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Growth and Trend Analysis of Area, Production, and Yield of Major Cereals

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Abstract

Farmers in Bhutan have developed and produced varieties of food crops well-adapted to microclimatic niches over centuries. Farmers had been cultivating at least nine food crops known as *Dru-Na-Gu*. However, only rice, maize, wheat, barley, buckwheat, and millets are commonly grown by farmers as staple food crops, with the remaining *Dru-Na-Gu* losing their popularity. Bhutanese farmers are predominantly small-scale, marginal, and reliant on integrated subsistence agriculture systems, and farming is still labor-intensive and deeply ingrained in tradition. As much of the agriculture is non-commercial subsistence agriculture, technological backwardness still prevails. Despite the effort to overcome technological backwardness with research and development initiatives such as the release of well-adapted, improved food crop varieties and management practices, little attention is paid to the overall trends and growth rates in spite of their utility in crop forecasts and planning. This study examined the trend and growth rates for 60 years (1961-2020) of time series data on the area, production, and yield of *Dru-Na-Gu.* Semi-log trend function was used to ascertain the trend and growth rates of the area, production, and yield. Although increasing agricultural production helped to lessen rural poverty, there was a significant deceleration in productivity and area under major cereals cultivation over the study period. However, there was a slightly accelerated growth in the yield of major cereals, which could be due to the introduction of improved varieties. Considering the significant deceleration of area and productivity of major cereals as opposed to the burgeoning import of cereals or cereal-based products, intensifying cereal production and regulating infrastructure development on agricultural land can conserve land needed to achieve food self-sufficiency.

Keywords: agriculture, subsistence, *Dru-Na-Gu*, intensification

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Introduction

The early history of agriculture in the nation is hazy because there is limited evidence of previous agricultural methods in Bhutan. If there is a record of early agricultural history in Bhutan, it is in Bhutanese astrology, which indicates the existence of agriculture since its inception. Even today, farmers in rural Bhutan realize the relevance of astrology in many aspects of their lives, including agriculture (NBC, 2015). Farmers have developed and produced a diverse range of crops and grain varieties that have adapted well to microclimatic niches throughout the ages. Almost all Bhutanese villagers living in favorable temperate zones cultivate a minimum of nine food crops such as rice, maize, wheat, barley, buckwheat, millets, pulses, oilseeds, and amaranth. *Dru-Na-Gu* is not only a staple meal for Bhutanese people, but it also has cultural and religious importance, serving as the backbone of Bhutanese civilization. People who lived in areas where all *Dru-Na-Gu* could be grown were considered lucky and wealthy; today, flourishing cities have the best contemporary prospects for comparable rich places (SJI, 2018).

Rice, maize, wheat, barley, buckwheat, and millets are the main staple grains grown by farmers, while other *Dru-Na-Gu* are losing popularity amidst a few other commodities dominating the markets. Bhutanese farmers are primarily small-scale and marginal, relying on integrated subsistence agriculture systems (Katwal and Bazile, 2020); traditional farming practices on valley and mountain range carving slopes pose challenges to farmers in producing adequate food commodities (Tshewang *et al.*, 2017). Farming has traditionally been committed to cultivating grains to fulfill subsistence requirements, and it is still labor-intensive and deeply ingrained in tradition (NBC, 2016; Norbu, 1995). Given this situation, where rural people rely only on agriculture for their living, it is critical to increase farm production to encourage people to pursue viable farm-related businesses and diversify their sources of income; moreover, the increase in agricultural production is identified as a strategy for decreasing rural poverty (Ammani, 2015). Since the increase in agricultural production is one of the strategies for lessening rural poverty, scale and technology have an important role in farm production; however, as much of the agriculture is non-commercial subsistence agriculture, technological backwardness still prevails (Christensen *et al.*, 2012; Tobgay, 2006).

In an effort to overcome technological backwardness, numerous research and development initiatives are ongoing in the country led by four agriculture research and development centers under the Department of Agriculture (DoA), such as the release of well-adapted, improved food crop varieties and management practices. The Variety Release Committee of DoA released 23 rice varieties, 4 maize varieties, 3 wheat varieties, 2 finger millet varieties, 2 mung-bean varieties, 5 mustard varieties, and 4 soybean varieties between 1988 and 2017 (DoA, 2017). However, little attention is paid to the overall trends and growth rates of *Dru-Na-Gu* production indicators. The subject of productivity, pricing, and output index discussions often revolves around how growth rates have changed over time, and the trend rate estimates with and without significant fluctuation can provide handy information for crop forecasts and planning (Abid *et al.*, 2014). The present study analyzed the growth and trend of the major cereal production indicators in Bhutan: area, production, and yield per hectare to inform interventions for improving productivity for economic growth in the agriculture sector.

