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Yield Trends and Yield Gap Analysis of Cereal Crops in Ethiopia: Implications for Research and Policy

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Abstract: This paper presents the analysis of yield and yield gaps of cereal crops in Ethiopia. The result indicates that cereal acreage recorded an annual growth rate of 30.4 percent from 2006/07 to 2020/21. In the 2020/21s, growth in cereal production enhanced to about 159.9 percent as compared to the base year 2006/07. Growth in area cultivated has been the principal source of current production increases in most studied crops, except for rice and oats. The production increase can be attributed to 65.5 percent increase in area cultivated and a 34.5 percent increase in crop yield. The average cereal yield level is very low (2.1 tons/ha) as compared to that of the estimated average potential (3.2 tons/ha) in the country for the studied crops. In 2021, the gap between farmers' yield (25.3, 30.5, 41.8, 26.9, 19.7 and 31.5 qt/ha) and released cultivars potential yield were (31.2, 35.2, 61.1, 36.9, 32.9 and 37.2 qt/ha) for barley, wheat, maize, sorghum, oats, and rice in the country, respectively. The gap analysis is promising and if farmers had closed Yg for studied crops in the same order, Ethiopia could have the potential grain surplus by a respective of 0.6, 4.8.2, 0.02, 0.05, 1.6 and 0.9 million Mt, without expanding cropland area. The empirical analysis based on the Pooled Mean-Group (PMG) model result, if cultivated area and yield of crops is increased by 1 percent then the production growth will be increased by 0.999 percent and by 0.995 percent in the long run respectively. If improvement in breeding can be sustained at existing levels, various yield gaps even appear to increase over time. This means that exploitable yield gaps remain large, which is thought necessary to uphold growth in average farm yields.

Keywords: Cereals, Potential Yields, Actual Yields, Yield Gaps, Grain Production, Ethiopia

1. Introduction

The grains required to feed the approximately nine billion people that are projected to be living on the planet by 2050 and ten billion by 2100 [1], must rely on intensification on existing crop lands as opportunities for sowing new agricultural lands are rapidly diminishing. [2].

By 2030, double the agricultural productivity and incomes of small scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment. [3].

Cereal consumption in sub-Saharan Africa (SSA) depends on massive imports. [4]. Ethiopia's economy is dependent on agriculture, which accounts for 40 percent of the GDP, 80 percent of exports, and an estimated 75 percent of the country's workforce. [5]. In Ethiopia, cereals, pulses and oilseeds, are the grain crops that occupy almost 86.8 percent of the total area cultivated (12,9 million hectares) and constituted the major food crops, source of income at household level and a contributor for the country's foreign currency earnings, among others. [6]. Food production is dominated by smallholder farmers, who together produce more than 90 percent of the country's agricultural output. [7]. Within the category of grain crops, cereals are the major food crops both in terms of the area they are planted and volume of production obtained. In the production season of 2020/2021, 81.2 percent of the area planted was under cereals and the total grain production reached to 341.8 million quintals, of which cereal production accounted for 302 million quintals. They are produced in larger volume compared with other crops because they are the principal staple crops.

The government of Ethiopia targeted to increase the total annual quantity of crop production in all production systems from 543 million quintals to 925 million quintals in 2030. [8]. The impact of increased agricultural production through certain technical solutions also often overlooks the wider impact on the landscape and the ecosystem services which underpin agricultural production and livelihoods. However, crop productivity varies greatly from place to place, depending on weather, amounts and quality of inputs applied, change in farming practices, amounts of fertilizer used, quality of seed varieties, technology and use of irrigation. [6, 13-15].

Moreover, crop yield increases per unit area can be attained through increases of yield potential (Yw) and/or through reductions of yield gaps (Yg). [16]. Assessing the yield gap of existing cropped lands will indicate the possible extent of yield increase from actual values. This yield gaps can be quantified at different scales in space and time. [9].

However, yield gap studies in Ethiopia do not make explicit assumptions about time scale. In addition to looking at cropland area and production trends across years, this study evaluated yield differences across time using sixteen years farm survey data for Ethiopia. [10]. To examine this renewed interest and propose policy measures or initiatives that will assist yield gains in Ethiopia, it is important quantifying the yield gap to identify research and development gaps.

2. Objectives

The overall objective of this study was to analyze potential yields and yield gap trends for extra grain in production.

Specifically,

1) To assess the area of land planted and production patterns of cereal crops over the years.
2) To analyze the yield gap trends in production varies across years and the potential production increase on existing crop area.
3) To analyze the impact of Yield and area on production.

