grassland with improved forages to improve sward composition and productivity. Manual methods are used on small areas, but aerial seeding should be used on large ones. The cost/benefit ratio is 1: 2–4, the investment could be recouped within two years. The following details require attention during aerial seeding:

1. the area should exceed 350 to 650 ha of which the target area should be more than 80%;
2. seed should be pre-treated by coating, de-awning, scarification and legumes should be inoculated;
3. the land should be smoothed with a heavy harrow, plus burning and weeding;
4. after aerial seeding, treading by livestock can improve the establishment rate.

Irrigation Water shortage is a major constraint for grass and animal production since most of China's grassland is in arid and semiarid areas. Grass yield could be increased by 6 to 9 times through irrigation and the proportion of legumes in the sward could be increased as well, improving nutritive value. In Inner Mongolia, 5% of water for agriculture is used for grassland irrigation. Thirty two reservoirs have been built in pastoral areas of Qinghai, their storage capacity is 1 739 000 m^3. 512 water channels, totalling 2 190 km, were built to irrigate 40 000 ha of grassland. The area of irrigated grassland is 140 000 ha in Xinjiang and 240 000 ha in Tibet. Surface flooding is the common irrigation method. The problem is that over half of the area can be missed because of poor land-levelling. Sprinkler irrigation is not used in practical situations.

Fertilizers Fertilization is important for grassland improvement. A large amount of nutrients is absorbed by grasses, especially highly productive grassland for hay and dual use. The deficit should be supplemented by fertilizing. Dung is widely used combined with chemical fertilizers for artificial grassland establishment. Trace fertilizers and rare earth fertilizers are also applied in some places. On natural grassland the commonest and most practical fertilization application method is night penning, i.e. concentrate animals in one place for two nights and then move them to another. This method can increase grass yield by half in the following year.

Surface Tillage Shallow tillage (with surface cultivator) has a positive effect on grass yield on pasture dominated by rhizomatous grasses such as *Leymus chinense* and *Phragmites communis* and those with dense sod (dominated by *Kobresia* spp.). Shallow tillage improves air and water permeability of the soil and enhances vegetative propagation by cutting rhizomes. The yields of grasslands dominated with *Leymus chinense*, *Kobresia* spp. and *Agropyron cristatum* could be increased by 50 to 200%. Seed yields of *Leymus chinense* and *Agropyron cristatum* can be increased by 180% to 1 500%.

Burning is an old, practical method for grassland improvement. It is no longer used in northern China because the grassland is so severely degraded. It is, however, still widely used in the shrub grassland and swamp grassland in southern China.

Forage grasses and artificial grassland

Artificial grassland is special agricultural land combining pastoralism with agronomy. Even as the artificial grassland constituted by *Lolium perenne-Trifolium* is symbolic of the western agro-pastoral

civilization, the artificial grassland of *Medicago sativa* is typical of the eastern agro-pastoral one. China was one of earliest countries to grow *Medicago sativa*. In 126 BC, China began raising lucerne along the Yellow River, and it was rotated with wheat. Apart from improving crop yield and soil fertility, this system directly and indirectly contributed to forming livestock breeds such as Qingchuan cattle, Jinnan cattle, Zaosheng cattle, Nanyang cattle, Guanzhong donkey, Zaosheng donkey (the donkey is less important than before because of mechanized cultivation and transport).

Compared with natural pasture, the area of artificial grassland is small. In 1995 it was 13 800 000 ha, which is 3.4% of all grassland. It increased to 15 480 000 ha in 1997, 3.8% and 20 000 000 ha in 2000, 4.8%. Aerial seeding plays an important role for establishment; it began in 1979 and the area of aerial seeded artificial grassland was 2 497 000 ha; by the end of 1998 the established area was 1 472 000 million ha Among provinces or regions, the artificial grassland areas in Inner Mongolia, Gansu, Xinjiang, Shaanxi and Sichuan are large: over 2 500 000 million ha in Inner Mongolia and close to 1 000 000 ha in Gansu. The priority is given to lucerne in all provinces except Sichuan. The lucerne area in Gansu is close to 400 000 ha, which is 34% of the national total.

Nowadays, cereals, cotton, oilseeds and fruits are in relative surplus in China, but forage is scarce in both urban and rural areas. Besides, environmental deterioration has drawn serious attention to reseeding grassland; returning arable land to grassland and forest is one of 10 projects for reconstruction in western China. It is expected that the development of artificial grassland will be speeded up in the near future.

Major forage grasses and forage crops

China has many forage grasses and forage crops. There are more than 100 species of cultivated forage in China; most are legumes and grasses. Among these, over 30 species are sown on more than 10 000 ha (excluding mixed sowing, see Table 28).

Forage Legumes Around 21 genera and around 60 species of legume are grown in China. The major genera and species are briefly introduced as follows (Cheng Baoshu, 2001; Hong Fuzeng, 1989):

Astragalus: *Astragalus huangheensis* (=*Astragalus adsurgens*) is thermophilic, cold resistant, salt tolerant, wind and sand resistant, adapted to sandy land with 300 mm to 400 mm of rainfall and mainly used for aerial seeding for soil protection and forage. *Astragalus sinicus* has its provenance in the subtropical area of China from 24° to 35° N and has been cultivated for more than 600 years; it is used as a green manure on paddy fields (inferior 1/3 and roots) and forage (top 1/3) for pigs. It is also a honey resource.

Caragana: *Caragana korshinskii*, *Caragana intermedia* and *Caragana microphylla*, sub-shrubs tolerant to cold, drought, wind and sand, can be sown in arid sandy land where the rainfall ranges from 150 mm to 250 mm.

Coronilla: *Coronilla varia* (a dual-purpose legume for forage and soil conservation).

Desmodium: *Desmodium*. *intortum*, *Desmodium uncinatum,* etc.

Table 28. Major forages and sown area (thousand ha, 1998)

Forage	Area	Life period	Rank
Medicago sativa	1 804.7	Perennial	1
Astragalus sinicus	1 686.9	Perennial	2
Caragana koshinskii	1 108.7	Shrub	3
Astragalus huangheensis	653.2	Perennial	4
Vicia villosa	123.9	Biennial	12
Vicia sativa	98.9	Annual	14
Onobrychis viciaefolia	65.2	Perennial	17
Trifolium repens	31.7	Perennial	19
Oxytropis coerulea	28.7	Perennial	20
Trifolium pratense	28.2	Perennial	21
Stylosanthes guianensis	26.9	Perennial	22
Melilotus alba, *M. officinalis*	20.7	Biennial	24
Zea mays (forage)	570.5	Annual	5
Leymus chinensis	403.7	Perennial	6
Hordeum vulgare	358.7	Annual	7
Elymus sibiricus	230.3	Perennial	8
Lolium multiflorum	183.2	Annual	9
Avena sativa	155.7	Annual	10
Elymus dahuricus, *E. excelsus*	138.6	Perennial	11
Avena nuda	118.7	Annual	13
Setaria italica (forage)	80.0	Annual	15
Sorghum sudanense	77.2	Annual	16
Bromus inermis	22.5	Perennial	23
Secale cereale	20.1	Biennial	25
Lolium perrene	17.6	Perennial	26
Agropyron cristatum	14.4	Perennial	28
Dactylis glomerata	13.7	Perennial	29
Artemisia sphaerocephala	55.3	Sub-shrub	19
Raphanus sativus	17.0	Biennial	27
Amaranthus paniculatus	10.5	Annual	30

Source: Cheng Baoshu (2001)

Hedysarum: *Hedysarum laeve*, *Hedysarum scoparium*, *Hedysarum fruticosum* (sub-shrubs suitable for temperate areas where the rainfall is 150 mm to 350 mm).