Materials and Methods

Source of data

Time series data from 1961 to 2020 (60 years) regarding the area, production, and yield of major cereals (paddy, maize, wheat, barley, millets, and buckwheat) of Bhutan were sourced from the Food and Agriculture Organization website (Food and Agriculture Organization of the United Nations [FAO], 2020). For this study, yield in metric tons per hectare, area in hectares, and production in metric tons was used.

Analytic approach

The semi-log trend function was used to estimate the growth rate of major cereals from 1961 to 2020. Semi-log trend function is widely used in studying the trends and growth rates of harvested area, production, and yield of all crops (Ammani, 2015). The equation 1 was adopted from Abid *et al.*, (2014):

$$\ln Z = \beta_0 + \beta_1 X + e \qquad \text{(equ. 1)}$$

Where,

Z = dependent variable (area, yield, and production);

X = trend over specific period;

β_1 = coefficient of trend;

ln = natural logarithm;

e = error term;

The trend coefficient (β_1) estimates the proportionate or relative change in Z for a given change in X.

$$\beta_1 = \frac{relative\ change\ in\ regressand}{absolute\ change\ in\ regressor}$$

Multiplying the relative change in Z by 100 gives the percentage change or growth rate in Z for an absolute change in X, the regressor. Multiplying 100 by β_1 gives the growth rate in Z, also known as the semi-elasticity of Z for X, and gives the instantaneous (at a point in time) rate of growth (IGR). Taking the antilog of 1 and subtracting 1 from it and then multiplying by 100 gives the compound growth rate (CGR) over some time.

$$CGR = [antilog\ \beta_1 - 1] \times 100$$

If the coefficient of trend (β_1) is positive and statistically significant there is acceleration in growth, if β_1 is negative and statistically significant then there is a deceleration in growth, if β_1 is statistically insignificant there is stagnation in the growth process. Statistical significances were calculated at $p < 0.05$ and all the statistical tests were performed in EViews version 12.

Results and Discussion

Trends and growth rates of paddy production

The result of the semi-log model for the area, the production, and the yield revealed a negative trend coefficient for the paddy area, while the production and the yield were positive (Table 1). The compound growth rates showed that the production and yield of paddy were growing at a rate of 0.852% and 1.157% per annum, while the area diminished at a rate of -0.302% per annum. Though the diminishing rate of area under paddy cultivation (Figure 1) is statistically insignificant, Bhutan has lost 5816 hectares of paddy cultivation land for other purposes in the last 60 years (Table 3); urbanization and a growing population are constant threats.

Rice is the most widely consumed cereal in the country, although it is not the most widely produced cereal. The annual per capita rice consumption is 172 kg (Ghimiray *et al.*, 2013). Though rice is the main staple in Bhutan and plays a significant role in Bhutanese tradition, religion, and culture, with the restricted possibilities for additional development, the area under cultivation has remained nearly steady for over half a century (Tshewang *et al.*, 2016). Malfunctioned irrigation facilities and depletion of water resources could have resulted in the abandonment of paddy cultivation (Japan International Cooperation Agency (JICA) and Sanyu Consultants Inc., 2017), so it is crucial that government take up this matter and seek experts' help to resolve the flaws in present irrigation facilities and other infrastructures to revive the

Table 1: Growth rates and trend for paddy production, area, and yield in Bhutan (19961-2020)

Parameter	Production	Area	Yield
β_2	0.008	-0.003	0.012
F(p-value)	36.294(0.000)**	3.751(0.058)	40.226(0.000)**
t-statistic	6.024**	-1.937	6.342**
Instantaneous Growth Rate (%)	0.848	-0.302	1.151
Compound Growth Rate (%)	0.852	-0.302	1.157

*Statistically significant statistics at $\alpha = 5\%$ **Statistically significant statistics at $\alpha = 1\%$

