Towards Sustainable Agriculture in a Marginal Area

A Case Study in Tibet

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1. Abstract

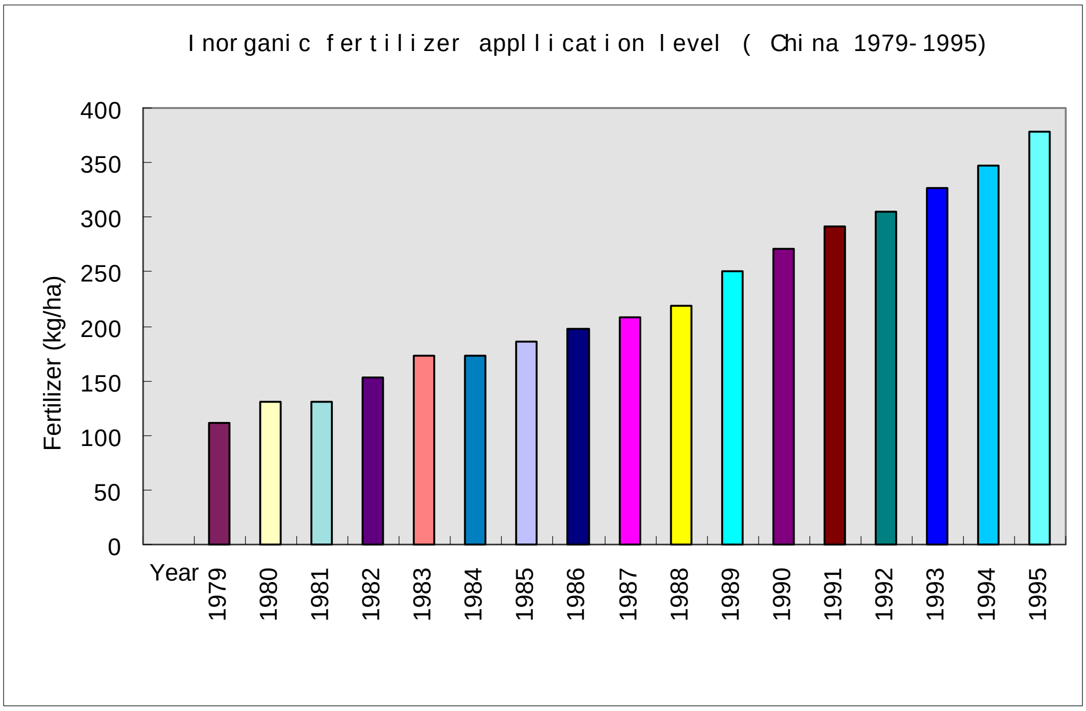
Fossil fuel-based agriculture is unsustainable because of the decreasing efficiency of this input-intensive paradigm, its undesirable effects on the environment, and its finite nature of input supply. However, primitive, organic farming system does not naturally lead to sustainable agriculture either. This paper analyses a primitive agricultural system in Tibet, a place characterized by sparse population, plenty of resources, and a fragile environment. Firstly, the paper explores the specific man-nature relationship in the Tibetan physical-social context. It has been found that the increasing demand for food and fuel influences both the environment and sustainability. Three subsystems are discussed: man-arable land, man-forest, and man-livestock-pasture. Through subsystems analysis, it has been found that the system is experiencing increasing resources inefficiency, environmental degradation, and social poverty. Secondly, the problems resulting from lacking sustainability are identified, including unfavorable natural conditions, primitive technology and management, and lack or failure of necessary social and economic infrastructures. Finally, a set of measures is recommended to change the current agricultural system towards a sustainable one. But it is stressed that it may take a very long time to realise this shift and that this may have an important effect on the Tibetan society.

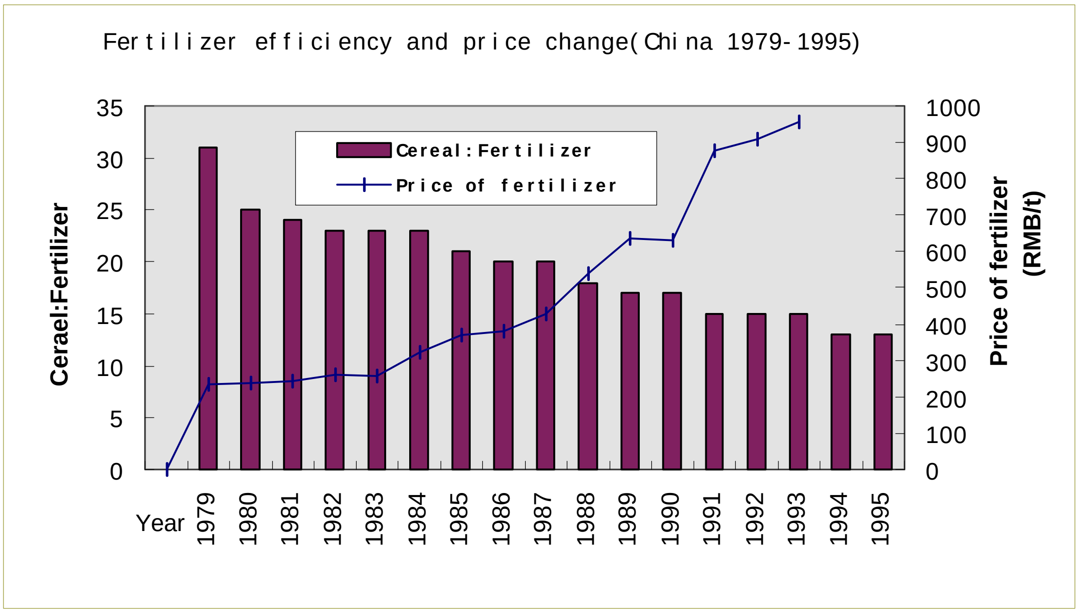
Keywords: sustainable agriculture, Tibet.

