An Explorative Analysis of the Productivity of Croplands in Tibet Autonomous Region, P.R. China

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Introduction

The potential productivity of croplands can be defined as the maximum amount of food produced under ideal conditions in a particular eco-region or administrative region. Analysis of productivity has significance for planning to ensure food security. A number of studies of potential food production have been carried out in Tibet. Liu Yanghua (1991) studied the potential productivity of croplands in the middle reaches of the Yalongzangpo River (Brahmaputra River), where the majority of the Tibetan population is concentrated. He examined the maximum potential yield of crops such as barley and wheat; the potential productivity of cropland; the carrying capacity of rangeland; and the co-dependence of land resources, food production, and population. This research became the guideline for integrated development of agriculture in this region. Yang Gaihe (1995) focused on the potential productivity of cropland and rangeland, and the capacity for food production based on the existing cultivated land and pasture land. Other studies have focused on resource management and assessment of agricultural productivity, and potential productivity of technological innovation and dissemination (Nyima Tashi 1998).

In the study described here, an explorative analytical approach was used to distinguish the potential, attainable, and actual production of croplands in different agricultural systems for different crops in Tibet.

Potential Productivity of Cropland

The potential productivity of cropland has been estimated by a number of scientists using different methods (Dang Anrong 1997; Liu Yanghua 1992). The data were aggregated according to agricultural systems (Table1) and administrative prefectures (Table 2). The potential productivity of climate (light, temperature, and water) and potential productivity of cropland (light, temperature, water, and land) were calculated and compared to actual yields.

Table 1 indicates that the potential productivity of cropland varies greatly among agricultural systems. The crop-dominated system has the greatest potential productivity for both climate and cropland: 24.6 t ha^{-1} and 13.4 t ha^{-1}, respectively. These figures are 53% and 63% higher, respectively, than the average for Tibet, whereas pastoral system potentials are 56% and 78% lower, respectively, than the average for Tibet. Actual yields in the crop-dominated system (3.2 t ha^{-1}) were 56.7% higher than the Tibet average, whereas in pastoral systems where cropping is practised, the yield (0.75 t ha^{-1}) was 63.5% lower than the Tibet average.

Table 2 shows the great variation in potential productivity of both climate and cropland among the seven prefectures. The actual yield is affected by both the potential productivity

Table 1: Potential productivity (t ha^{-1}) of climate and cropland in agricultural systems

Yields	Crop-dominated system		Agro-pastoral system		Pastoral system		Agro-forest-livestock mixed farming system		Tibet average
	t ha^{-1}	% of Tibet average	t ha^{-1}	% of Tibet average	t ha^{-1}	% of Tibet average	t ha^{-1}	% of Tibet average	t ha^{-1}
Potential productivity of climate	24.63	53.2	12.59	-21.6	9.66	-56.5	15.79	-1.7	16.07
Potential productivity of cropland	13.35	62.6	5.56	-32.2	1.81	-77.9	9.50	15.7	8.21
Actual yield	3.23	56.7	1.91	-7.2	0.75	-63.5	2.36	14.5	2.06
Yield gap P1	11.28		7.03		7.85		6.29		7.86
Yield gap P2	10.12		3.65		1.06		7.14		6.15

Note: Yield gap P1 = difference between potential productivity of climate and potential productivity of cropland; yield gap P2 = difference between potential productivity of cropland and actual yield

Table 2: Potential productivity (t ha^{-1}) of climate and cropland in prefectures

Yields	Lhasa		Changdu		Shannan		Shigatse		Naqu		Ali		Linzhi		Tibet average (t ha^{-1})
	t ha^{-1}	% of Tibet average	t ha^{-1}	% of Tibet average	t ha^{-1}	% of Tibet average	t ha^{-1}	% of Tibet average	t ha^{-1}	% of Tibet average	t ha^{-1}	% of Tibet average	t ha^{-1}	% of Tibet average	
Potential productivity of climate	24.54	52.7	13.48	-16.1	18.24	13.5	19.01	18.2	5.92	-63.1	11.59	-27.8	18.35	14.1	16.07
Potential productivity of cropland	13.43	63.5	5.64	-31.3	10.35	26.0	9.62	17.1	2.19	-73.3	3.99	-51.4	12.06	46.8	8.21
Actual yield	2.59	27.5	1.53	-24.6	3.09	52.2	2.43	19.7	0.38	-81.2	0.93	-54.1	2.68	32.0	2.03
Yield gap P1	11.11		7.84		7.89		9.39		3.73		7.60		6.29		7.86
Yield gap P2	10.84		4.11		7.26		7.19		1.81		3.06		9.38		6.15