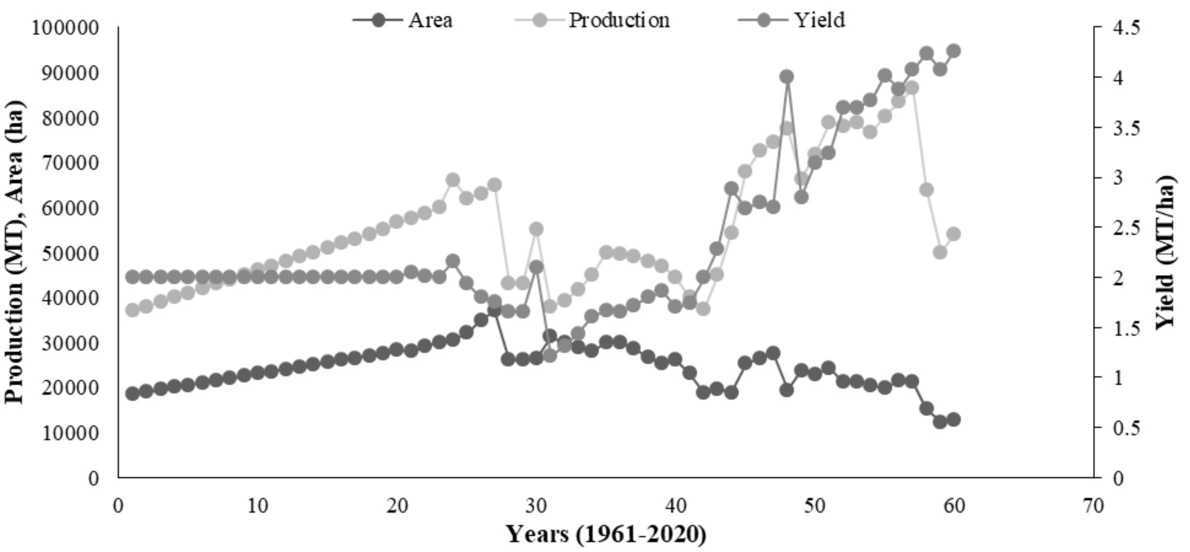

Figure 1: Trends and rates of growth in area, production, and yield of paddy

Table 2: Growth rates and trend for maize production, area, and yield in Bhutan (19961-2020)

Parameter	Production	Area	Yield
β_2	0.002	-0.014	0.016
F(p-value)	1.293(0.260)	48.526(0.000)**	56.651(0.000)**
t-statistic	1.137	-6.966**	7.527**
Instantaneous Growth Rate (%)	0.224	-1.408	1.632
Compound Growth Rate (%)	0.224	-1.398	1.646

*Statistically significant statistics at α = 5% **Statistically significant statistics at α = 1%

paddy farming to feed the nation with self-grown produce.

Trends and growth rates of maize production

The result of the semi-log model for the area, the production, and the yield presented in Table 2 revealed a negative trend coefficient for the maize area, while the production and yield were positive. The compound growth rates indicate that the production and yield of maize increased by 0.224% and 1.646% annually, respectively, whereas the area decreased by -1.398% annually. Though maize is the most widely cultivated cereal, the area under maize cultivation has decreased by 22986 hectares in the last 60 years (Table 3).

Among the food crops, maize ranks first in the cultivated area, being highly adaptable. Maize cultivation extends from less than 300 meters to over 2,800 meters above sea level (Katwal *et al.*, 2013). The most common forms of maize consumption in Bhutan are Kharang (grits), Tengma (roasted and pounded maize), Ashom munang (popcorn), and cornflour. Although maize consumption as a staple appears to be declining, it plays a vital role in food and nutrition security. Maize is the primary raw material for feed and fodder for dairy, poultry, and piggery, which produce milk, eggs, and meat, all of which are chief sources of nutrition. It is also the best cereal crop for the country because of its mountainous terrain and rain-fed agroecology (Wangchuk & Katwal, 2014).

Trends and growth rates of wheat production

The result of the semi-log model for the area, the production, and the yield presented in Table 4 revealed a positive trend coefficient for

Table 3: Net change in production, area, and yield of major cereals (1961 – 2020)

	Parameters	Major cereals					
		Paddy	Maize	Wheat	Barley	Millet	Buckwheat
Year (1961)	Production	37000	48000	5000	2200	3208	3000
	Area	18500	34300	4900	2000	4300	4300
	Yield	2	1.4	1.02	1.1	0.75	0.7
Year (2020)	Production	54088	40965	1623	1123	1613	2701
	Area	12684	11314	995	714	1089	2004
	Yield	4.26	3.62	1.63	1.57	1.48	1.35
Net change	Production	17088	-7035	-3377	-1077	-1595	-299
	Area	-5816	-22986	-3905	-1286	-3211	-2296
	Yield	2.26	2.22	0.61	0.47	0.74	0.65

Minus sign (-) indicates a net loss of production/area/yield over the years.
Production = Metric tons, area = hectares, yield = Metric tons per hectare.

