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Use of rural energy resources and eco-environmental degradation in Tibet

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Abstract: Cattle dung, firewood, and crop straw have being used as survival necessities by farmers and herdsmen for thousands of years in Tibet. Until recently such biotic energy source still constitutes more than 92 per cent of total rural energy consumption due to lack of petroleum, coal and new alternative energy sources. As a result, environmental degradation such as land desertification, soil erosion, grassland degradation and soil fertility reduction is increasingly aggravated, the area of desertified land has increased 1467.5 km^2 from 1991 to 1997. Degraded area of grassland has reached 2.60×10^7 hm^2, increased by 116.1% from 1987 to 1996. To prevent further deterioration of eco-environment in Tibet great efforts should be made to make full use of ample solar energy, wind energy and other biotic energy of the Qinghai-Tibet Plateau. The solar cooking stoves and solar hothouse, expand forest area and replace existing abiotic energy sources with firewood forest should be popularized. This is an urgent task to protect the eco-environment of Tibet today.

Keywords: energy sources; eco-environment; degradation; rural; Tibet

Introduction

Reported as the third pole of the earth (Zheng, 1996), the Tibet region is the main body of the Qinghai-Tibet Plateau. It crosses 9°50′ of latitude from south to north and 20°30′ of longitude from east to west, with a vast area of 1.2 million km^2 and a high average elevation of over 4000 m. The plateau's uplift makes its eco-environment variable and unstable (Li, 2000). In the meantime, it is also endowed with the environmental features of high altitude, cold and dry climate, low oxygen content and strong solar radiation. Such environmental features lead to the very high population-resource-environmental sensibility.

Fuel is essential consumer goods of the Tibet Plateau with harsh natural condition. Over the last few thousands of years farmers and herdsmen in Tibet have been relying upon cattle dung, firewood and crop straw to cook food and warm them. Until now, many people, especial the most farmers and herdsmen use these biotic energy as their essential fuel of life due to the limitation of economic condition, energy resources and traditional custom and such fuels generally occupy 92% or more of their total energy consumption. With rapid increase in population, biotic energy sources are being overused, and excessive depletion of biotic energy sources has become a main factor responsible for eco-environmental degradation in Tibet (Min, 2001; Li, 2000; 2001; Liu, 1999; 2001; Zhang, 2001a; 2001b).

In this paper, based on investigation of the status of energy resources consumption of over 30 families in each serious desertification regions (e.g. Shannan Prefecture, Xigaze Prefecture, Arli Prefecture, Nagqu Prefecture) and five times field investigation and thematic map data of 1991 and 1997 about desertification in Tibet, in addition, the results of soil and vegetable changed and control technologies of desertification land in Xigaze and Nagqu, our purpose is to discuss the status and trend of consumption of biotic energy and to determine it's effects on eco-environmental degradation in Tibet's rural and set prevention strategy.

1 Status of fuel use structure and trend in farming and grazing regions of Tibet

Owing to backward energy industry, underdeveloped rural economy and thousand-year-long traditional custom, farmers and herdsmen in Tibet still use biotic fuel as their main energy source, as shown in Fig.1, although petroleum, electric power and solar energy have been widely used in other regions. With the growth of rural population (Fig.2), people's demand for fuel is continuing to increase, calculated on the coal equivalent, the consumption of biotic energy source in the 20-year period from 1980 to 2000 increased by 100353 t, or an increase of 8.74%; and other energy sources (oil, electric power and solar energy) increased by 87181 t, or an increase of 539.85%. However, the consumption of biotic energy sources has always accounted for over 92% of the total energy consumption, dominated by cattle dung and firewood (Fig.3). Therefore, Tibet is the only region in China in which uses biotic fuel as the main energy source in the socioeconomic development. Owing to climatic difference, the distribution of vegetation resources is different from place to place and the proportion of cattle dung, firewood and crop straw in different regions is also different (Table 1). Total, the farmers and herdsmen consume 979447 t of cattle dung, 884120 t of firewood and 171034 t of crop straw in rural of Tibet every year. The consumption of biotic energy source is still increasing due to population growth but its proportion decreased by 6.8% in