3. Methodology

To realize the objectives of the study, three approaches have been used to. The statistical database of the CSA (Central Statistical Agency) of Ethiopia [10] statistical bulletin for the rainfed farming has been used to compute crop average actual yields, cultivated area and production trends of cereal crops in Ethiopia. Potential yields of cereal crops of Ethiopia have been derived from crop variety register issue [11]. These yields have been used to evaluate the yield gap of cereal crops in Ethiopia for the period 2006 to 2021.

The data was analyzed using descriptive statistics and econometric analysis. Production increase on existing crop area was assessed for cereal crops by quantifying the yield gap (Yg), that is, the difference between yield potential (Yw) and actual yield (Ya). The data was analyzed using graphs, figures, tables and narrations.

Pooled Mean-Group (PMG) model was used to analyze the impact of yield and area on production, as developed by [12].

$$d.y\_it = phi*(y\_(it-1) + beta*x\_(it)) + d.y\_(it-1)a\_1+\ldots + y\_(it-p)\ a\_p+d.x\_(it)\ b\_1+\ldots+d.x\_(it-q)\ b\_q + e\_(it)$$

$$i = \{(1,\ldots,N)\};\ t = \{(1,\ldots,T\_i)\},$$

Where,

phi is the error correction speed of adjustment parameter to be estimated;

beta is a (k X 1) vector of parameters;

a_1,...,a_p are p parameters to be estimated;

x_(it) is a (1 X k) vector of covariates;

b_1,...,b_q are q parameters to be estimated;

and e_(it) is the error term.

The pooled mean-group model (pmg) estimates where the long-run effects, beta, are constrained to be equal across all panels. The short-run coefficients, including phi, are allowed to differ across panels.

4. Result and Discussion

4.1. Area of Land Planted and Production Patterns of Cereal Crops

Ethiopian crop production was dominated by cereals. Cereals were grown on 80.2 percent of the total grain crop area cultivated (10,5 million hectares) in 2021. Cereal crop area showed an annual growth rate of 30.4 percent from 2006/07 to 2020/21. Wheat, maize, rice, teff, sorghum, and finger millet area cultivated increased (by 30, 65.5, 1266.6, 30.4, 14.4 and 44.2 percent, respectively) during 2006/07–2020/21, while barley and oats area cultivated decreased by 7.2 and 65.1 percent respectively.

Since 2006s, teff has always accounted for the largest share of cereal area cultivated. However, over the past decades the share of sorghum has declined gradually, while the share of wheat has increased gradually and becomes the third cultivated area preceding sorghum.

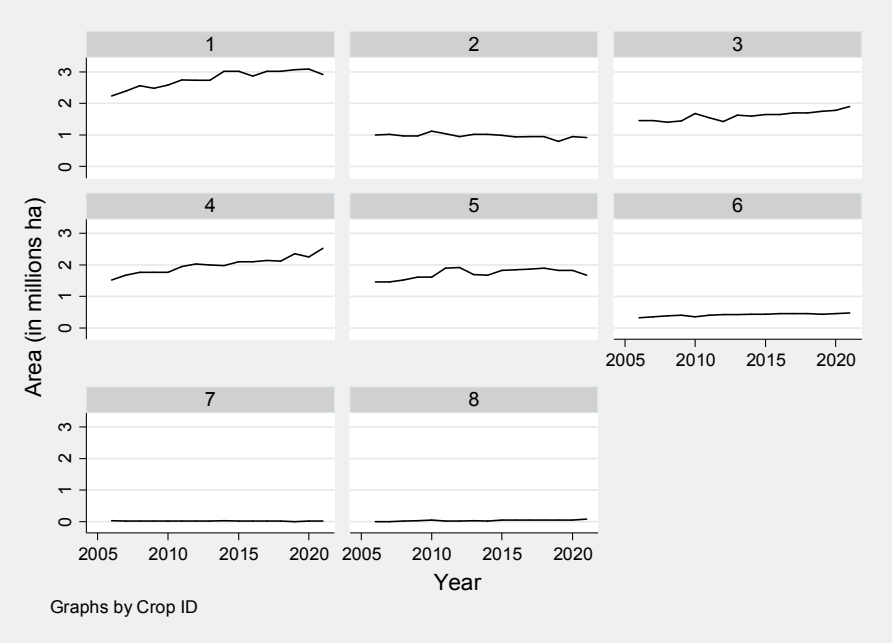
Production Patterns

According to CSA data, in the production season of 2020/2021, the total grain production reached to 341.8 million quintals, of which cereal production accounted for 302 million quintals. The major cereals are teff, wheat, maize, sorghum, rice, finger millet, barley and oats. Together, these crops account 88.4 percent of total grain production.