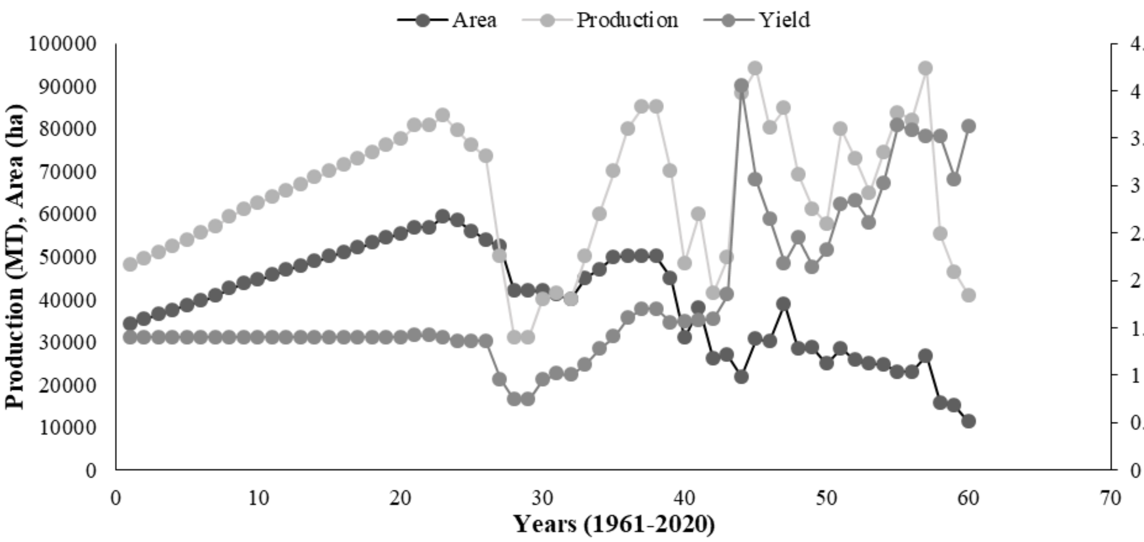

Figure 2: Trends and rates of growth in the area, production, and yield of maize

the wheat yield, while the production and the area are negative. Wheat production and area are decreasing at a compound growth rate of -0.971% and -2.123% per year, respectively, while yield is increasing at a rate of 1.177% per year.

Though wheat-based products are gaining popularity, the area under wheat cultivation and production has been shrinking gradually over the years (Figure 3). Wheat was formerly an indigenous crop for Bhutanese farmers; scores of varieties were brought by their forefathers through seed exchange between countries when the barter system among countries was robust. At least 19 of those varieties are currently in use (Katwal *et al.*, 2015). All the wheat varieties grown are common spring and facultative winter types. Even though rice is the most popular and most often consumed cereal in Bhutan, wheat-based products are becoming more popular as the country becomes more urban, more people can afford to buy things, and eating habits change (Neuhoff *et al.*, 2014).

Trends and growth rates of barley production

The result of the semi-log model for the area, the production, and the yield presented in Table 5 revealed a positive trend coefficient for the barley yield, while the production and the area are negative. The compound growth rates indicate that the production and area of barley decreased by 1.216% and 1.751% each year, respectively, while the yield grew by 0.544 percent per year. Even though the yield goes up, the area where barley is grown and made has been getting smaller over time (Figure 4).

There are two types of barley grown in Bhutan known as Femong (hooded) and Shophu (awned); it is required for certain religious ceremonies (Konishi *et al.*, 1993). Napchi, or barley flour, is not as famous as Kapchi, or wheat flour, in the country, and barley is used mostly for brewing purposes. Though not very popular, the study suggests that the cultivation of barley and buckwheat in Eastern Bhutan predates that of millets and rice (Hyslop & d'Alpoim-Guedes, 2021). When rice and millets were brought to Eastern Bhutan, they must have made barley less popular over time.