Kummerowia: *Kummerowia striata*, an annual legume with wide adaptation: drought tolerant, flood resistant, photophilic and shade tolerant, and can be sown in tropical, subtropical and temperate areas where the pH values range from 4.1 to 7.5.

Lathyrus: *Lathyrus sativus, Lathyrus pratense* etc. Annual legumes.

Lespedeza: *Lespedeza bicolor*, *Lespedeza cuneata*, *Lespedeza dahurica* (all indigenous and widely sown in the north), *Lespedeza hedisaroides*.

Leucaena: *Leucaena leucocephala*, a shrub or tree with various varieties suited to tropical and subtropical areas.

Lotus: *Lotus corniculatus*.

Lupinus: *Lupinus luteus*, *Lupinus albus,* etc.

Macroptilium: *Macroptilium atropurpureum*, is a tropical perennial creeping legume with high proportion of leaf and high protein content and can be used as both fodder and for water and soil control.

Medicago: *Medicago sativa* (most important and widely sown), *Medicago falcata* and *Medicago denticulata,* etc.

***Melilotus*:** *Melilotus alba* (widely sown in 1950s and 1960s), *Melilotus officinalis*, *Melilotus dentatus,* etc.

Onobrychis: *Onobrychis viciifolia* (mainly used in sandy area where the conditions are unsuitable for *Medicago sativa* through low temperature and rainfall), *Onobrychis transcausia*, *Onobrychis arenaria,* etc.

Pocockia: *Pocockia ruthenica* (= *Trigonella ruthenica*, it is a rare legume in the alpine region, extremely cold resistant and with stool shoots).

Pueraria: *Pueraria lobata* (sown in north) and *Pueraria thomsonii* (sown in south, high starch content in roots), both good both for forage and water and soil conservation.

Stylosanthes: *Stylosanthes guianensis* (introduced).

Trifolium: *Trifolium repens* and *Trifolium pratense* (mainly sown in the humid hilly area in southern China), *Trifolium incarnatum*, *Trifolium hybridium*, *Trifolium lupinaster*, *Trifolium fragiferum*, *Trifolium subterraneum*, *Trifolium alexandrinum,* etc.

Vicia: *Vicia sativa*, *Vicia villosa, Vicia faba* (used for fodder and green manure, sown in autumn in southern China), *Vicia amoena*.

Cultivated Grasses Around 24 genera and 60 species of grasses are cultivated in China. The major genera and species are briefly introduced as follows:

Agropyron: *Agropyron cristatum* (sown in the northern China), *Agropyron mongolicum* (adapted to steppe and desert zones) and *Agropyron desertorum*.

Alopecurus: *Alopecurus pratense* and *Alopecurus arundinaceus*; are not used much.

Arrhenatherum: *Arrhenatherum elatius*.

Bromus: *Bromus inermis* (has been sown in China for more than 100 years and its cultivated area is increasing in the humid regions of northern China and the Qinghai-Tibet Plateau), *Bromus catharticus*.

Cynodon: *Cynodon dactylon* (widely used as forage and turf).

Dactylis: *Dactylis glomerata* (sown widely in China and the area is large).

Elymus: is an important grass and of great value for establishing perennial artificial grassland. Cultivars in this genus are characterized with strong adaptation, strong cold tolerance and easy maintenance. *Elymus sibiricus* and *Elymus nutans* were domesticated in the 1950s and are major cultivated grasses in northern China (especially on the Qinghai-Tibet Plateau). They can be sown in pure stand but perform better if the two are mixed. *Elymus dahuricus* and *Elymus excelsus* are also cultivated.

Elytrigia: *Elytrigia repens*, *Elytrigia intermedia* and *Elytrigia trichophora*.

Hemarthria: *Hemarthria compressa* (mainly grown in the subtropical south-western humid areas and Sichuan).

Hordeum: *Hordeum brevisublatum* and *Hordeum bogdanii* (used for both grazing and hay with features of hydrophile and salinity tolerance).

Leymus: *Leymus chinensis* (has a wide ecological range and is salinity resistant, with high nutritive value and was sown on a large scale in the 1950s as one of the key cultivars of permanent artificial grassland), *Leymus secalinus* (is resistant to cold, drought and salinity with strong colonising ability, but its cultivated history is short).

Lolium: *Lolium perenne* (a famous perennial grass, widely cultivated since 1970s; an important forage grass and also the most important turf grass in humid regions) and *Lolium multiflorum* (mainly sown in winter in rice raising areas of subtropical zone can be grown in the warm Temperate Zone of North China).

Paspalum: *Paspalum dilatatum* and *Paspalum wettsteinii* (all cultivated species in this genus are introduced and these two are important in tropical and subtropical areas).

Pennisetum: *Pennisetum purpureum* (introduced in the 1930s, is grown in subtropical areas on a large scale).

Phalaris: *Phalaris arundinacea* (is all over China, and is widely sown since it tolerates waterlogging, salt and pests), *Phalaris tuberosa* (introduced in the 1970s, is cultivated in southern subtropical areas) and *Phalaris canariensis* (not used much).

Phleum: *Phleum pratense* (is cultivated and widely sown, but the area is small).

Poa: *Poa pratensis*, *Poa pratensis* var. *anceps* (wild on the Qinghai-Tibet Plateau and adapts to cold with grazing and cutting tolerance), *Poa trivialis*, *Poa erymophila* and *Poa compressa*.

Puccinellia: *Puccinellia tenuiflora* (domesticated in 1930s) and *Puccinellia chinampoensis* (both are famous for salinization control).

Roegneria: *Roegneria semicostata*, *Roegneria ciliaris* (both are widely distributed), *Roegneria kokonorica* (domesticated in the 1960s and is important for artificial grassland with its strong cold tolerance in alpine regions of Qinghai-Tibet Plateau).

Setaria: *Setaria anceps* (introduced, sown in southern subtropical areas).

Sorghum: *Sorghum sudanense* (introduced in the 1930s and sown nationwide. It is a vital fish fodder).

Spartina: *Spartina anglica* (introduced from United Kingdom in 1963 and widely planted in coastal areas. It is of great value for the improvement of saline coastal areas).

Zoysia: *Zoysia japonica*, *Zoysia sinica*, *Zoysia tenuifolia*, *Zoysia matrella*, *Zoysia macrostachya* etc. (creeping grasses for grazing, slope consolidation and turf).