Maize accounts for 35 percent of total annual cereal production, while wheat stands for 19.1 percent of total annual cereal production, closely followed by teff production 18.2 percent and sorghum production rose by 15 percent per year. The slowest output growth was recorded in barley production 7.7 percent, 4 percent in finger millet production, 0.9 percent in rice production, and 0.1 percent in oats production.

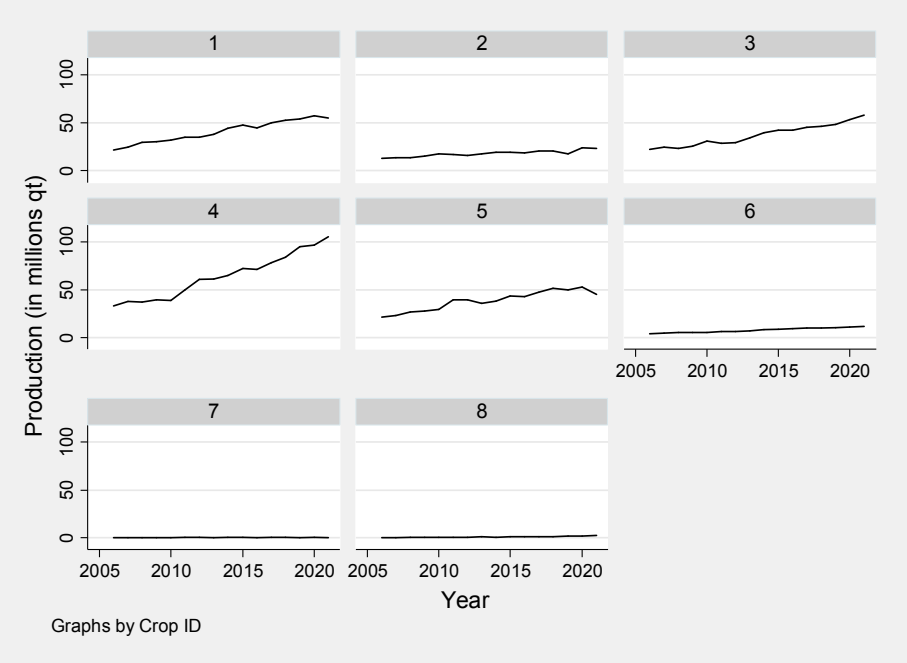
In the 2020/21s, growth in cereal production accelerated to about 159.9 percent compared to base year 2006/07. Area

cultivated growth has been the dominant source of recent production increases in most crops, except for rice and oats. The rise was due to 65.5 percent increase in area cultivated and a 34.5 percent increase in crop yield.



Crop ID: 1=Teff, 2=Barley, 3=Wheat, 4=Maize, 5=Sorghum, 6=Finger Millet, 7=Oats, 8=Rice

Figure 1. *Cropland area trends of cereal crops.*



Crop ID: 1=Teff, 2=Barley, 3=Wheat, 4=Maize, 5=Sorghum, 6=Finger Millet, 7=Oats, 8=Rice

Figure 2. *Production patterns of cereal crops.*

4.2. Potential Yields and Yield Gap Trends

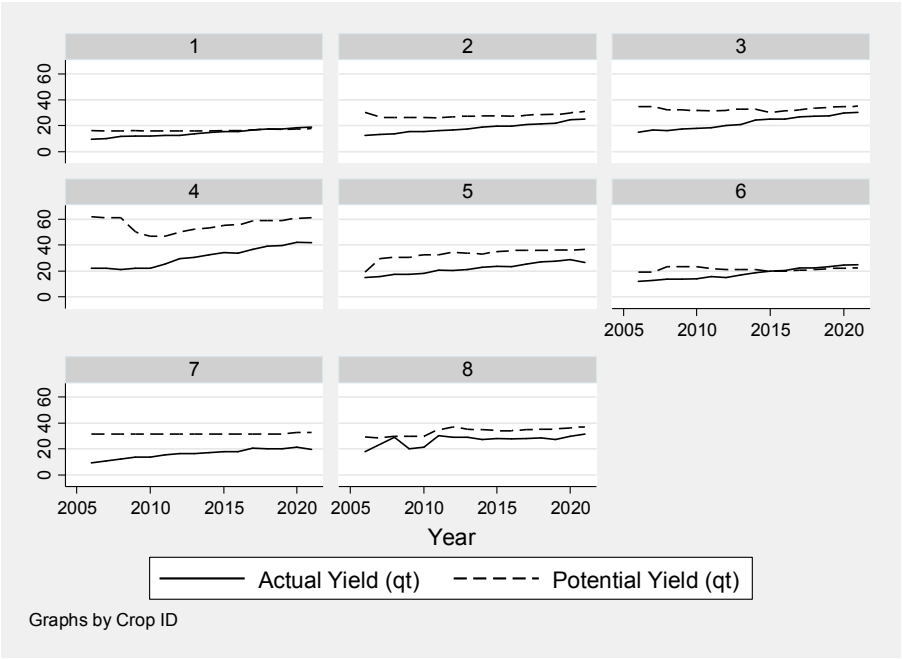
Production increase on existing crop area was assessed for barley, wheat, maize, sorghum, oats, rice, teff and finger millet by quantifying the yield gap (Yg), that is, the difference between farmer management yield potential (Yw) and actual yield (Ya).