Trends and growth rates of millets production

The result of the semi-log model for the area, the production, and the yield presented in Table 6 revealed a positive trend coefficient for the millet yield, while the production and the area are negative. The compound growth rates indicate that the production and area of millets decreased by -0.739% and -1.871% each year, respectively, while the yield grew by 1.541 percent per year. Though yield increases, the area

Table 4: Growth rates and trend for wheat production, area, and yield in Bhutan (19961-2020)

Parameter	Production	Area	Yield
β_2	-0.01	-0.021	0.012
F(p-value)	6.132(0.016)*	29.575(0.000)**	47.732(0.000)**
t-statistic	-2.476*	-5.438**	6.909**
Instantaneous Growth Rate (%)	-0.976	-2.146	1.17
Compound Growth Rate (%)	-0.971	-2.123	1.177

*Statistically significant statistics at α = 5% **Statistically significant statistics at α = 1%

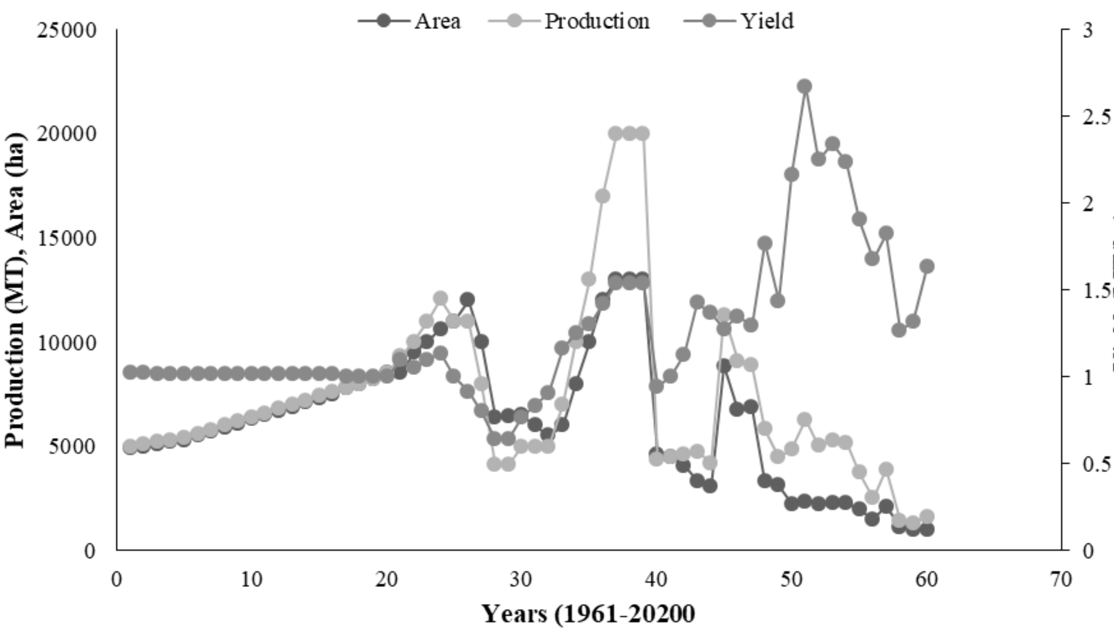

Figure 3: Trends and rates of growth in the area, production, and yield of wheat

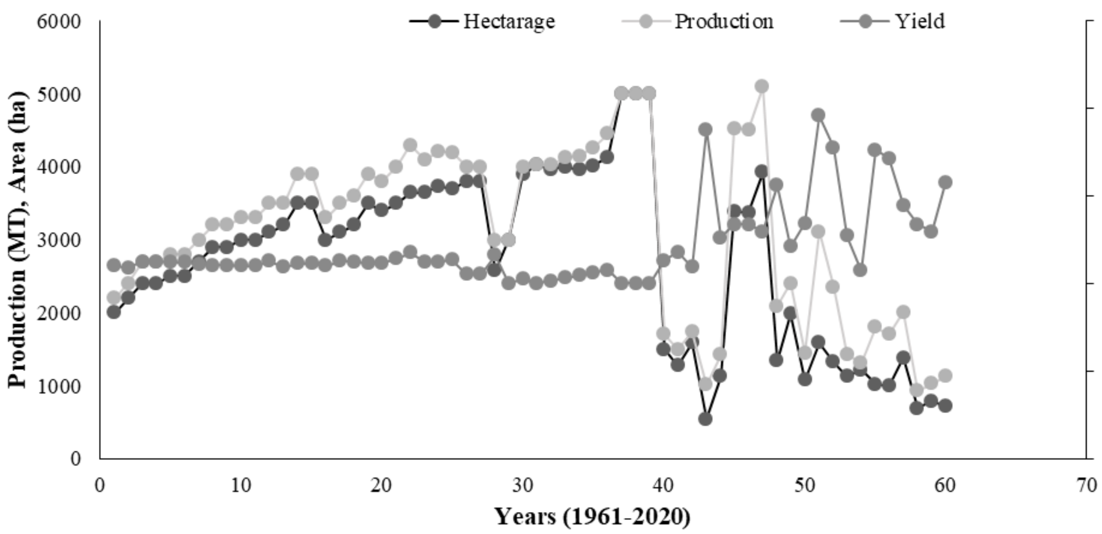

Figure 4: Trends and rates of growth in the area, production, and yield of barley

Table 5: Growth rates and trend for barley production, area, and yield in Bhutan (19961-2020)

Parameter	Production	Area	Yield
β_2	-0.012	-0.018	0.005
F(p-value)	16.172(0.000)**	25.041(0.000)**	28.992(0.000)**