2. Introduction

Over the past three decades, the concerns about conventional, technology-based, and energy-intensive agriculture is deepening, while the interest in sustainable agriculture is increasing rapidly. Industrialized nations are making such a shift principally based on the consideration that increased cost and uncertain availability of energy and farm chemicals make conventional agricultural less profitable and more vulnerable. The energy crises of the 1970s demonstrated that loss of sustainability is not only a theoretical possibility for the future, but a reality.

Ecologically and environmentally, the continued use of chemical fertilizers has increased soil erosion and decline soil productivity. Increased resistance of weeds and insects to herbicides and insecticides, combined with the destruction of wildlife and beneficial insects by pesticides may trigger a new vicious cycle both economically and ecologically. As a result of the intensive use of chemicals in agriculture soil and water are more and more contaminated, human beings are faced with the dilemma of consuming unsafe food and drinking polluted water, or spending extra money to restore the damaged environment. From the natural resources perspective, fossil fuel and other chemicals are non-renewable, thus, the depletion of finite reserves of concentrated plants nutrients is only a matter of time. At present and in foreseeable future, there are no substitutes that can replace these depleted resources. Therefore, it seems sensible to consider alternative approaches, like sustainable agriculture. However, many developing countries have attempted to produce sufficient food to fulfill the needs of their increasing populations. This forces them to apply more chemicals to their land because it is effective in the short term.





Currently about 17 million people are added to China's already very large population each year, and food security is logically one of the most important national concerns. Chemical fertilizer application increased by more than 230% in the last 17 years (1979-1995), i.e. from 11 million tons (m.t.) to 36 m.t. Meanwhile, grain yields increased by 40%, from 332 mt. to 467 m.t. This increase is politically successful: it accounts for more than 95% of the national grain consumption. However, the development is vulnerable economically and ecologically. In 1995, China's chemical fertilizer use was 284 kg/ha, nearly triple the world's average level (97kg/ha). The ratio of chemical fertilizer (input) and grain yield (output) declined from 1:31 to 1:13. In contrast, chemical fertilizer prices increased by 305%, from 236 RMB/t to 955RMB/t. Together with the reduction in fertilizer efficiency and increase in fertilizer price, farmers' economy deteriorated. Formerly, the central government stimulated grain production with incentives like supplying cheaper fertilizers and raising purchasing prices, the Chinese government now begins to rethink its agricultural policy (China's Agriculture Development Report, 1996). As a consequence, eco-agriculture is now greatly appreciated in China.

The problems of fossil fuel-based agriculture have alerted both the developed and the developing countries. However, the problems associated with conventional 'organic-based' agriculture seem to be neglected. This raises a question: Will conventional, primitive, organic-based agriculture naturally lead to sustainable agriculture? This paper takes Tibet as an example, explores its problems and discussed the necessity to shift towards sustainable agriculture.

3. System Description

This paper considers Tibet as a system. Since there have been some reports about its biophysical and socioeconomic conditions (Li Wenjua and Kk. Pandey, 1985), only basic elements will be discussed. The basic structure of the system can be modeled as in Figure 1.

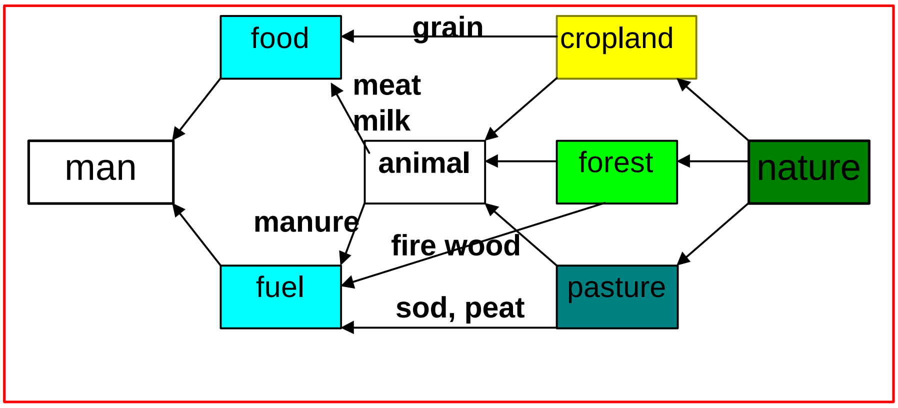


Figure 1. System structure and major components (man as a consumer).

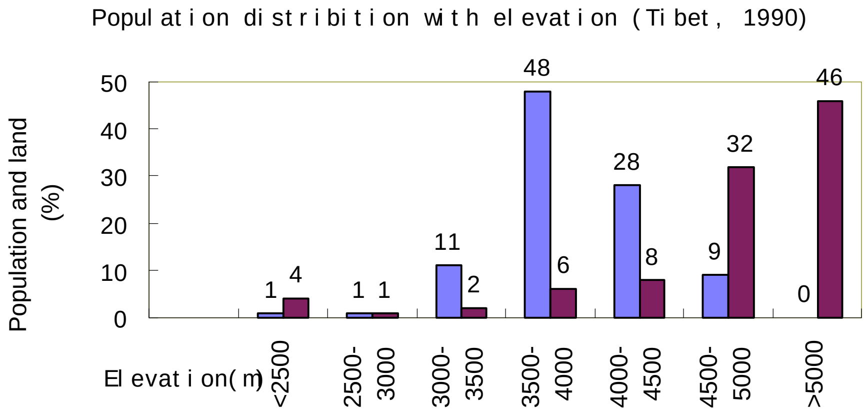
3.1 Geographical Location and its Implications

Tibet is situated in China, with an area of 1.2 million km^2 and a population of 2.39 million (1995). Geographically, Tibet occupies the major part of the Qinghai-Xizang Plateau (the Roof of the World), ranging in attitude from 110m near the Yalazabujiang River, to 8848.13m (Mt. Qomolanmo or Sagarmatha). Some 86% of its territory lies above 4000m, more than 50 peaks are over 7000m and 11 peaks over 8000m. Two aspects characterize this remote highland. Firstly, this is a semi-closed system. On the one hand, it is difficult for the system to communicate with outside world. Even though a road network has been developed since the 1950s that connects almost every city or country with the outside world, it is still quite costly and time consuming transport large amount of goods. On the other hand, the road systems are even poorer inside Tibet, partly due to its relatively large territory and small and scattered population. Historically, major trade (barter) practices were importing salt and tea exporting rare Chinese medicine and animal products. Secondly, this is a vulnerable system. Table 1 shows that 76% of the population lives between 3500m and 4500m; this highland zone is also the major area to cultivate cropland, to log wood or collect firewood, and to graze livestock (pasture may extend to 5400m in the warm season). Because of its high elevation marginal most humans, animals and plants, are actually living in a marginal environment.