As total cereal yield growth was particularly rapid from 2006/07 to 2020/21. The speed of growth was somewhat varied across crops. The average cereal yield level is very low (2.1 tons/ha) as compared to that of the estimated

average potential (3.2 tons/ha) in the country for the studied crops. Average annual growth in yield was fastest in oats (117.7 percent), followed by finger millet, wheat, barley, teff, maize, sorghum and rice by 117.7, 110.1, 100.4, 98.4, 94.2, 91.1, 81.6 and 74.5 percent respectively.

The gap between farmers' yield (25.3, 30.5, 41.8, 26.9, 19.7 and 31.5 qt/ha) and released cultivars potential yield were (31.2, 35.2, 61.1, 36.9, 32.9 and 37.2 qt/ha) for barley, wheat, maize, sorghum, oats, and rice respectively under farmer management, in 2021.

For the analyzed period 2020/21, the national level Yg represented 23.5 percent of Yw for barley, 15.6 percent for wheat, 46.2 percent for maize, 37.2 percent for sorghum, 67 percent for oats, and 18.2 percent for rice. Teff and finger millet exceeded the released cultivars potential under farmer management.



Crop ID: 1=Teff, 2=Barley, 3=Wheat, 4=Maize, 5=Sorghum, 6=Finger Millet, 7=Oats, 8=Rice

Figure 3. *Potential yields and yield gap trends of cereal crops.*

If farmers had closed Yg, Ethiopia could have the potential grain surplus of barley, maize, oats, rice, sorghum, and wheat production by a respective of 0.6, 4.8.2, 0.02, 0.05, 1.6 and 0.9 million Mt, without expanding cropland area. The two crops finger millet and teff indicated a strong increase in yield during the last decades and meet the potential yield.

4.3. The Impact of Yield and Area on Production

The relative contributions of land to output growth were statistically significant, except for barley and oats. Moreover, statistically significant correlation can be detected between yield changes as a source of growth in that crop's output except oats.

Table 1. *Pairwise correlations.*

Variables	(1)	(2)	(3)
(1) production	1.000		
(2) area	0.841	1.000	
	(0.000)		
(3) yield	0.520	0.073	1.000
	(0.000)	(0.412)	

Based on the Pooled Mean-Group (PMG) model result, in the short run area and yield variables are insignificant while in long run these variables are significant. If cultivated area and yield of crops is increased by one percent then the production growth will be increased by 0.999 percent and by 0.995 percent in the long run respectively.

Table 2. *Impacts of yield and area on production.*

D. production	Coef.	Std. Err.	z	p>|z|	[95% Conf. Interval]	
_ec						
area	.9993207	.0030972	322.66	0.000	.9932503	1.005391
yield	.9955745	.0018126	549.24	0.000	.9920218	.9991272
SR						
_ec	-1.005413	.0905935	-11.10	0.000	-1.182973	-.8278528
area D1.	-.0155561	.0892926	-0.17	0.862	-.1905664	.1594541
yield D1.	-.0162887	.0888803	-0.18	0.855	-.190491	.1579136
_cons	.0230025	.0020832	11.04	0.000	.0189195	.0270856

5. Conclusion and Recommendation

This study interpreted yield trends and yield gaps of cereal crops in Ethiopia. The study revealed that the average cereal yield level is very low (2.1 tons/ha) as compared to that of the estimated average potential (3.2 tons/ha) in the country for the studied crops. In our analysis of yield gaps, we have explored that if farmers had closed Yg, Ethiopia could have the potential grain surplus of 162.9 million Mt of cereal crops, without expanding cropland area. This shows that impending crop yields may well emphasis on the capability of farmers to close the gap between current yields and maximum yield potential because average crop yields are critical drivers of food prices, food security and cropland expansion. Therefore we suggest that ecologists, farmers, crop scientists and policy-makers cooperate to explore the promising mechanisms to close yield gaps.

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