t-statistic	-4.021**	-5.004**	5.384**
Instantaneous Growth Rate (%)	-1.224	-1.766	0.543
Compound Growth Rate (%)	-1.216	-1.751	0.544

*Statistically significant statistics at $\alpha = 5\%$ **Statistically significant statistics at $\alpha = 1\%$

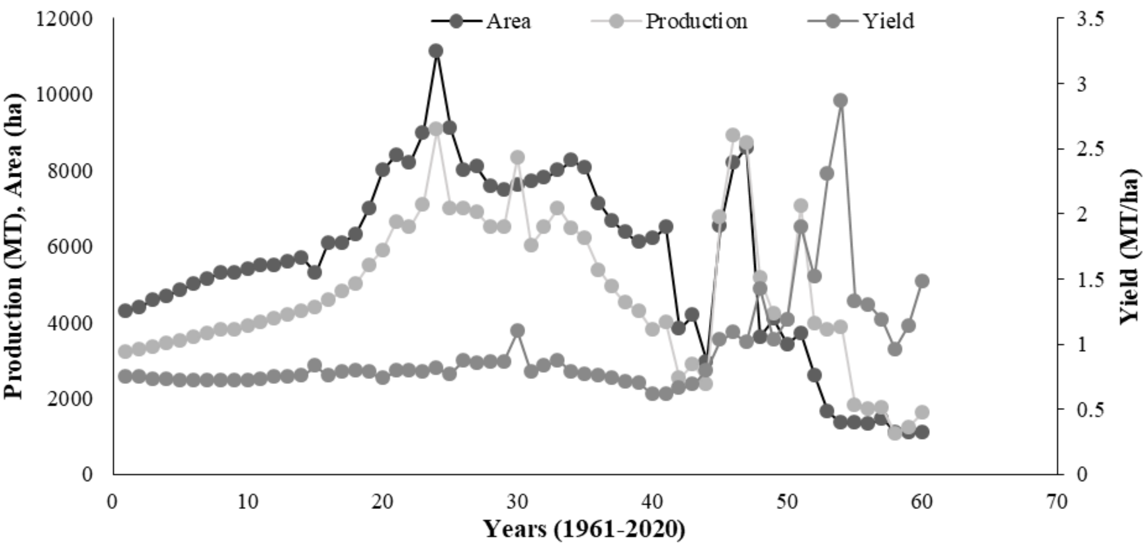

Figure 5: Trends and rates of growth in the area, production, and yield of millets

under millet cultivation and production has been shrinking gradually over the years (Figure 5).

Millets are the most important cereals of the semi-arid and sub-humid regions due to their adaptability to marginal environments (Obilana & Manyasa, 2002). Though millets are tolerant of harsh climatic and soil conditions and are suited to the topography of Bhutan, they are not popular among Bhutanese.

Trends and growth rates of buckwheat production

The result of the semi-log model for the area, the production, and the yield presented in Table 7 revealed a positive trend coefficient for the buckwheat yield, while the production and the area are negative. The compound growth rates indicate that the production and area of buckwheat decreased by -0.093% and -1.381% each year, respectively, but the yield grew by 1.307% per year. Though buckwheat-based products are gaining popularity, the area under buckwheat cultivation and production has been shrinking gradually over the years (Figure 6).