Note: Yield gap P1 = potential productivity of climate minus potential productivity of cropland; yield gap P2 = potential productivity of cropland minus actual yield.

of the cropland and the management of the farmland, including irrigation, inputs, and agronomic practices. It is clear that there is a need to improve the management level of farmland. If this is accomplished, self-sufficiency of cereals could be achieved.

There is a huge gap between potential productivity of climate and cropland, and between potential productivity of cropland and actual yield. Table 1 shows this in more detail. In the crop-dominated system, the yield gap P1 (gap between potential productivity of climate and cropland) and the yield gap P2 (gap between potential productivity of cropland and actual yield) are both high and quite close. This indicates that both land suitability and management constrain the production of cereals. On average, both yield gaps are considerable and indicate that improvement of land suitability, land fertility, and farming management are crucial for increasing production of cereals.

Yield gaps were also estimated for each prefecture (Table 2). The P2 yield gaps in Lhasa and Linzhi prefectures are high at 10.8 t ha^{-1} and 9.4 t ha^{-1}, respectively, with Naqu and Ali prefectures, at 1.8 t ha^{-1} and 3.1 t ha^{-1}, respectively, and medium in Shannan and Shigatse prefectures at about 7 t ha^{-1}.

Tibet possesses substantial potential production of both climate and cropland; on average, 16.1 t ha^{-1} and 8.2 t ha^{-1}, respectively. Extrapolating from the existing cultivated land, total production of cereals could reach 5.6 million t and 2.7 million t, respectively. Comparing the 1 million t of cereals produced in 2000 with the potential productivity of cropland, less than 40% has been utilised. There is a tremendous gap between the theoretical yield of cropland and what is actually produced.

Potentially Attainable Crop Yields

In most cropping areas, there is great potential productivity of land, and thus a possibility for increasing crop yield per unit area. Two factors have to be considered. One is biological productivity, which differs for different crops and varieties. The other is managerial: the economic and technological capability for crop farming, determined by farmers' knowledge, technological innovation, agricultural infrastructure, level of agricultural input, and related policies.

The potential production and yields achieved at different management levels in the different production systems are shown in Table 3. In the crop-dominated system 'grains' are spring and winter barley and wheat, in the agro-pastoral system they are mostly spring barley with some spring wheat, and in the mixed system spring and winter barley and wheat. Rice and maize are also grown in the mixed system areas.

In the crop-dominated system, the average historical record of highest yields for cereal crops and rapeseed are 12.0 t ha^{-1} and 6.6 t ha^{-1}, respectively. The highest yields in experimental plots for grain was 7.7 t ha^{-1} and for rapeseed 3.4 t ha^{-1}. Actual yields of cereal crops and rapeseed in 1997 were 3.3 t ha^{-1} and 1.4 t ha^{-1} (Table 3). This indicates a yield gap. Similar situations can also be seen in the agro-pastoral system and the agro-forest-livestock mixed farming system. In addition, there are also big differences between agricultural systems influenced by different management and biophysical conditions. All

Table 3: Yield changes at different management levels (potentially attainable yields) in four agricultural systems (t ha^{-1})

Productivity	Average grain yield				Average rapeseed yield			
	Crop-dominated	Agro-pastoral	Agro-forest - livestock mixed farming system	Tibet average	Crop-dominated	Agro-pastoral	Agro-forest-livestock mixed farming system	Tibet average
Potential productivity of cropland	14.1	5.9	8.6	9.5				
Historical record of highest yield	12	5.8	7.6	8.5	6.6	3.6	4.8	5.0
Highest yield in experimental plot	7.7	4.9	6.5	6.4	3.4	2.2	3.2	2.9
Highest yield in ideal farmland	6.2	4.7	6.2	5.7	2.4	1.9	2.1	2.1
Average yield in 1997	3.3	2.8	3.3	3.1	1.4	1.2	1.4	1.3
Average yield in recent five-year period	3.1	2.1	3.1	2.8	1.3	1.1	1.2	1.2

Note:

[1] Historical record of highest yield is the yield of a crop variety produced in one plot under best conditions and management in each zone. The minimum experimental area was 30 m^2.