Other Cultivated Forages: *Amaranthus paniculatus*, annual herb of Amaranthaceae, is a high quality fodder for pigs, poultry and cattle. It is of ancient cultivation in China where the area is the largest in the world.

Calligonum mongolicum, the super-xerocole shrub of Chenopodiaceae; a pioneer plant for sand fixation in desert and gravel desert with tolerance to drought and cold. It is usually used for aerial seeding.

Ceratoides latens, a shrub of Chenopodiaceae, important in Temperate Zone and alpine desert for artificial pasture with tolerance to drought and cold, and adaptation to sandy and rocky soils.

Kochia prostrata, a creeping sub-shrub of Chenopodiaceae, is good forage in desert and semi-desert areas with tolerance to drought, salt, poor soil and a high protein content, and it is suitable for establishing rainfed grassland.

Lactuca indica, a biennial herb of Compositeae, indigenous to China and sown country-wide as fodder for pigs and poultry.

Silphium perfoliatum, a perennial herb of Compositeae, introduced in the 1980s and is cultivated nationwide as fodder for cattle, pigs and rabbits.

Symphytum peregrinum, a perennial herb of Boraginaceae, introduced in the 1970s is widely cultivated between the Great Wall and Yangtze River as pig and cattle fodder.

Forage Cereals: *Avena sativa* is the most important fodder crop in the north and alpine areas. It is generally sown pure; the sown area has increased rapidly in recent years because it is easy to grow and harvest. Its seeds do not ripen on the Qinghai-Tibet Plateau, but high quality freeze-dried hay could be got through adjusting sowing time to enable it to complete heading before the frost.

Hordeum vulgare is an important forage and its cultivated area is only slightly less than forage maize. It is sown country-wide both in the north (spring barley) and the south (winter barley). Naked barley is the Tibetan staple food.

Secale cereale introduced from Russia in 1940s and now widely cultivated in northern and alpine areas. In 1979 an American cultivar “winter grazing 70” was introduced and extended nation-wide.

Setaria italica, annual, is indigenous to China and has been cultivated for more than 6,000 years. It is widely sown in the north as a cereal. The nutritive value, palatability and digestibility of its straw are higher than those of wheat and rice. It could be made into high quality hay (not removing the grain) by dense planting.

Sorghum bicolor has been cultivated in China for 4 000 years, but its area is much less than *Sorghum sudanense* and is increasing in recent years.

Zea mays is the most important forage in China and sown country-wide in a long, narrow belt from northeast to southwest. It was used as human food before 1980, but now is almost all used as animal feed.

Grain Legumes as Forage: *Cicer arietinum* is a dual-purpose crop, introduced from Russia in the 1950s. Now it is cultivated both in the north and the south. Its grain is a very nutritious concentrate.

Glycine max is indigenous to north-eastern China and the forage variety is a primitive form. Both green chop and grain are good forage with high protein content.

Pisum sativum (white flower) and *Pisum arvense* (purple flower) are annuals and have been cultivated for 2 000 years in China. It is sown country-wide because of cold tolerance and it is better to mix with oats than *Vicia sativa*.

Vicia faba is a dual-purpose crop and has been cultivated for 2 100 years in China where its cultivated area is the greatest in the world. A forage cultivar introduced in 1960 is cold resistant with high yield and high quality.

Root Tuber, Stem Tuber and Melon Forages *Beta vulgaris*, biennial herb of Chenopodiaceae, is widely grown in the north for sugar (main purpose) and fodder. Fodder cultivars normally cannot grow in alpine regions, but it could be grown and yield well by using plastic sheet mulching.

Brassica rapa, a biennial crucifer, is an old cultivated crop. It was mainly grown on the Qinghai-Tibet Plateau in early times and now is extended to the whole country as a succulent fodder. Its yield could be greatly increased by using plastic sheet mulching.

Cucurbita moschata, annual Cucurbitaceae, gives high yields and high quality succulent fodder. The contents of carotene, vitamin A, B and C in flesh and fruit are 100 times higher than grain cereals.

Daucus carota, biennial of the Umbelliferae, grown country-wide as a succulent fodder.

Helianthus tuberosus perennial herb of Compositeae; leaf, stem and tuber can be used.

Aquatic Forage Crops: *Alternanthera philoxeroides*, amphibious perennial herb of Amaranthaceae, from Brazil and was introduced in 1920s. Cultivated both in the north and south as fodder for pig, poultry, cattle, sheep and fish. Its dry matter content is less than 5%.

Aneilema keisak, an annual herb of Commelinaceae, has been cultivated in subtropical southern China for a long time. Its dry matter content is around 5%. It grows fast and is used as fodder for pigs, cattle and rabbits.

Azolla imbricata, a floating fern of Azollaceae, widely distributed in tropical and subtropical zones; has been cultivated in China for 500 years. It forms a fern-algal symbiosis with blue green algae (*Anabena azolla*, Cyanophyta) and can fix atmospheric nitrogen. Its yield is as high as 300 to 500 tonnes/ha with 16 to 18% of crude protein (DM base). It is high quality fodder for pig, poultry and fish, and a good green manure.

Eichornia crassipes, a floating herb of Pontederiaceae, is a high yielding aquatic forage indigenous to South America. It is cultivated in the warm Temperate Zone in China. Its dry matter content is around 5%. It is used as fodder for pigs, poultry, cattle, sheep and fish or as green manure.

Pistia stratiotes, floating herb, of Araceae, is a high yielding aquatic forage in tropical and subtropical zones. It has been extended to the watershed of the Yellow River. The dry matter content ranges from 5 to 6%. It is mainly fed to pigs, poultry and fish or is a green manure.

Zizania caduciflora, perennial temperate and subtropical grass, long cultivated in southern China. Its height is 1 to 2.5 m and it is high quality fodder for cattle, horses and fish with 14% of crude protein.

Classification of Artificial Grassland (Hu Zizhi, 1997)

Artificial grassland is playing an increasingly important role and its area has increased in recent years. To understand and guide the artificial grassland development scientifically, its classification has been given great attention.