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the 20-year period, and per capita consumption also decreased from 0.733 t in 1980 to 0.549 t. From 1990 onwards, the consumption of abiotic energy sources greatly increase, in 10-year period it increase to 79330 t, an annual increase of 33.0%, but it still occupied a small percentage of 7.65% in the total energy consumption. In 10-year period electric power significantly increased and is mainly used for indoor lighting. In addition, the consumption of solar energy in 10-year period increased by 6829 t or annual increase of 16.65%, mainly used to cook food and warm houses. Owing to lack of coal and oil resources and relatively backward economy in Tibet, large-scale energy development is seriously affected and most of farmer and herdsman cannot afford new energy equipments, hence central government should allocate more funds to develop new energy source. Viewed from present developmental trend, at least 20 years or more are required to replace the region's biotic energy sources.

Table 1 Status of rural consumption of biotic energy in degraded regions

Region	Population of rural	Consumption per capita, kg			Total consumption, t		
		Cattle dung	Firewood	Crop straw	Cattle dung	Firewood	Crop straw
Grazing region of north Tibet Plateau	328764	0	0	0	369859	0	0
Half-farming and half-grazing region	280000	550	200	80	154028	56010	22404
Farming region in central Tibet valley	832000	380	300	120	316160	249600	99840
Forest region in southeast Tibet	697000	200	650	70	139400	578510	48790
Total	2137764				979447	884120	171034

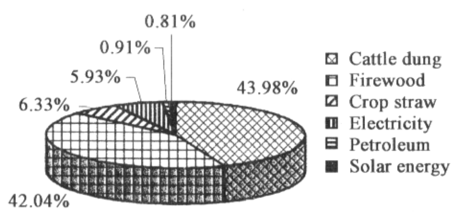

Fig.1 Rural energy source consumption composition in the year of 2000, Tibet

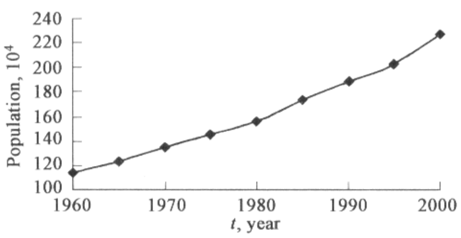

Fig.2 Variations of rural population in Tibet

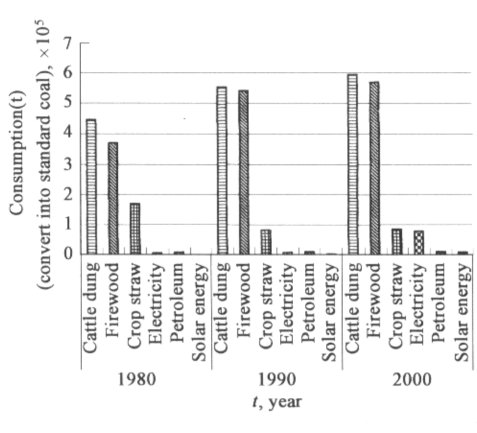

Fig.3 Consumption of different energy source in Tibet's rural

2 Ecological problems caused by biotic resource use

According to the total consumption of biotic energy, there are about 853280 t of organic C was emitted into the air from burning every year. Rapid population growth and excessive use of biotic energy sources lead to and exacerbate the degradation of eco-environment of the Tibet that is located in the fragile ecological zone(Li, 2000; 2001).

2.1 Desertification exacerbation

Shrub vegetation such as *Form. sophora moorcroftiana* and *Form. caragana maximovicsiana* as the most important vegetation community type in the middle basin of the "One River and Two Tributaries" plays a very important role in the regions eco-environment (Chen, 1997; Shen, 1997; Zhao, 1994). Due to lack of other firewood resources, such sparse shrubs become farmers' and herdsmen's most widely used fuel source. In autumn farmers and herdsmen dig and store large amount of *S. moorcroftiana* and *C. maximovicsiana* for cooking and heating in winter. As a result, shrubs around residential areas almost entirely destroyed. Even more serious is that grubbing out shrubs make root propagation impossible. In general, 4 years after seed germination *S. moorcroftiana* can reach a height of 50 cm (Zhao, 1994), while *C. maximovicsiana* grows even more slowly. In the farming area in the central Tibet valley people consume about 20807 t of firewood per year, this leads to the destruction of 32143.3 hm^2 of shrubs. Wind tunnel experiments showed that under the action of wind force 10 for 15 min on undisturbed soil surface without cutting of *S. moorcroftiana* vegetation about 0.34 kg of soil was eroded; when 30% of vegetation was removed, soil deflation amount was 1.46 kg; when 60% of vegetation was cut down, soil deflation amount was 4.68 kg; as all vegetation was cleared, soil deflation amount was 9.12 kg (Dong, 1996). Serious wind erosion leads to the exacerbation of desertification in the region (Li, 2001; Zhang, 2001b). According to the result of desertification monitoring in Tibet Autonomous Region, in 1991, about 199743.5 km^2 of productive land have became desertified land, accounting for 97.5% of arable land area, and 58.7%