Both common buckwheat and Tartary buckwheat species are grown in Bhutan (Ohnishi,

Table 6: Growth rates and trend for millets production, area, and yield in Bhutan (19961-2020)

Parameter	Production	Area	Yield
β_2	-0.007	-0.019	0.011
F(p-value)	4.631(0.036)*	24.726(0.000)**	41.290(0.000)**
t-statistic	-2.152*	-4.973**	6.426**
Instantaneous Growth Rate (%)	-0.074	-1.889	1.148
Compound Growth Rate (%)	-0.739	-1.871	1.541

*Statistically significant statistics at α = 5% **Statistically significant statistics at α = 1%

Table 7: Growth rates and trend for buckwheat production, area, and yield in Bhutan (19961-2020)

Parameter	Production	Area	Yield
β_2	-0.001	-0.014	0.013
F(p-value)	0.133(0.717)	27.232(0.000)**	82.128(0.000)**
t-statistic	-0.364	-5.218**	9.062**
Instantaneous Growth Rate (%)	-0.093	-1.391	1.298
Compound Growth Rate (%)	-0.093	-1.381	1.307

*Statistically significant statistics at α = 5% **Statistically significant statistics at α = 1%

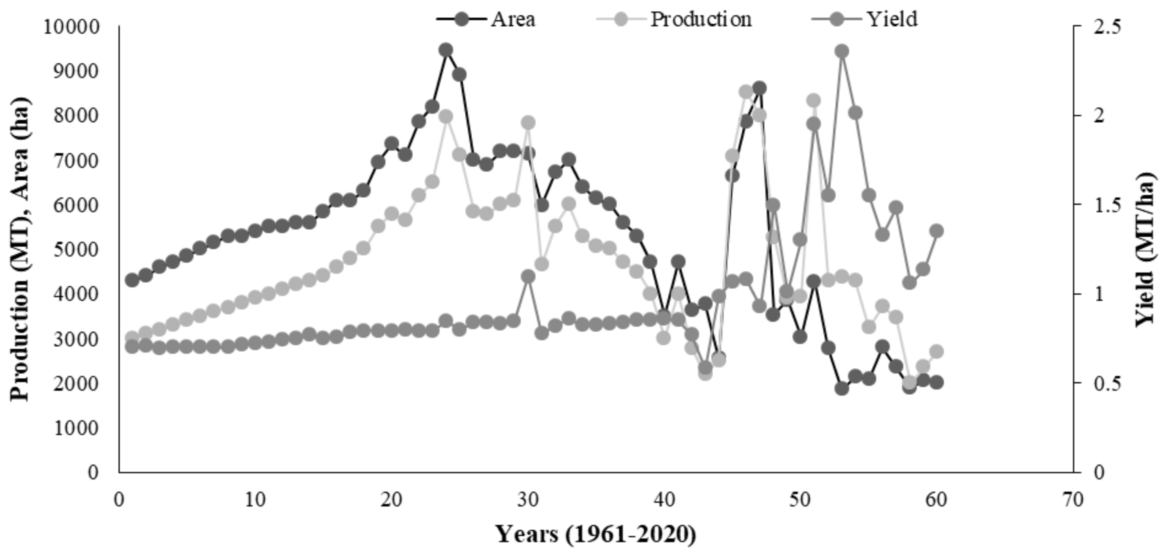

Figure 6: Trends and rates of growth in the area, production, and yield of buckwheat

1992). Buckwheat is traditionally farmed on the higher dryland using a *tseri* cultivation system with extended grass fallows. Buckwheat, once considered a poor man's meal, now served as pancakes and noodles has become a popular restaurant food (Norbu & Roder, 2003).

Conclusion

The study investigated the acceleration, stagnation, or deceleration of major cereal production in terms of area and yield from 1961–2020. The major findings of the study are: (i) there is a significant accelerated growth in major cereals yield over the period from 1961-2020; (ii) there is a deceleration in the area under major cereal cultivation over the same period; the area under wheat cultivation has the highest deceleration, with a -2.123% compound growth rate; and (iii) except for paddy, which has a compound growth rate of 0.852%, productivity of major cereals has slowed significantly between 1961 and 2020.

Recommendation

Based on the findings of this study, controlling infrastructure development on agricultural land must be pursued to conserve agricultural land, given the shrinking area under major cereal cultivation, and land use zoning needs to be developed to protect the agricultural area.

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