Table 1. Population distribution with elevation (1990, calculated by county)

Elevation	County	Population		Land		Population. Density
(meter)		(1000)	%	(1000 km^2)	%	(persons/km^2)
<2500	2	32	1	53	4	1
2500-3000	2	40	1	15	1	3
3000-3500	8	247	11	30	2	8
3500-4000	29	1057	48	74	6	14
4000-4500	23	612	28	103	8	6
4500-5000	8	208	9	393	32	1
>5000	0	0	0	562	46	0
Total	72	2196	100	1229	100	2

Source: Doujiouzu (1994), The population of China towards the 21st century – Tibet.



3.2 Population

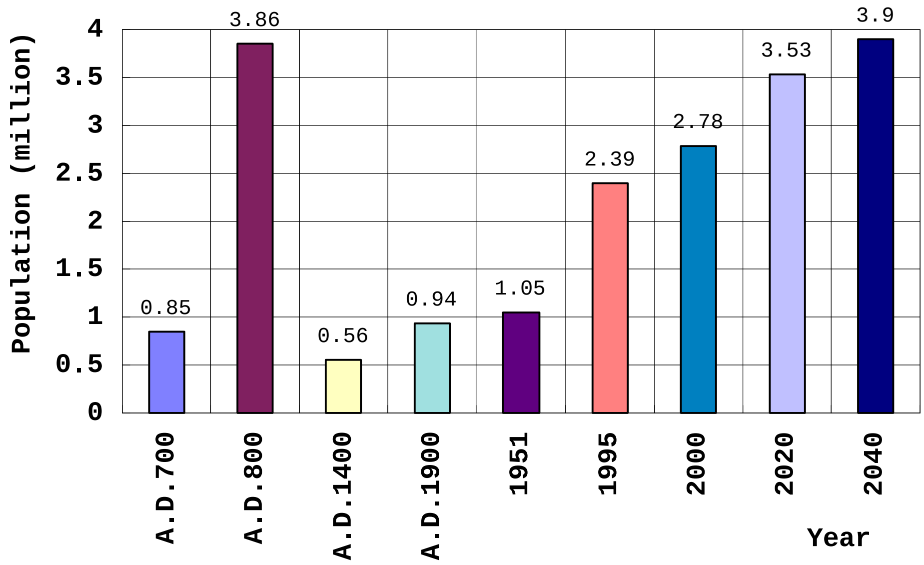
In 1995, the population of Tibet was 2.39 million, 96% of which were Tibetan. Liu (1986) and Li (1994) estimated that the population numbered 3.61-3.86 million in Tibet in the 7th century, when Tufan conquered other small tribes and built the first united kingdom (Table 2). However, this lasted only about 100 years; the population had decreased to 0.56 million at the time of the collapse of the kingdom. There are various explanations, for this dramatic change such as wars, epidemics or migration of the population, but few researchers have mentioned the possibility of unsustainable land use. We have evidence that the Tibet Plateau became drier in the last 5000 years (Tibet's Vegetation, 1988). The large amount of stone tools discovered in northern Tibet (today, this is an uninhabited region due to the extremely dry and cold environment) indicate that this region could have been productive rangeland 5000 years ago. However, this is a very slow process and unlikely to have a dramatic effect on population numbers.

At present the population of Tibet grows again since the 1980s. The population growth rate increased from 12.38 ‰ in the middle 1990s. Meanwhile, the population growth rate of the whole of China increased from 12.80 ‰ to 9.66‰.

Table 2. Population of Tibet in different periods (millions)

Historical estimates					Statistics		Projections		
Time	A.D.700	A.D.800	A.D.1400	A.D.1900	1951	1995	2000	2020	2040
Liu, 1986	0.85	3.86	0.56	0.94	1.05	2.39	2.78	3.53	3.9
Duo, 1994	0.9	3.61	0.64	0.94					

Population dynamics (Tibet,700-2040)



3.3 Resources

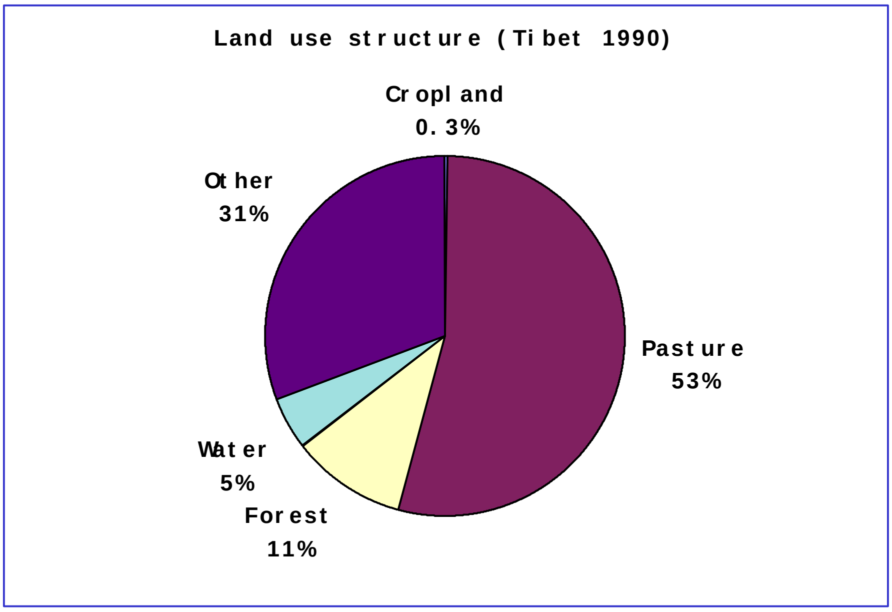
There are two major issues with respect to natural resources. Firstly, there are limited occurrences of fossil fuel in Tibet, which means that Tibet's agriculture cannot be a fossil-based system. Other renewable energy resources are relatively abundant, but have not been exploited effectively due to various limitations. The theoretical hydroelectricity reserve is 198 mkw, of which 60mkw can be exploited, accounting for approximately 1/3 of China's potential. By 1995, the hydroelectricity capacity installed was only 0.01mkw. Solar energy s about 180 Kcal/cm^2.day for most of the area. Windy days over scale 5-8 number 120-150. Some 4300 geothermal fields have been identified with 0.55 mkw/s potential, some are exploited for electricity.

Secondly, there are plenty of renewable land resources. Table 3 presents the land use structure by acreage. Tibet is the second largest province (autonomous region) in terms of forest area and also one of the five largest pasture regions in China. Compared with the average Chinese, a Tibetan possesses 44 times more forested land, 77 times more pasture land, 7 times greater water resources, and 94 times more timber stock.

Table 3. Tibet's land resources (1990)

	Total	Cropland	Pasture	Forest	Water	Other
Tibet (million ha) (%) ha/capita m3/capita	120.48 100 50.41	0.36 0.30 0.15	64.8 53.78 27.11	12.65 10.50 5.29 872	5.61 4.65 2.35 19600	37.06 30.77 15.51
Whole China ha/capita m3/capita	0.96	0.08	0.35	0.12 9	2700	

Source: Cu (1990), Tibet's Land use Report



3.4 Environment

Tibet has still the cleanest environment of all Chinese regions in terms of industry-urban standard. However, its agricultural environment is degrading. There is no comprehensive evaluation of the agricultural conditions because data are very limited and outdated. But there are some reports for specific areas and for specific problems. For example, cropland or over 15 degrees slope still accounts for 15% of the total area and in subject to erosion in summer. Slash-and-burn is still a popular practice in remote regions, which constitute 2/3 of the cropland in Bomi County, for instance. Loss of soil fertility is a problem for most cropland; for example, the soil organic matter of cropland nearby Lahsa decreased by 20% in last two decades. Croplands, which are usually confined to valley areas, are frequently threatened or damaged by flooding. The forest area is shrinking due to increased gathering of fuel wood, timber mining, and unsuccessful reforestation, so that people have to spend more time to collect firewood. An experienced local official stated that firewood collecting shifted to even higher places and the types of firewood on the local market have changed recently. It is estimated that about 1/3 of the range lands have degraded since 1950s. In northern Naqu, one of the major pasture areas in Tibet, grass yields decreased by 50-60% from 1960s to 1980s, and less and unpalatable species increased by 20-30% in the same period. It is also reported that the average animal size decreased by 30-50% over last three decades, both in northern Naqu and eastern Bengda (field interviews). Advanced techniques are needed to monitor such environmental changes because traditional field survey cannot supply timely and geographically accurate data.

3.5 Problems Confronting the Current System

The present system has the following problems:

Economic Vulnerability: Financial revenue and its structure may be used as a general indicator for a system's economical viability. Tibet's revenues are composed of two parts: local income and income obtained from central government support. Although local income increased 80fold from RMB 3 million in 1952 to 215 million in 1995, local expenditures increased 289fold, from RMB 13 million to 3761 million. Table 4 shows that local income only plays a minor role in Tibet's economy.

Agriculture is an important part of rural Tibetan economy. By 1995, the income from cropland, forest, and pasture land constituted 83% of the income in rural areas (48% for pasture, 33% for cropland, 2% for forest). However, generally land productivity became very low (table 5).

Table 4. Financial revenues and expenditure (1952-1995)

Tibet revenues (millions)				b/Total
Year	Total	a: Local income	b: Central government support	(%)
1952	13	3	10	77
1960	129	102	27	21
1965	140	22	118	84
1970	162	-21	183	113
1975	262	-30	292	111
1980	541	-60	601	111
1985	997	-60	1058	106
1990	1262	18	1244	99
1995	3741	215	3134	83

Source: Tibet's statistics yearbook (1996)

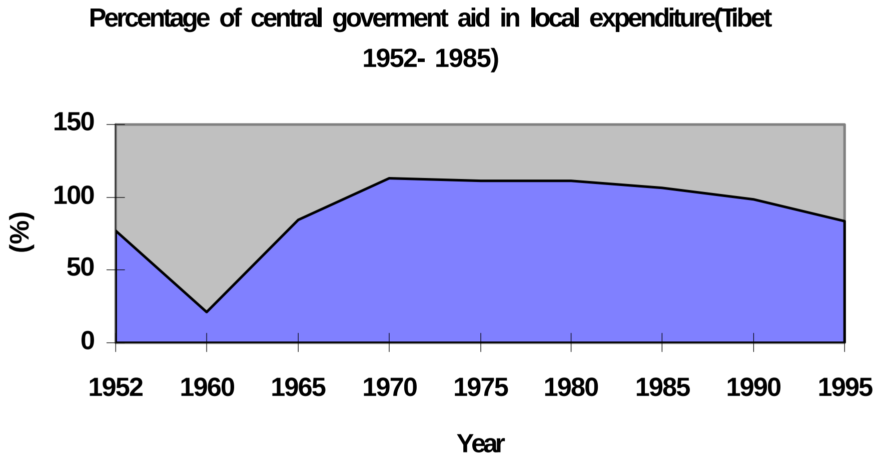
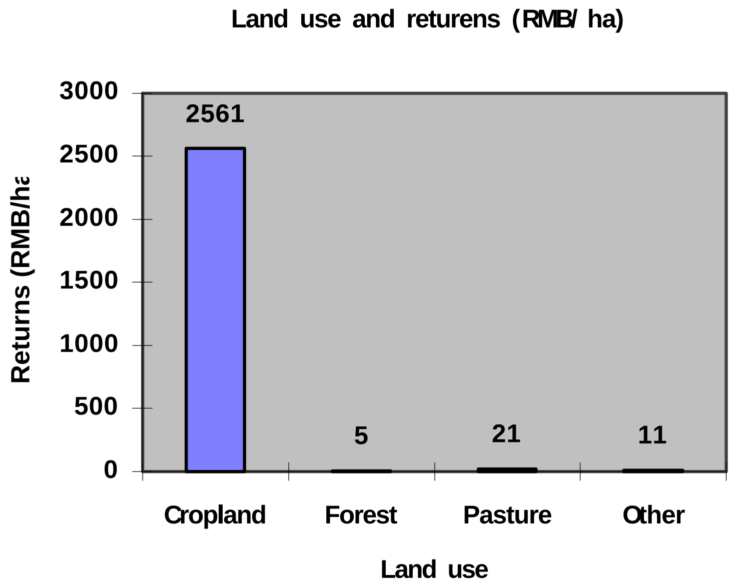


Table 5. Gross returns from major land uses (1995)

	Total	Cropland	Forest	Pasture	Other
Gross income (mi. RMB)	2809	922	57	1357	473
(%)	100	33	2	48	17
Area (mi.ha)	120.48	0.36	12.65	64.8	42.67
RMB/ha	23	2561	5	21	11

Source: Derived from "Tibet's Statistics Yearbook, 1996" and "Tibet's land use, 1990"

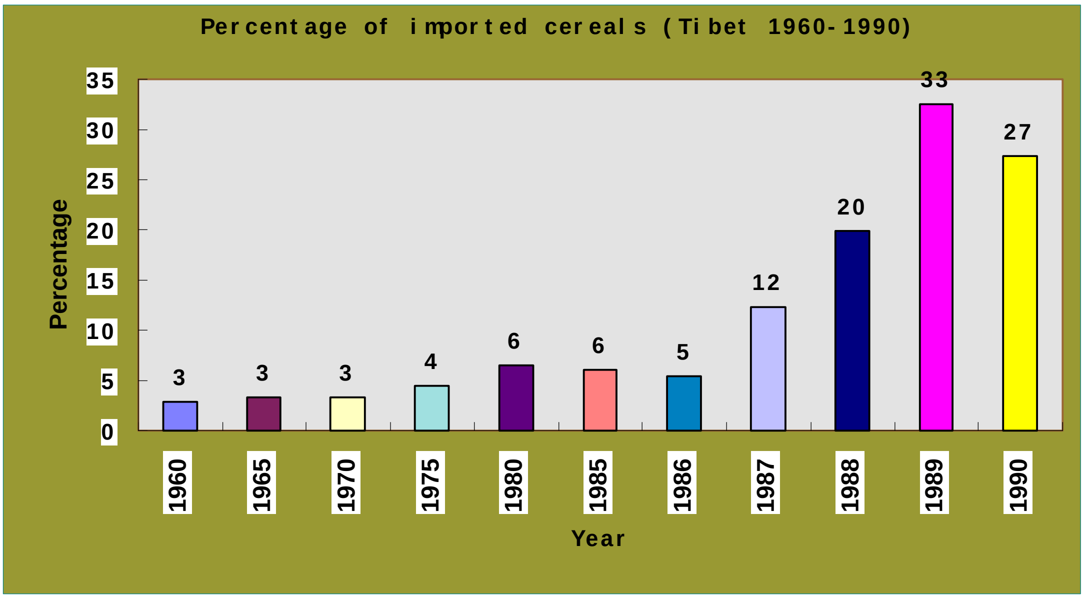


Insecurity of Food: Food production has increased considerably since the 1960's. While local grain yield increased nearly 3fold and meat production increased 138%, the per capita grain production increased only 5% due to population growth, from 290 kg in 1978 to 305 kg in 1995. The slight increase in local food supply, coupled with a great increase of demand, resulted in the need to import more grain and vegetable oil from neighbouring provinces, some of the oil is even imported from Beijing. Table 6 demonstrates that there is a trend to rely more and more on food import. This is not practical for two seasons: firstly, food shortage is also a long-term problem for China as a whole. Secondly, even if there were a food surplus situation somewhere outside Tibet, it is very costly to transport and deliver it to the areas in need. At present, the cost of transporting and delivering one kg grain is RMB 1-2, probably one of the highest in the world.

Table 6. Food security dynamics (1960-1995)

Grain consumption (1000t)				b/Total
Year	Total	a: Local yield	b: Imported	(%)
1960	212	206	6	3
1965	301	291	10	3
1970	305	295	10	3
1975	467	446	21	4
1980	540	505	35	6
1985	565	531	34	6
1986	480	454	26	5
1987	533	467	66	12
1988	635	509	126	20
1989	816	550	266	33
1990	837	608	229	27

Source: Tibet's social and economic statistics yearbook (1991).



A more comprehensive research paper on fuel consumption was presented by Sun (1988). Fuel consumed in 1988 and its components are listed in Table 7. The table shows that fossil fuel made up only 15%, and biological energy 73% of total energy consumption. In fact, in most remote areas, local inhabitants have no access to, or cannot afford electricity or fossil fuel and biological energy sources are their only choice. For example, dry manure and sods are the principal sources in range lands, apart from short bushes; In forested areas, a great deal of good timber is burned as firewood; and in cropland, crop by-products and dry manure are used. These practices break the linkages between different parts of the ecosystem, lead to widespread soil degradation and waste much labour and time. Therefore, it is economically and ecologically unsustainable.

Table 7. Fuel consumption and structure (1988)

Fuel consumption		Equivalent (1000 toe)	(%)
Dry animal manure	1.04 Mi.t.	520	33
Firewood	0.99 Mi.t.	430	27
Sod, peat	0.45 Mi.t.	198	13
Electricity	268 Mi.kwh	188	12
Oil	0.16 Mi.t.	229	15
Coal	0.0125 Mi.t.	6	0
Solar energy	9.8 Mi.kwh	6.8	0
Wind energy	0.2 Mi.kwh	0.1	0
Total		1573	100

Source: Tibet's development and reform, Sunyong (1990)

Vulnerability to natural disasters: Rangeland accounts for 54% of the total land area, but is very poorly managed and prone to disasters. The number of animals who died of various natural disasters are given in Table 8.

Table 8. Ratio of animals lost to natural disaster and normally culled

Large Animals (Mi.)				Small Animals (Mi.)		
Year	Died	Culled	%	Died	Culled	%
1990	0.55	0.44	125	1.34	3.17	42
1991	0.44	0.43	102	0.71	3.34	21
1992	0.18	0.47	38	0.37	3.57	10
1993	0.15	0.54	29	0.32	3.53	9
1994	0.18	0.58	31	0.53	3.65	15
1995	0.16	0.68	23	0.57	3.89	15

Source: Tibet's statistics yearbook (1996)

Table 8 shows that, in a normal year, animals that succumbed to natural disasters account for 23-28% of the normally culled animals (traded on the market or consumed by herdsmen and their families) in the case of large animals and 9-21% for small animals. In unfavourable years, this ratio becomes much higher.

4. Sub-system analysis

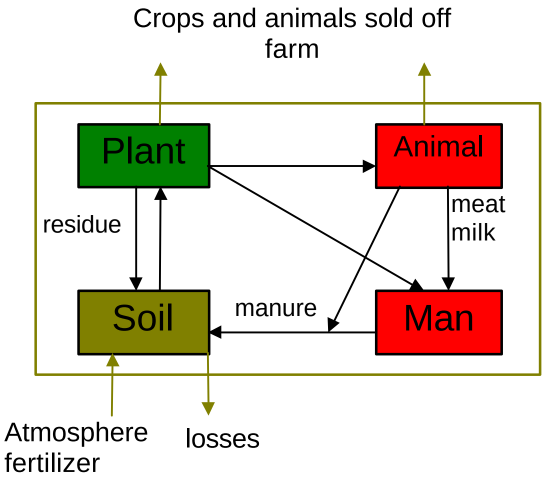
Figure 1, suggests that three sub-systems are the most important: man-cropland, man-forest, and man-animal-pasture.

4.1 Cropland

The total cropland area in Tibet is 0.36 mi.ha, i.e. only 0.3% of the total land area because of various limitations. It is difficult to improve on this number because it already includes marginal land, that is usually excluded in government statistical yearbooks (cropland area in the Statistics Yearbook is 0.22 mi.ha. in 1995). Therefore, it is critical to preserve cropland and its productivity.

Soil nutrient cycling is a key factor for sustainable productivity. King (1990) modeled soil nutrient cycling (Figure 2) that can be divided in three parts: nutrient input to soil, nutrient inherent in soil, and nutrient output from soil (Figure 3). In present Tibet cropland, the main sources of input nutrients are organic and chemical fertilizers (nutrients from legumes are very limited). The output is nutrient harvested in grain. Other losses may be important, but there is no data about it. To calculate the soil fertility budget, figure 3 can be further simplified into figure 4, and nutrient cycling in 1995 is presented in Table 9.

This rough estimate shows that there is a 21300 t nutrient deficit in Tibet's cropland in 1995. The pasture soil is relatively high and due to its cool environment, the average organic matter content of the surface soil is over 5%, much higher than in the rest of China. The cropland converted from pasture or forest can maintain a grain yield of 2250 kg/ha for three years without application of fertilizers. However, the current crop systems cannot sustain long if no nutrients are added. The current system may turn out to be an impoverishing development as described by Islam and Jolley (1996).



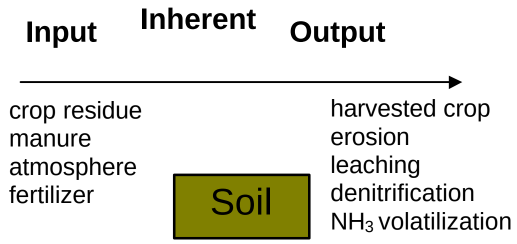


Figure 2. Nutrient flow on a farm (King, 1990).

Figure 3. Nutrient flow in cropland.

Figure 4. Simplified nutrient flow in Tibet.

Table 9. Estimates of soil nutrient cycling in cropland (1995, t)

		N	P_2O_2	K_2O	Total	Note
Output		35800	14300	3500	53600	
Input:	Organic	8500	3400	800	12500	
	Inorganic	9700	4400	500	14600+5200*	5200 t compound fertilizer
Budget					-21300	

Source: Derived from statistics yearbook (1996) and agriculture handbook

4.2 Forest

Tibet is the second largest forest province in China, but the forests are mainly situated in south eastern Tibet. Land used for forest amounts to 12.65 mi.ha., of which forested land is only 7.17 mi.ha. (Table 10). Not only large in quantity, its quality is also high. Per hectare the timber stock is about 336 m^3, which is threefold that of Heilongjiang province, and tenfold that of Guangdong province. Mature and over-mature trees (>200-300 years for *Picea* and *Abies*, and >100-150 years for *Pinus*) accounts for 79% of the total stock, and large wood accounts for 90% of the total stock. The current annual increment rate is 1.53%, or 4.5 m3/ha, but it has begun to decline, probably because most trees are aging.

Table 10. Forest resources and timber stumpage

	Forest		
	Total	Forest for timber	Forest easily accessible
Area (Mi.ha.)	7.17	5.83	0.76
Stumpage (Bi. m^3)	2.08	1.68	0.24
Ha/Capita	3	2.44	0.32
M^3/Capita	871	703	100

Source: Tibet' forest resources (1990)

It is difficult to estimate forest exploitation because data about uncontrolled logging are scarce. Table 7 and statistics, suggest that the total yield is 0.84 Mi.m^3/yr. (o.34 Mi. m^3 timber, 0.5 Mi. m^3 firewood). If the per hectare stock is 336 m^3, and logging efficiency is 40%, the consumed forest stumpage is 2.1 Mi.ha/yr., equal to felling an area of 6250 ha. According to forest statistics, the reforested area is about 4000 ha, but little of this is successful. In general, the current annual increment may be still high (32 Mi. m^3 in total, 26 Mi.m^3 for timber forest, and 3.67 Mi.m^3 for accessible timber forest) but it cannot last long because most of the trees are too old.

In short, there are two principal problems in Tibetan forest management. The first is the unacceptably low resource efficiency. The current logging practice use only 40-50% of the standing stock, the rest (50-60%) is wasted during felling, transport and processing. Much high quality stock is consumed as fuel wood rather than building timber, due to lack of other available fuel.

The second problem is the "large-area-clear-felling" practice, which is detrimental to reforestation. Yuan (1985) conducted research on the natural regeneration of forest (*Picea*) in Biru county, northern Tibet. Three "cut-over land" sites were observed: by clear felling (1965), by forest fire (1959), and by selective felling (1965). On clear-felled land, surviving *Picea* seedlings numbered only 820/ha after 22 years (the lowest number should be 1000, by national standard), and there was ample evidence of severe soil erosion (depth <25 cm, bare rock area 15%). On burnt land, *Picea* seedlings amounted to 14600/ha, but there were other competitive species. On selective-felling-land, *Picea* seedlings numbered 30200/ha, and only very slight erosion occurred. Also, reforestation took longer on burnt land than on selective-felling-land because there were no stock tree left and conditions were less suitable. Yuan concluded that natural reforestation was basically unsuccessful on most "clear felling lands". In fact, this practice has been forbidden by the National Forest Law. However, local people know little of Forest Laws and the Law is poorly implemented and enforced in remote areas.

4.3 Pasture

The main problem of pasture management is its sharply different carrying capacity in different seasons. Due to the highland climate, grass grows only 3-5 months. Some pasture is only usable in warmer seasons due to the cold and long winter. Traditionally, the rangelands of Tibet are divided into two classes, 'cold pasture' and 'warm pasture'. The theoretical carrying capacities of the current rangeland is presented in Table 11. The real load in 1995 is added for comparison.

Table 11. Carrying capacity of range lands in cold and warm seasons

	Area	Grass yield	Grazing period	Carrying capacity*	Stock in 1995	Balance
	(Mi.ha)	(Bi.kg)	(day)	(Mi. sheep unit)		
Whole year	64.62	84.81	365	66.39	47.39	+19
Cold season	23.39	20.74	180	32.92	47.39	-14.47
Warm season	41.23	64.07	185	98.95	47.39	+51.56

*** per sheep forage consumption = 3.5 kg/day**
Source: Derived from Tibet's land use

Table 11 suggests that theoretically, the total carrying capacity is 66.39 for whole year, which is 140% of the real load in 1995. However, this means little because warm pasture can only be grazed in warm seasons, and the grass in Tibet is too short to be collected and stored for winter use. By season, there is a 14.47 million sheep units overgrazing in the cold season and a 51.56 million undergrazing in the warm season.

This imbalance makes it inevitable to cull surplus animals before the cold sesaon comes. However, it seems very difficult for local people to do so. Local people regard the animals as their major property: the larger their stocks, the more they are respected. Therefore, most people have the tradition to keep as many animals as possible to show their standing. In addition, local people only cull this animals before festivals or holidays and only few are traded in markets (Table 12).

Table 12. Animals culled and sold and their percentage of total stock

Large animals (x1000)					Small animals (x1000)			
Year	Culled	%	Traded	%	Culled	%	Traded	%
1978	229	4.97	47	0.99	2137	12.27	462	2.65
1980	223	4.94	73	1.55	2250	12.39	460	2.53
1985	343	6.96	86	1.75	2833	17.44	551	3.39
1990	437	7.57	119	2.15	3175	18.61	725	4.32
1994	581	9.88	133	2.26	3651	21.54	462	2.70

Source: Tibet's statistics yearbook (1994)

Table 12 shows that the proportion of large animals culled is still less than 10%, although it has increased since 1978. This is still very low compared with world figures (large animals culled 30-40%, small animals culled 50-70%). Field interviews showed that some large animals are as old as 17 years. Quite a lot of old animals are kept year after year, some animals died naturally without producing any profit after many years of grazing. In general, animals are experiencing the cycle of "summer full fed, autumn fat, winter famine, and spring death" (Zhang, 1989). Failure to cull animals before the winter is the key reason for low productivity and grassland degradation.

5. Problems and Recommendations

Generally, the agricultural production on cropland and pasture has increased over the last three decades. This increase is based on many improvements, such as extending the irrigated area, using improved hybrids and varieties, terracing land, etc. However, this should not be confused with long term sustainability. Islam and Jolley (1996) defined: "impoverishing growth or unsustainable growth is a type of economic growth when the economy has grown in quantitative terms but the economy's reproductive capacity has declined because of environmental and natural resource degradation and other associated problems in the economy". In the case of Tibet, unsustainable growth is occurring in cropland, forested land, and pasture land. By and large, the current system is not a sustainable system because it cannot provide sufficient life supporting opportunities for human beings and it leaves less productive land to the next generations. In other words, the current practices are not resource efficient, environmentally benign, and economically viable. Therefore, measures should be taken to change the current system to a sustainable system.

5.1 Soil Fertility and Sustainability of Cropland

It is logical that Tibetan agriculture should based on organic fertilizers, simply because there is not sufficient fossil fuel in Tibet. The key point is to maintain soil fertility at such a level that the land can yield sufficient products sustainably. Tibet has the advantage that it can maintain organic-based sustainable agriculture. By 1995, there were 44.39 Mi.sheep-units and only 0.36 Mi.ha cropland, or 123 sheep-units per hectare. Although not all animals graze near cropland, it is certain that Tibetan cropland has much more nutrient potential than the rest of the cropland in China. The present problems for gathering animal manure are: first, much manure is used as a fuel because no other fuel is available; second, only a small fraction of all animals are confined, which makes manure gathering time-consuming;

third, local people are not fully aware of the importance of 'organic fertility'. The following measures are recommended.

- Enlarge nutrient resources: save animal manure from fuel consumption; promote stall-feeding;
- Improve the transport and road conditions to ensure that organic fertilizer can be delivered timely and efficiently;
- Apply crop rotation. The current problems are: local people traditionally prefer highland barley, which is planted in at least two or three consecutive years. Winter wheat yields higher but is refused by the local people because of dietary customs. Similarly, potatoes yield more and is maintain soil fertility better but people think that it takes too much fuel to cook. In a human-centered system, man's real demand should be considered before an instruction works properly. Sometimes the social and cultural factors involved play a greater role than people assumed at first.
- Improve fertilizer efficiency: Much information is needed to sustain quality-based growth.

5.2 Forest Land

The key point of forest management is to convert resource potential into economical values, without affecting sustainability. Present problems are: too much high-quality timber is used as fuel, and brushes in marginal areas are collected exhaustively (by pulling roots, rather than cutting stems). Therefore, suggestions are:

- Save good timber from fuel wood collecting. Alternative sources of energy must be found first.
- Save brushes in marginal land. Planted fuel forest is strongly recommended. Improve the way of collecting firewood (selective cut).
- Policy and regulation. There are forest laws in place, the point is how to implement and enforce the law. The first priority is to set a forest price, and keep all licensed logging under control: forbid "large-area-clear-felling", and promote "selective felling".
- Use RS and GIS to monitor forest conditions, shift to more efficient management.

5.3 Pasture Land

- Improve matching of grazing land and animals with a spatial-temporal dimension. The current warm-cold system is based on a roughly divided grazing area, and is not necessarily rational. With the aid of detailed information, both of pastures and animals, management could be improved.
- Improve pasture productivity. The priority should be to clarify the right of pasture ownership at an operational level. Every family should know where their pasture is both on site and on map, what their rights and responsibility are, and what might happen if too many animals graze it for too long. At present, there is no clear boundary even between counties, let alone sub-counties. Under this situation, rotational grazing cannot be expected, and no investment is possible. Conflicts resulting from pasture utilization are increasing.
- Improve animal composition through timely culling and marketing. However, the market can develop only if there is a surplus and local people prefer to sell them. Local governments have to play an important role in this process.

5.4 Energy Management in Rural Areas

Sustainability cannot be attained until the current fuel situation has improved. The solutions may be divided into two categories: more efficient stoves and new sources such as mini-hydroelectricity, solar energy (PVs), wind energy, and thermal energy. Recently, some programs have been initiated such as the "Tibet Sunshine Program". The energy situation has improved greatly in the program area. But in general, it is still in the experimental stage: expensive and less reliable. However, a better understanding of the importance of this program should encourage investing more in research and extension.

5.5 Social and Economic Measures

All measures suggested above require strong social and economic capabilities to be implemented effectively. This is particularly important in Tibet. Every society has its own tradition and culture. Most Tibetans are pious Buddhists, they have their specific ecological view: human beings should live in harmony with nature; live a moderate life and not be greedy, etc. There is a religious society, which coexists with the current administrative system. Each system has its advantages to build a better environment for our common future, however no research has been conducted yet.

6. Conclusions

- Primitive, organic-based agriculture is not naturally sustainable. The theoretical assumption is that renewable resources are usable forever. However, the system might be regenerative only in favourable conditions. This is critical in areas like Tibet where ecosystems have developed in 3500-4500m marginal highland and any improper practice is dangerous.
- The present system is not sustainable because it is not resources efficient, environmentally sound and socially viable. Failure to fulfil the increasing demands for food and fuel is the main reason for this lack of sustainability.
- At present, while the existing theory and techniques can be very useful to convert the current system to a low-level system of sustainable agriculture, any single theory or technique should not be overestimated because it has to work in harmony to make agriculture sustainable. Many effective techniques cannot be popularized, some simple but usable theories cannot be applied, some successes in stations cannot be extended, and even some national laws and local regulations cannot be implemented and enforced. All these failures and inefficiencies imply that the current researchers may be still somewhat superficial. Therefore, a better understanding of the reasons underlying the present problems is necessary.
- In the long run, Tibet's agriculture should be information- or science-intensive to maintain its sustainability at a higher level. The integrated utilization of GPS, GIS and RS may play an important role in Tibet's agriculture.

7. References

Duojieouzu, Li and Xi (1994). The population of China towards the 21st Century (Tibet Volume), Chinese Statistics Press, Beijing

Francis, C.A., Flora, C.B. and Kink, L.D. (1990). Sustainable agriculture in temperate zones

Liu Rui (1986). China's population (Tibet Volume). Chinese Finance and Economy Press, Beijing

Li Wenhua and Panday, K.K. (1986). Watershed Management, Processing of International Workshop on Watershed Management in the Hindu Kush Himalayas Region, ICIMOD, 1985

Mak K-N and Shearer, W. (1996). Sustainable Energy Development in rural Asia Natural Resources Forum, Vol. 20, No. 4

Ministry of Agriculture, PRC (1996). China Agriculture Development Report '96, Chinese Agriculture Press, Beijing

Sardar, M.N. and Ainsley Jolley (1996). Sustainable Development in Asia: the current state and policy options. Natural Resources Forum, Vol. 20, No. 4

Tibet's Land Use (1992). Science Press, Beijing

Zhang Rongzu (1989). Case study on Mountain Environmental Management: Nyemo County (Tibet), ICIMOD Occasional Paper no. 13, Kathmandu, Nepal, August 1989

Tibet Forest Proceedings (1994). Tibet People's, Lahsa