of which occur in the densely populated river valley basin, in 2001, the area of desertified land has became 201895.5 km^2, annual increase area was 209.64 km^2 (Table 2).

Table 2 Area Changes of desertified land and potential desertified land in Tibet

Prefecture	Total land area, km^2	1991				1997				Annual average increasement	
		Desertified land		Potential desertified land		Desertified land		Potential desertified land		Area, km^2	Annual increasement, %
		Area, km^2	%	Area, km^2	%	Area, km^2	%	Area, km^2	%		
Nagqu	392139.9	100270.2	25.57	10498.9	2.67	101871.9	25.98	9574.3	2.44	+676.8	0.087
Arli	296842.2	60506.7	20.38	1332.5	0.45	60287.2	20.31	1884.6	0.63	+332.7	0.077
Xigaze	181615.9	33150.7	18.25	915.6	0.50	33822.6	18.62	731.8	0.40	+488.1	0.203
Shannan	79410.8	1759.7	2.21	231.7	0.29	1847.0	2.32	216.3	0.27	+71.6	0.506
Qamdo	108780.4	1502.8	1.38	478.6	0.44	1523.0	1.40	427.1	0.39	-31.2	-0.227
Lhasa	29533.6	1695.8	5.62	152.2	0.51	1652.3	5.59	116.0	0.39	-79.7	-0.628
Nyingchi	114669.9	857.6	0.75	42.1	0.04	891.6	0.78	17.2	0.02	+9.2	0.145
Total	1202996.5	199743.5	16.60	13651.8	1.13	201895.5	16.78	12967.3	1.08	+1467.5	0.097

In Shiquanhe township, a capital of Arli Prefecture, because no other energy source exists, people can only rely on the basin's dominant shrub vegetation—*Form*. *Myricaria elegans* for their livelihood. They dig out plant roots as fuel or even use bulldozers, trucks and explosive to gather firewood. As a result, *M*. *elegans* shrubs almost entirely disappeared within the range of 80 km from the upper and lower Shiquanhe River course in less than 10 years, shifting sand has moved over many courtyard walls. Especially during April to May of every year, when a fierce gale comes, sand and dust are swept over the surface and lifted high into the sky, people have to shut their doors so as not to venture out.

2.2 Soil erosion aggravation

Natural forest area in Tibet is decreasing at a rate of 8700 hm^2 per year, in the meantime, increased artificially afforested area compensates one half of the lost area. The destruction of alpine vegetation accelerates soil erosion process, especially in the southeast Tibet and the midstream area of the Yarlung Zangbo River. Soil erosion area in the middle reach (Lhaze and Gyaca section) of the Yarlung Zangbo River occupies over 80% of its drainage area. Intensely developed debris flow area in southeast Tibet has reached 130200 km^2, with a debris flow density exceeding 50 sites/100 m^2 (Zhang, 2001b).

The distance of shrub forest *Sabina pinkie var*. *wilsonii* which widely distributed on the south slopes of the Nyainqentanglha-Gandise Mountains in Xaitongmoin County in Xigaze City from upper to the lowest has decreased by 150 km after 70 years of cutting from 1930s to 1999. Shrub forest on slopes at both sides along the 19 km long Jiangxiong Gully in Gonggar County of Shannan Prefecture has entirely disappeared and thus caused flash flood in July of 1998, which flooded 81% of the region's cropland and flood-hit area reached 330.2 hm^2 (Guan, 1991).