[2] Highest yield in experimental plot was the average yield of a crop variety produced in a minimum of three plots under best conditions and management in each zone. Different crops were tested in each zone. Each crop was planted in a plot of 30 m^2 in replicates of three. All varieties used were newly released cultivars.

[3] Highest yield in ideal farmland is the yield of a crop variety produced under ideal farmland and management conditions in each zone. The result was obtained using the farmer's own management supervised by a scientist. The minimum area was over 667 m^2. The ideal farmland was located on a flat riverbank with fertile soil and access to irrigation.

[4] Actual yield was the yield of a crop in 1997 in each zone with farmer's normal level of management.

[5] Average yield in recent five-year period is the average crop yield in recent five-year period in each zone using farmer's management.

Table 4: Potential increases in yields of cereals and oilseed (t ha^{-1})

Yield gaps	Average cereal yield				Average oilseed yield			
	Crop-dominated system	Agro-pastoral system	Agro-forest-livestock mixed farming system	Tibet average	Crop-dominated system	Agro-pastoral system	Agro-forest-livestock mixed farming system	Tibet average
Yield gap 1	2.1	0.1	1	1				
Yield gap 2	4.3	0.9	1.1	2.1	3.2	1.4	1.6	2.1
Yield gap 3	1.5	0.2	0.3	0.7	1	0.3	1.1	0.8
Yield gap 4	2.9	1.9	2.9	2.6	1	0.7	0.7	0.8
Yield gap 5	0.2	0.7	0.2	0.3	0.1	0.1	0.2	0.1

yields in the crop-dominated system are much higher than the Tibet overall average, while the agro-pastoral system has much lower yields than the average.

Considering the actual crop yields, there is a great potential to attain much higher yields and to increase cereal crops and rapeseed production. To attain the potential maximum yield in practice, it is important to understand why there is a gap, what the constraints are, and how to close the gap.

Potential to Increase Crop Yields

Generally, there are three possibilities for increasing production. The first is to expand the sown area of crops; the second is to increase cropping intensity; the third is to increase per unit area crop yield. At present, there is little scope for expanding cropping land because of poor economic capability. Intensification of cropping is also not possible on a large scale at the moment owing to low temperatures, technological limitations, and financial incapability. This leaves increasing per unit area yield.

Yield gap 2 is the gap between potential productivity and the highest ever recorded yield. For both foodgrain and oilseed production, it is highest in the crop-dominated system: 4.3 t ha^{-1} and 3.2 t ha^{-1}, respectively (Table 4). This indicates that breeding of high-yielding varieties or using high-yielding varieties with best possible crop practices has a great potential to boost crop yields in this area. Yield gap 4 (the gap between the highest yield in ideal farmland and the actual yield in 1997) was high in all three food-production areas. This indicates that improvements in farm management and the quality of farmland are key for increasing per unit area yields of crops under all three systems. In Tibet, poor management and poor quality of cropland are the most crucial factors that constrain increases in food grain and oilseed production.

Conclusions and Implications

Increasing per unit area crop yields is a useful approach to increasing production of cereals and oilseed. Potentially attainable crop yields are promising, and there is considerable room to increase yields. Sloppy and poor topographic conditions constrain increases in yields, but it is not easy to change topographic conditions. Selection of farmland on flat areas and land levelling would help.

Breeding and selection can improve the productivity of crop varieties. Extension of new varieties or replacement of old varieties often needs improvements or changes in cultivation techniques. With improved cultivation techniques, the whole system is more productive. Extension of improved varieties and modification of cultivation techniques posesses great potential for increasing production and contributes to increasing production of cereals and oilseed substantially.

In most of the agro-pastoral and crop-dominated systems, improved varieties have not replaced local landraces, and changes in cultivation techniques have not taken place. Breeding for a new variety requires more than eight years. Breeding programmes for high-altitude and non-irrigated areas have not been undertaken. Production of cereals and oilseed will increase rapidly if improved varieties for these areas are developed.

References

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