Principles of Artificial Grassland Classification The following five principles should be followed for classification:

1. The classification should depend on the labour factor. It differs from natural grassland, for artificial grassland is an agricultural resource created through human effort and can only exist while the cultivation is kept going. So cultivation differentiates natural from cultivated grassland. Then artificial grassland could be differentiated from semi-artificial grassland depending on the degree of cultivation, i.e. permanent cultivation or periodic cultivation. Semi-artificial grassland should be included in natural grassland because the vegetation components are not changed radically.
2. Moisture and thermal conditions are basic factors for artificial grassland type determination. The thermal condition is the priority basis for determining the high-grade units. It is the same as with natural grassland, the bio-community of artificial grassland is formed and maintained under certain water conditions. People can considerably modify the water supply to grasslands under current production conditions. However, the thermal condition cannot be changed by human intervention. The thermal condition becomes, therefore, the crucial factor to define the type of artificial grassland. Besides, the type difference caused by the variance of water condition in the same thermal zone has been eliminated by irrigation and other cultivation practices to a great degree, so the number of types in a thermal zone is decreased remarkably and most of the types are mesophytic.
3. The major feature of land is determined by soil, thus the soil is used to define the middle classification grade. Land preparation is an important step for artificial grassland establishment. The soil should be levelled for irrigation and machinery operation. The influence of topography on the distribution of water is greatly decreased. In this case, the effect of soil on restricting the characteristics and production of artificial grassland stands out. It is the reason to treat soil as the parameter of middle grade of artificial grassland classification.
4. Forage species and species components are used as the basis to determine the lower classification grades. The grass component in vegetation is the most distinct feature of the structure and appearance of the community, and it also indicates its feeding value. Compared with natural grassland, the grass component of artificial pasture is simple and it is therefore easy to be used as the parameter to classify types. At the same time, the stability of the grass component is much lower than that of temperature and soil, which is why it can only be used as the classifying parameter of low grade.
5. The classification system of artificial grassland should be linked with the natural grassland classification system. This is because any piece of artificial grassland is established and maintained under the ecological environment of natural grassland. In substance, artificial grassland is the result of highly intensive management of natural grassland. Furthermore, from the view of agricultural resources, natural grassland and artificial grassland are two parallel levels with the same use. Therefore, each classification system should be properly linked in an integrated system.

Classification System and Classification Standards Based on the above-mentioned principles, the classification system of artificial grassland may be constituted with three grades, i.e., class, subclass and type. The classification standards of each grade are described as follows:

Class: is divided according to thermal condition. The features of class can be used to guide artificial grassland regionalization. Thermal grade is determined with >0 ºC accumulative temperature (sum theta, see Table 29), totally 5 grades, i.e. tropical zone, subtropical zone, temperate zone, cold temperate zone and frigid (alpine) zone. The thermal values of each zone are shown in Table 29. Class is named

with the name of the thermal grade, the five Classes are Tropical Zone Artificial Grassland, Subtropical Zone Artificial Grassland, Temperate Zone Artificial Grassland, Cold Temperate Zone Artificial Grassland and Frigid Zone (Alpine) Artificial Grassland.

Table 29. Division of thermal grade

Thermal zone	>0 ºC cumulative temperature (sum theta)	Thermal grade
Frigid (Alpine) Zone	< 1 300 ºC	Frigid
Cold Temperate Zone	1 300 to 2 300 ºC	Cold Temperate
Temperate Zone*	2 300 to 3 700 ºC	Cool Temperate
	3 700 to 5 300 ºC	Warm Temperate
Subtropical Zone*	5 300 to 6 200 ºC	Warm
	6 200 to 8 000 ºC	Subtropical
Tropical Zone	> 8 000 ºC	Tropical

** Please refer to Table 11, the division of thermal zone is simplified because the rate of dependency of cultivated forage grasses on temperature is lower than wild ones.*

Subclass: after class Subclasses are divided by soil type. The features of subclass can be used to guide soil improvement and fertilizer regime. Subclass is named by soil type and temperature zone is used as a prefix to express the features of subclass, for example, Tropical Zone Latosol Artificial Grassland, Temperate Zone Chernozem Artificial Grassland, Frigid Zone Alpine Meadow Soil Artificial Grassland etc.

Type: after subclass determination, the type is determined according to forage species or species component. The features of type can be used to select cultivation and utilization patterns. Type is named with the forage or forage group. For example, *Sorghum sudanense* forage, *Lolium perenne* + *Trifolium pratense* + *T. repens* mixture. For convenience of mapping, several types could be merged according to life form, economic group or life span.

Connection of Artificial Grassland Classification to the Comprehensive and Consequence Classification System of Natural Grassland The classification system has an inherent relation to the Comprehensive and Consequence Classification System of Natural Grassland; this is embodied in the following points:

- First, both systems have three basic grades, Class, Subclass and Type. The thermal, soil and forage species are used as the classification parameters for these three grades in the artificial grassland classification system. This is similar to the Comprehensive and Consequence Classification System of Natural Grassland. Therefore, this system can be called "the Comprehensive and Consequence Classification System of Artificial Grassland".
- Second, the temperature could be used as the "interface" to connect the systems because water and temperature are used for class division in both. So, the two systems could be merged and expressed in a unified index chart (see Figure 13).
- Third, soil and topography are used for subclass division in natural grassland and soil is used in artificial grassland. Topography is not as important in artificial grassland classification as in natural grasslands.
- Fourth, the type of both systems is determined by forage species, so it could be connected directly to compare the aspects of community and grass production.

Grass cultivars and seed production

The selection and breeding of forage grasses in China can be traced to early times, farmers selected many native forages. However, modern grass breeding began quite late. In the nineteen-fifties two cultivars of *Medicago sativa* were bred, i.e. Gongnong No. 1 and Gongnong No. 2; breeding has speeded up since 1980. The National Examining and Approval Committee for Forage Cultivars, affiliated to the Ministry of Agriculture, was constituted in 1987. A set of laboratories and experimental stations was set up. There are more than 300 researchers working in forage breeding in 2000. 379 forage cultivars were submitted for registration and 219 were approved by the end of 2000 (44 during 1998 to 2000), including 90 of improved cultivars, 39 of native cultivars, 55 of introduced ones, 35 of cultivated wild varieties. Out of the registered cultivars 17 are *Medicago sativa* and these can increase yields by 10 to 30% (National Examination and Approval Committee of Forage Grass Cultivars, 1992; Su Jiakai, 2001).

In 1986, the National Crop Germplasm Store in the China Agricultural Academy (based in Beijing) was set up It is in charge of long term conservation of crop genetic resources (including forage: seeds can be conserved for over 50 years). In 1989, a Forage Germplasm Store was set up in the Grassland Institute

of the Agricultural Ministry. Its storage capacity is 40 000 and it is in charge of midterm conserving and supplying forage germplasm. Meanwhile, five Resource Gardens of perennial forages in Hohhehot, Beijing, Wuhan, Nanning and Kunmimg were set up for field conservation, propagating and supplying germplasm. In 1998, the nationwide Testing Centre of Forage Seeds was founded. All these units, based on the Forage Germplasm Store, combined with the National Crop Germplasm Store and Resource Gardens, make up a national network for conserving, supplying, and testing of forage germplasm.

Good forage grass cultivars

The characteristics of some important cultivars in terms of breeding targets are introduced below (detailed information can be obtained from the National Examining and Approval Committee of Forage Grass Cultivars, contact address: Animal Husbandry and Veterinary Medicine Division, Ministry of Agriculture, Beijing 100026)

Early Ripening Cultivars Erect milkvetch (*Astragalus huangheensis = A. adsurgens*) cannot produce seeds or the seed yield is very low north of the Yellow River because of insufficient accumulated temperature. New cultivars, "Huanghe No. 2", Longmu No. 2" and "Zaoshou" were bred by systematic selection or ^{60}Co-$_{y}$. Flowering date could be 20 days earlier and the seed yield can be increased by 80 to 120%.

Lactuca indica originated in the warm temperate and subtropical zones. New cultivars, "Gongnong", "Longmu" and "Mengzao" were bred by mixed selection, and these new cultivars are early maturing, cold resistant and high seed yielders.

Cold Resistant Cultivars Legume cultivars suitable for mixed sowing and pure stand are very scarce in northern China. New cultivars of *Medicago sativa*, "Caoyuan No. 1", "Caoyuan No. 2", "Gannong No. 1", "Longmu 893", "Tumu No. 1", "Xinmu No. 1" and "Xinmu No. 3" were bred using interspecific crossing or intergeneric crossing of *M. sativa* x *M. falcata*. Hybrid cold resistant cultivars of *Onobrychis viciifolia* are "Mengnong" and "Gannong No. 1".

Disease Resistant Cultivars Downy mildew is a major diseases of *Medicago sativa.* "Shingling No. 1" is a cultivar resistant to downy mildew, bred by identifying disease-inoculated strain, selecting, and crossing. Its disease-free rate is 95 to 100%.

Stylosanthes guianensis is severely infected by anthracnose. "Reyan No. 2" was bred through selection and "907" through 60Co-? for resolving the problem.

Salt Tolerant Cultivars A salt-resistant cultivar of *Medicago sativa*, "Zhongmu No. 1", was crossbred with four good cultivars as parents through open pollination and mix selection for four generations. It enables *Medicago sativa* to be grown in saline soil and yields can be higher by more than 10% compared to ordinary cultivars.

Drought and Heat Resistant Cultivars It is hot and dry in the Yangtze River catchment in summer and this is to the detriment of over-summering temperate forages. The new cultivar, "Emu No. 1", was bred from cultivar "Regal" of *Trifolium repens* as parent material through natural selection, artificial selection, individual selection and multiple crossbreeding. The summer survival rate was increased by 15%.

A new cultivar, "Nannong No 1." (*Lolium perenne* x *Festuca arundinacea*), was bred by intergeneric crossing with *Lolium perenne* cv "Manawa" as female parent and *Festuca arundinacea* as male. It is cold resistant, and tolerates waterlogging and drought.

Grazing Tolerant Cultivars of Lucerne with Stool Shoots Based on introduced stoloniferous lucernes, two new cultivars, "Gannong No. 3" and "Gannong No. 2" of *Medicago sativa*, were bred respectively in semiarid area and alpine area through spot sowing, individual fixed planting and cloning. The proportion

of plants with stolons of the former is more than 30%, and the proportion of plants with horizontal roots of the latter ranges from 50 to 80% (Geng Huazhu, 1995).

Polyploid Cultivars Polyploid plants are characterized by eugonic growth, high yield and strong cold and drought resistance, but low seed yield. This feature could be used to increase the yield of vegetative organs. Up to now, heptaploid *Triticosecale wittmack* cv "Zhangxin 1881" and hexaploid cv "Zhangsi 237" have been bred octoploid. Tetraploid *Lolium multiflorum* cv "Ganxan No. 1" and "Shangnong" were bred as well.

Hybrids These cultivars include *Zea mays* cv "Jiqing No. 7" (Pa91 X 340), "Longmu No. 3" (GJ60 X GB47-1), "Longmu No. 5" (J38 X GB33), "Liaoqing No. 8" (Liaoyuan No. 1 X Gueiqong), "Huanong No. 1" (Tian 111 X Mexico *Euchlaena mexicana* inbred line A1), "Xinduo No. 2" (Huangyu 5–5–5 X 7G) and "Zhongyuandan No. 32" etc. These cultivars have significant heterosis.

Cultivars of *Sorghum bicolor*, "Liaosiza No. 1" (*S. bicolor* male sterile line T X 623A X sugar *S. bicolor* restorer line 1022) and "Liaosiza No. 2" (*S. bicolor* sterile line LS3A X sweet *S. bicolor* restorer line Roma), are waterlogging tolerant, drought tolerant and salinity tolerant. "Wancao No. 2" (*Sorghum bicolor* x *S. sudanense*) has low hydrocyanic acid content and is suitable for green use. *Pennisetum purpureum* (male sterile line Tifa 23A X restorer line Bil 3B-6) is taller and has more tillers. "Mingmu 42" is a fodder cultivar of *Saccharum officinarum* bred from CO419 (female parent) and PT43-52 (progeny of wild variety, male parent). It is has high yield, high quality and multiple resistance.

Cultivars Selected from Wild Plants *Puccinellia chinampoensis* can grow in salty soil (pH > 9.4, salt content of topsoil 2.0 to 2.5%), but native types only germinate where the temperature range is more than 10 ºC. This limits their widespread use. Using four excellent strains and an integrated variety a new cultivar, "Jinong" has been bred. Its germination and yield are improved significantly.

Hedysarum laeve and *Hedysarum scoparium* are excellent pioneer shrubs for wind breaks, sand fixation and fodder. The productivity of wild strains is low. New cultivars, "Zhongcao No. 1" of *Hedysarum laeve* and "Zhongcao No. 2" of *Hedysarum scoparium*, were bred through single plant selection, mix selection, strain test, regional testing and production testing. New cultivars retain the excellent features and strong vitality of wild plants and the biomass could be increased by 20%.

Seed production

China has a very long history of grass seed production, but seed supply is still a bottleneck for grass and forage production because of the weak breeding work. Despite a set of bases for foundation seed having been set up in the nineteen-eighties, the output of commercial seed is very low. China can only produce seeds of *Medicago sativa, Astragalus huangheensis, Melilotus alba, Vicia sativa, Vicia villosa, Leymus chinensis, Puccinellia tenuiflora, Puccinellia chinampoensis, Elymus sibiricus, Elymus nutans, Elymus dahuricus,* and *Sorghum sudanense* to a certain degree. The seeds of *Astragalus sinicus* are produced and used by farmers themselves, but there are no commercial seeds in China due to the small production scale. The situation of *Lolium multiflorum* is similar to *Astragalus sinicus*, the vigour of harvested seeds by farmers is quite low since humid weather and the local government encourages farmers to use the seeds produced in drier areas. Imported seeds are also used in these areas.

Seeds of other grasses and forages that cannot be produced commercially include seed of *Lolium perenne, Dactylis glomerata, Festuca arundinacea, Trifolium repens, Trifolium pratense* and the cold season turf grasses *Poa pratensis, Festuca elata, Festuca capillata* (*Festuca tenuifolia*), and *Agrostis stolonifera*; for these there is almost total dependence on imports. Although large amounts of seed of *Zoysia japonica,* and *Cynodon dactylon* can be produced in China, seeds would have to be exported for further selection and cleaning and then reimported for end use because of lack of seed cleaning technology and related equipment.

Turf culture in China has developed rapidly at 20% annual growth since 1996.

Since the demand for grass products from East Asia and within China keeps increasing and the price is steady since 1995, the production of forage products has been promoted especially based on *Medicago sativa*. In 2000, the central Chinese government started the "West Development Plan", including returning arable land to pasture and forest on a large scale; this is ongoing. This is strongly increasing the demand for grass, forage and turf seeds. According to statistics, the imported grass seed in 2000 was around 10 000 tonnes and both forage and turf account for 50%. Because of the long term increasing demand for grass seed, China is beginning to invest in their production and since 2001 has set up production bases to promote self-sufficiency. However because turf seed production has high technical requirements, dependence on imports will not be changed in the long term.

Zonation of grassland for sustainable ecological and economic development

The Zone of Grassland Agro-ecosystems is a multiple-component complex that consists of the environment, flora and fauna, social and economic systems in a geographical area and functions as an ordered and structured integration. Natural conditions vary significantly over the vast territory of China and various grassland types and grassland ecosystems have developed in different regions. In these regions grassland exploitation is characterized by different local social and economic factors.

Principle of division of economic zones of grassland agro-ecosystems

The grassland industry, based on a well-functioning grassland agro-ecosystem, can use both native and introduced forages in a large range of varying ecological environments. Therefore, its adaptability to natural characteristics is wider and more flexible than traditional crop production and forestry. Considering the regional characteristics of grassland industry in relation to natural, social and economic conditions, the zonation for sustainable development is based on the following criteria:

1. Similarity of ecological conditions, precipitation and temperature in particular;
2. Similarity of grassland types and landscape;
3. Similarity in grassland production and its structure;
4. Consistency between grassland ecosystems and economic systems;
5. Consistency between grassland policy and critical technology adopted; and
6. Consistency of grassland zones and administrative divisions that provide practicability of regional programming for grassland development.

Grassland zones

On the basis of the above criteria, China's grasslands can be divided into seven ecological-economic zones as follows:

Zone 1: Inner Mongolia-Ningxia Arid Grasslands, which includes the Ningxia Huizu Autonomous Region, the bulk of the Inner Mongolia Autonomous Region and that part of Hebei Province north of the Great Wall.

Zone 2: Northwest Desert Shrublands, which includes Tibet Autonomous Region, the Hexi Corridor of Gansu and Alashan Meng of Inner Mongolia Autonomous Region.

Zone 3: Qinghai-Tibet Alpine Shrublands, including Tibet Autonomous Region, Qinghai Province, the southern part of Gansu Province, the western part of Sichuan Province and the northwest of Yunnan Province.

Zone 4: Northeast Forests, including Heilongjiang Province, Jilin Province, Liaoning Province and the northeast of Inner Mongolia Autonomous Region.

Zone 5: Loess Plateau and Huang-Hai Plain, which covers Shanxi Province, Shandong Province, Henan Province, Beijing and Tianjing Municipalities, the north of Shaanxi Province, the east of Gansu Province, that part of Hebei province to the south of the Great Wall and the parts of Anhui Province and Jiangsu Province to the north of the Huaihe River.

Zone 6: Southwest Karst Shrublands, including Guizhou Province, Chongqing Municipality, the east of Sichuan Province, the southeast of Yunnan Province, the bulk of the Guangxi Zhuang Autonomous Region and the west of Hunan Province and Hubei Province.

Zone 7: Southwest Evergreen-broadleaf Forests-shrublands, including Zhejiang Province, Jiangxi Province, Fujiang Province, Guangdong Province, Hainan Province, Taiwan Province, Hongkong and Macao, the Sichuan Basin, the south of Shaanxi Province Tianshui Prefecture of Gansu Province, the east part of the Guangxi Zuang Autonomous Rejoin, the parts of Anhui Province and Jiangsu Province to the south of the Huaihe River and the eastern parts of Hubei Province and Hunan Province.

Statistical data on local natural and social conditions and agricultural production in each Zone are given in Tables 30–33.

Current grassland situation and proposed strategy for each zone

Inner Mongolia-Ningxia Arid Grassland Zone This is one of the most important pastoral areas in China. Grassland types change from meadow grasslands to typical grasslands, then to desert grasslands from northeast to southwest, with decreasing precipitation. The environment is fragile due to severe desertification caused by frequent gales, coarse soils, overgrazing and poor management. Deserts and desertified lands make up 11% and 18.4% respectively of the land of this zone.

The rich grassland resources have high primary productivity and stocking capacity. Typical grasslands in Hulun Beir Meng and Jirem Meng in the east of the zone are one of the best grassland areas in China, with annual hay yield and stocking capacity of 900–1 500 kg/ha and 0.7–1.2 sheep unit per ha, respectively; desert grassland types are in the Ulanqab Meng, on the Ordos Plateau and in the areas to the east of the Helan Mountain Range, with *Stipa* spp., *Salsola collina*, *Artemisia frigida* etc. as dominant species. Annual hay yield and stocking capacity are 400–600 kg/ha and 0.25–0.40 sheep unit per ha, respectively.

Winter grasslands are scarce, only 30–60% of the warm-season grasslands, so they are heavily grazed and their grazing usually lasts five months, longer than on warm-season grasslands. Significant annual variation in precipitation causes great differences in forage production, which can be as much as four times between a year of good rainfall and a dry one. Crop growing has been expanding to the north, taking over more and more grasslands, resulting in sharpened conflicts in the local society.

Nomadic, extensive management still prevails. With rapid growth in livestock numbers and slow development in establishing artificial pastures in past years, the grasslands have deteriorated seriously under heavy grazing. Shortage of pasture and frequent natural disasters cause heavy losses of livestock: loss, sale and domestic consumption by local herders makes up a third each of the total animal production each year.

In this zone, crop production should be restricted and development focused on livestock, grassland protection and establishment of artificial pastures and integration of crop production with feedlot operation. Feed processing and mechanization of forage production should have a high priority in development planning.

Northwest Desert-shrubland Zone This is the largest of the zones defined in this study; it is in arid and semi-arid desert areas, in most of which annual precipitation is less than 250 mm, with long hours of solar radiation between 2 600–3 400 hr/annum. An extremely arid climate, frequent wind and sparse vegetation are features of the fragile environment (Geography Institute, Chinese Academy of Science, 1983). Sand storms often cause serious

Table 30. Major climate data of each grassland zone

Zone	Annual 0=°C accumulated temperature (°C)	Annual precipitation (mm)	Humidity (K) (mm/°C)
1	2 000–3 000	250–400	0.5–1.4
2	4 000–5 700	< 250	0.1–0.9
3	2 000–1 600	500–700	0.1–4.4
4	1 700–3 500	500–1 000	1.6–3.3
5	3 000–4 800	500–900	1.1–2.1
6	4 000–7 000	1 000–2 000	1.2–3.5
7	4 500–7 500	2 000–2 500	1.6–2.7

Note: K = r/(0.1 sum theta), r is annual precipitation (mm), theta is annual ≥0=°C accumulated temperature (°C)

damage to grassland production. By estimation, desertification and salinization have affected 486 000 km^2 and 1 730 700 km^2, respectively, which account for 21.6% and 47.5% of the total affected land in China.

There are 676 continental rivers in the zone that are fed by melting snows and glaciers in the Tianshan Mountains, the Kunlun Mountains, the Altay Mountains and the Qilian Mountains. These rivers have played an important role in nourishing the development of local oases agriculture for thousands of years. Nowadays, however, only the Yili, the Ertix and Shule Rivers can maintain their supply to the increasing population in the zone, while the others are seriously short of water. Meanwhile, the area of arable land affected by secondary salinization has reached 14.7% and 31.1%, respectively, of the total arable lands in Xinjiang and the Hexi Corridor of Gansu (Ren Jizhou and Zhu, 1998).

The forage yield (dry matter) of the native grasslands is 300 kg/ha in mountain areas, and 300–1 200 kg/ha from sown pastures. It is an indicator of the great potential of grassland productivity of this zone. Livestock production is mainly in the mountains, where serious seasonal imbalance between forage supply and livestock requirement is a major constraint. Very often, in spring, livestock die in large numbers due to fodder shortage. On the other hand, the fodder resources of crop-producing areas in the zone are not used efficiently for there could be a combination of grazing and crop production.

As measures of improvement, artificial pastures should be widely and intensively established in mountain areas to protect against natural disasters. Rotational grazing regimes need to be adopted and measures taken to protect water sources. In desert areas the stocking rate should be strictly controlled, while in oases feed and fodder production needs to be expanded. Livestock can be transferred from mountain areas to oases for fattening which would greatly improve the overall production system.

Zone of Qinghai-Tibet Alpine Shrublands The population here is the smallest of all zones, while the area of natural grassland is the largest. Due to high altitude, average more than 3 000 m, solar radiation in the zone is 50% higher than in neighbouring zones. However, heat resources are less.

Water resources in the zone are unevenly distributed. Annual precipitation is 1 000–2 000 mm, even as high as 3 000–4 000 mm in some places on the southern slopes of the Himalayas and in the southeast of the Hengduan Mountains. It is only about 50 mm in the Qaidam Basin and the northwest of the Qiangtang Plateau (Geography Institute, Chinese Academy of Science, 1983). Annual precipitation is between 500–700 mm in other areas. Many rivers rise on the Qinghai-Tibet Plateau, which is the area richest in hydraulic energy in China. The rivers are mainly in the southeast.

The primary productivity of native natural grasslands is low. Forages from the alpine meadow type are palatable and nutritious, while those from sparse wood and shrub grasslands are of poor quality. Due to the long cold season, windy weather, frequent snow disasters and droughts, the imbalance between fodder supply and livestock requirement is great and so the system has difficulty in resisting the impact of natural disasters. Long-term overgrazing has turned many places on grasslands into Black-Soil-Patches or Sandy Lands (Liu *et al*., 1999; Ma and Li, 1999; Ma *et al*., 1999).

The off-take of a marketable surplus of animal products in the zone is the lowest in China. Measures for improvement that should be taken include strictly controlling the stocking rate, breed improvement, adopting rotational grazing, establishing artificial pastures and accelerating the development of markets for animal products. Meanwhile, the problems of transport, low adoption of new technology and funding for development should be given a high priority in the agenda. Tourism could be integrated into the traditional grassland industry to take full advantage of the resources of beautiful scenery and native Tibetan culture. The zone is one of the least polluted regions in the world, and

Table 31. Major socio-economic data of each grassland zone (1995)

Zone	Land area (104 km^2)	Population (104)	Arable land (104 ha)	Grassland (104 ha)	Theoretical NPP of grassland (106 tonne DM/year)
1	69.77	2 038.87	488.67	5 404.55	255.60
2	222.33	1 999.04	407.81	8 854.78	214.29
3	220.95	918.98	108.25	13 562.62	810.09
4	96.56	10 211.30	1 715.36	2 153.78	122.38
5	97.96	32 398.91	3 243.06	2 610.76	164.71
6	83.50	1 1194.23	749.46	3 134.07	371.42
7	168.48	5 5081.53	2 749.90	3 589.18	436.33
All	959.55	113 843.23	9 491.02	39 309.74	2 374.82

Note: NPP is net primary productivity, calculated by the formula of Li et al. *(1998) and Zhou and Zhang (1996)*

thus there is a potential to produce green foods for the increasing demand for such products on the world market. Sustainable development in local society, environment and economy could be realized through organizing a grassland agro-ecosystem that functions well at all its production levels.(Hu Zizhi, 2000)

Table 32. Agricultural production in each grassland zone (10^8 RMB, 1995)

Zone	Crops	Forestry	Livestock	Fisheries
1	149.60	8.65	95.2	2.82
2	289.57	7.35	89.87	2.34
3	42.30	2.89	46.58	0.16
4	977.70	33.87	485.38	86.05
5	2 720.49	129.17	1 357.90	3.27
6	710.24	82.22	340.75	18.74
7	4 200.10	346.39	2 253.84	861.56
China	9 169.22	611.07	4 671.99	1 298.19

Table 33. Marketable surplus of livestock in the five most important regions (%)

Region	Cattle	Horse	Ass	Mule	Camel	Pig	Sheep
Inner Mongolia	21.3	8.7	8.7	3.2	15.4	62.1	33.4
Tibet	10.8	--	--	--	--	49.1	21.5
Gansu	16.6	4.0	7.1	1.9	13.1	85.2	32.0
Qinghai	11.5	1.3	2.5	1.1	16.2	71.9	23.0
Xinjiang	26.8	16.3	11.9	9.5	14.6	83.6	45.1
China	20.4	9.6	13.9	8.2	14.9	107.1	54.6

Northeast Forests Zone The zone is characterized by adequate rainfall but low temperatures. The major grassland types are meadow grassland, typical grassland, alpine meadow and marsh. The dominant species are *Leymus chinensis*, *Stipa baicalensis*, *Dendranthema maximowiczii* and *Cinnamomum austro-sinense*, with meadows of *Leymus chinensis* as the most important type. Annual forage yield is 1 000–1 500 kg/ha (dry matter) and remains quite stable from year to year. The stocking capacity is 1.5–2.0 sheep/ha

Dairy cattle and milk production in this zone takes first place in China and the grassland industry is integrated with local crop production to use local fodder and feed resources such as crop residues and maize, more efficiently. The strategy for development in the zone is to establish large-scale production bases through increased input and establish close co-operation between agricultural sectors for efficient utilization of resources. Ecologically healthy animal products should be the main output of the production bases.

Loess Plateau and Huang-Huai-Hai Plain Zone The zone is the area with the longest history of agriculture in China. There are many fine native breeds and rich feed resources. In addition to concentrates, silage and urea-treated maize stover have been widely adopted in recent years in beef feedlots which have become a profitable farm enterprise. To meet the demand for fodder, lucerne (*Medicago sativa)* cultivation is expanding rapidly. In Gansu and Shandong, farmers grow *Medicago sativa* (Gannong No. 2 and No. 3, and native or imported cultivars) for hay or selling to the processing company for pellet making. Farmers' income can be increased by more than 15% compared with cereal growing.

The climate is of humid or semi-humid monsoon type, with high consistency between rainfall and biologically active accumulated temperature, and is favourable for agriculture. However, the variation in rainfall between years is large and thus drought is a major problem (Hou *et al.*, 1991). Surface and underground water is insufficient to meet agricultural demand. Average runoff per capita is only about 500 m^3, only a fifth of the national average (Ren and Bao, 1992). The Loess Plateau is seriously eroded, while the Huang-Huai-Hai Plain is dominated by soils of poor quality for agriculture, such as Shajiang black saline soil and heavy sandy soil.

The zone is one of the major areas of forage seed production in China. The forages include *Medicago sativa*, *Melilotus* spp., *Onobrychis viciifolia*, *Sorghum sudanese*, *Astragalus adsurgens*, and *Zoysia* spp. Erosion control and conversion of farmlands to woodlands and pastures should be the major measures on the Loess Plateau for sustainable development. Pasture establishment can be integrated into the planning of small catchment management. In the Huang-Huai-Hai Plain wastelands on sandy river flats and beach areas near the sea can be used to grow pastures for fodder production and soil improvement. Based on established pastures and crop by-products, beef and dairy cattle, sheep and goats can be raised to expand the livestock sector of the local agriculture.

Southwest Karst Shrubland Zone There are 48 ethnic minorities and half of the poverty-stricken people in China live in this zone (Research Group of Sustainable Agricultural Development in Karst Regions of China, Chinese Academy of Engineering, 1999). The karst landforms have widely distributed limestone cliffs and bare stone deserts caused by irrational cultivation, overgrazing and deforestation on mountain slopes. It is estimated that the area of stone deserts has quadrupled in the past 50 years in Guizhou and Yunnan Provinces. This trend of land degradation has been accompanied by serious water loss and soil erosion and, as a consequence, general deterioration of the ecological environment (Research Group of Sustainable Agricultural Development in Karst Regions of China, Chinese Academy of Engineering, 1999).

Natural grasslands are fragmentarily distributed in mountainous areas and are usually difficult to manage. Moreover there are many poisonous plants, with palatable species accounting for only 30 - 60%. Native forage legumes are scarce, but the leguminous shrubs that exist in great number have not yet been utilized. Both overgrazing and under-utilization of local fodder resources exist in the zone.

Water and heat resources are rich here, but radiation is inadequate to support plant growth for seed production (Hou *et al*., 1991). Cereals can be grown but their yield and quality are low. However, local climatic conditions are suitable for making improvement in natural grasslands and establishing artificial pastures by vegetative production (Ren *et al.*, 1999). Sown pastures can have 3–4 cuts, even 6 cuts in some places, annually. Some forages, such as *Lolium* spp., *Stylosanthes* spp., *Trifolium repens*, *Trifolium pratense* and *Dactylis glomerata* grow well under local conditions. Annual hay yield is 3 400~4 500 kg/ha from natural grasslands and 8 000~10 000 kg/ha from sown pastures; on some it was more than 10 000 kg/ha, with 2 133 ha of pastures carrying 12 000 sheep that produced 2.5~3.0 kg clean wool each in a year (Jiang *et al*., 1996 ab).

The development of vegetative agriculture and rational utilization of native leguminous shrubs could be a way to realize sustainable development (Ren *et al*., 1999; Liu *et al*., 1999). The Central Government can provide funds and policy support to speed up the development on the basis of careful planning for rational utilization of local grassland resources. It is the responsibility of the local governments to allocate land-use rights among farm households as a measure to encourage them to establish artificial pastures on mountain slopes and on other types of wasteland.

Southeast Evergreen Broadleaf Forest-shrubland Zone Of all the zones in this study this has the largest population, the most developed economy and the best climatic conditions (Hou *et al*., 1991) (Tables 31 and 32). Natural grasslands are secondary after tropical and sub-tropical forest is cleared (Yu *et al*., 1996). Their annual hay yield is 2 000~3 000 kg/ha, but quality is usually poor. Productivity could be increased by 5~8 times if improvement measures are applied (Yang *et al*., 1997).

Traditionally green manure is grown on local farms, so it is easy to establish a new rotation scheme between paddy rice and commercial fodder production in the zone to realize better economic, ecological and social benefits. According to a study by Yang *et al*. (1997 ab) in Guangdong Province, rotation of Italian ryegrass (*Lolium multiflorum*) and rice increased the content of organic matter, total N, available N, biomass of micro-organisms and enzyme activity in the soil. These, in turn, increased the yield of early rice and late rice by 10% and 7%, respectively; furthermore, the annual forage production was worth RMB 15 000. The current area used for forage can be expanded in existing farming systems with available techniques. The processing industry needs to be developed for producing high-quality animal products with high added value.

The economic zone of the grassland agro-ecosystem is a kind of integrating system between Grassland Industry, Crop Production and Forestry. It is a multi-component complex of ecosystems in a large geographical area, involving various economic and social activities. The theory of system joining can be used to guide in planning and implementing development programmes in these zones for achieving sustainable economic, social and environmental benefits (Ren and Wan, 1994).

System discordance occurs when exchanges between system components or sub-systems are hindered. It usually takes the following forms (Ren and Zhu, 1995):

1. temporal discordance such as seasonal discordance between forage growth and livestock requirements;
2. spatial discordance between fodder supply and demand taking place in different regions;

3. interspecies discordance such as the discordance between forage species and the needs of different species of livestock.

Experience has proved that realization of system pairing between different zones or between subsystems in the same zone is the key to solving the problems (Ren and Zhu, 1998). If pairing is successful, the productivity of the systems as a whole can be greatly increased and the results are more likely to be sustainable (Ren and Wan, 1994).

China's population is 1 286 000 000 now and will be 1 385 000 000 by 2010. According to the government plan for the livestock sector, the annual output of meat, eggs and milk should be increased by 19.59%, 22.22% and 100%, respectively, by 2010 in comparison to 2000. Achieving these goals means that the productivity of the grassland industry must be 24.8 animal product units per hectare in 2010, therefore, it also means that measures must be taken to improve existing natural grasslands and establish artificial pastures on a large scale. In addition to pairing between different systems, pairing should be realized between different production levels, so that free flows of material inputs and information can be maintained between the levels.

7. RESEARCH AND DEVELOPMENT ORGANIZATIONS AND PERSONNEL

There are 23 organizations related to grassland and grass research in China, of which six national institutes are affiliated to the China Agricultural Academy and China Academy. Òf 36 agricultural universities, 16 can provide four-year bachelor education on grassland science. Gansu Agricultural University, Inner Mongolia Agricultural University, Xinjiang Agricultural University, China Agricultural University and China Agricultural Academy are authorized to provide a Ph.D. programme. The top-level technical extension organization in charge of grassland management and fodder production is the Animal Husbandry and Veterinary Medicine Station of China's Agriculture Ministry. Accordingly, each province has a Grassland Station or Forage Grass and Forage Crop Extension Station. Each county has an Animal Husbandry and Veterinary Medicine Station at county level or a Grassland Station where the grassland area is large.

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[The profile was edited by J.M. Suttie and S.G. Reynolds in April/May 2002 and some livestock data updated in October 2006 by S.G. Reynolds.]