2.3 Soil fertility reduction

Total annual dry cattle dung output in agricultural region and half-farming and half-grazing region of Tibet is estimated at 1164861 t and about 4701188 t of which are burned each year, accounting for 40.36% of its total. Total cultivated land area in Tibet is 238684 hm^2 and application rate of organic manure averages 2.91 t/hm^2. Although the application rate of chemical fertilizer has reached 112.45 kg/hm^2 in 1998 (Statistic Bureau of Tibet Autonomous Region, 2000), calculated in terms of N, P and K outputs of farmland ecosystem (Wang, 1995), at least an application rate of cattle dung of 6.01 t/hm^2 is required to keep the energy flow balance of farmland. Organic manure shortage of 739000 t/a leads to farmland degradation. According to the soil fertility investigation in 1985, soil fertility significantly reduced compared with the fertility level in 1953, in the same farmland organic matter decreased by 47%—93% and total N content reduced by 28.6%—37.9% (Guan, 1991). There are about 30700 hm^2 farmland has suffered from desertification, accounting for 13.8% of total farmland area.

2.4 Grassland degradation

Grassland area in Tibet is 8.12×10^7 hm^2, accounting for 71.15% of its total land area, of which high-cold steppe grassland and high-cold meadow grassland occupy 38.9% and 31.27% respectively (Land Management Bureau and Animal Husbandry Bureau of Tibet Autonomous Region, 1994). Owing to the influence of high-cold climate, high-cold meadow soil exhibit a significant Soddy humus accumulation process but decomposition and mummification of organic matter are weak. Such soil has a higher fertility but its nutrient availability is poor. Due to lack of available N and P, grass growth can be affected during grass vigorous growth period (Le, 1980; Yang, 1980). Under moderately grazing condition N consumption of grass is 17.7 kg/($hm^2 \cdot a$) (Zhou, 2001). Soil N loss caused by animal grazing can be compensated by animal dung and urine through organism decomposition and rainwater leaching, and adequate increase in available nutrients contributes to increase grass cover and enhance grass yield (Semmartin, 2001) and maintain soil nutrient balance (Augustine, 2001). Cattle dung collection results in large N output than N input and soil fertility reduction, thus further promotes grassland degradation. Fixed site sampling and analysis in Nagqu County during 14-year period from 1988 to 2002 showed that soil organic matter content at the same site decrease by 11.6%, total N, P and K decreased by 17.03%, 54.42% and 17.49% respectively (Fig. 4). In 20 years from 1960 to 1980 grass yield decreased at an annual rate of 2.5%, while from 1980s to 2001 grass yield decreased at an annual rate of 2.8%. By 1987 degraded grassland area in Tibet reached 1.203×10^7 hm^2, accounting for 14.83% of Tibet's total grassland area (Land Management Bureau and Animal Husbandry Bureau of Tibet Autonomous Region, 1994). By 1996 degraded grassland area in Nagqu that occupies 41.6% of Tibet's total grassland area reached 1.365×10^7 hm^2, 2.84 times the degraded grassland area of 1987 (Liu, 1999). Degraded grassland area in Tibet has reached 2.60×10^7 hm^2, accounting for 32.1% of its total grassland area, and in the 9-year period degraded grassland area increased by 116.1%.

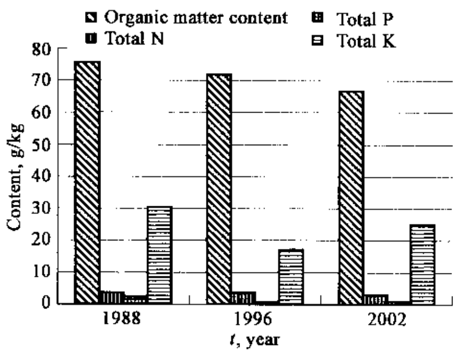

Fig.4 Fertility changes of surface soil (0—10 cm) of alpine meadow

3 Countermeasures

3.1 Quickening the development and use of new energy sources

Tibet is short of petroleum and coal resources but has abundant light energy, waterpower, geothermal energy and wind energy.

3.1.1 Widespread use of solar energy

Tibet ranks first in China in solar energy resource, it is also one of the regions with most abundant solar energy in the world. Due to thin air and high transparency annual duration of sunshine varies between 1600—3400 h, average annual number of days with a sunshine time exceeding 6 h ranges from 275—330 d, annual mean total solar radiation amounts to 7000 J/m^2, and therefore solar energy in Tibet has a bright application prospect. Solar energy development in Tibet mainly serves for lighting purpose. From 1980 to 2002 some 10 photovoltaic power stations have been set up in 7 counties in Tibet, with a power capacity of over 2 MW. In addition, solar cooking stoves and solar hothouses are being popularized in cities. Thus far about 91000 solar cooking stoves have been put into use, but only 180000 m^2 of hothouses, greenhouse and hot pens were set up. In winter as outdoor temperature reaches −25℃, temperature in hothouse could reach 9℃, with a maximum indoor-outdoor temperature difference of 35℃. If solar hothouses are widely adopted, there will be no need to make fire for heating in winter in most of regions in Tibet, or only make fire for heating in a few tens of days. However, such high-cost structures can only be used in cities and by rich family. Calculated based on annual cost of 5.95 dollar or so for a solar cooking stove (2 m^2), in 300 working days of a year can a family save about 1.11 t of cattle dung or firewood (Hu, 1995), in fact this is a receivable cost for most families in faming and grazing regions in Tibet. If 70% of families in farming and grazing regions of Tibet use solar cooking stoves, in total 369600 t of cattle dung or firewood can be saved, and the cattle dung consumption would be decreased by 28.26% compared to present consumption level.

3.1.2 Use of geothermal resources

Tibet is a strongest geothermal activity zone in China. More than 1000 geothermal sites are widely scattered all over the region, of which the Yangbajain is China's largest high-temperature geothermal vapour field, also one of the largest geothermal fields in the world. Yangbajain geothermal field covers an area of 17.1 km^2, with a hydrothermal temperature of 93—172℃, yearly released heat is equivalent to the heat energy released from 470000 t of standard coal. Its power generation potential is about 150000 kW, while present installed capacity is only 10646 kW, or an utilization factor of 7.09%. If 50% geothermal resource can be used for cooking and heating in the countryside, the use of Yangbajain geothermal source can save about 365600 t of firewood per year and the firewood consumption would be decreased by 27.96%.

3.1.3 Wind and water power generation

Theoretically potential water power resource in Tibet is about 2×10^6 MW, and annual energy output is 1.76×10^{12} kWh, accounting for 29.7% of the country total. According to preliminary investigation, exploitable water power is 5.66×10^7 kW, and annual energy output is 3.3×10^{11} kWh (amount to 1.32×10^8 t of standard coal), accounting for 17.1% of the country total. Potential wind power resource in Tibet is 9.3×10^{10} kWh. In the north Tibet where wind power resource is richest average annual effective wind energy density could reach 200 W/m^2. If 10% of existing water and wind power resources are exploited and 5% of which are used for cooking and heating in countryside, that amounts to 8.45×10^6 t of standard coal, about 1.32×10^6 t of firewood can be saved.

3.2 Increasing firewood forest area

Establishing protective forest is a rapid, effective and low-cost measure to solve energy shortage issue in countryside. Especially in the " One River and Two

Tributaries" basin and three-river (Nujiang River, Lancang River and Jinsha River) basin in southeast Tibet suffering from severe desertification, establishing protective forest not only can offer sufficient firewood but also can arrest desertification and soil erosion. In Shannan Region an forestation project was initiated at the end of 1980s in the seriously desertified area in the middle reach of the Yarlung Zangbo River, the establishment of 150 km long protective forest belt, 17000 hm^2 in area, along the river has effectively halted the exacerbation of desertification and provided about 25000 t of firewood from pruning each year, on an average, each farmer in three counties (Zhanang, Nedong and Gonggar County) along the river could get 198.2 kg of firewood, accounting for 79% of their total firewood consumption. Up to now, cultivated forest area in Tibet is only about 43900 hm^2 and firewood forest proportion is less than 10%, this is far from meeting the rural energy demand. Hence, forest culture in desertification regions is not only protecting grasslands from wind erosion, but also provide abundant fuel resources for local dwellers.

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Correction:

In this journal, Vol. 16, No. 5, P. 811 "Plasma induced degradation of Indigo Carmine by bipolar pulsed dielectric barrier discharge (DBD) in the water-air mixture" by Zhang Ruo-bing *et al*., Fig. 8 should be corrected as follows: