

# Fertilizer Use Trends for Major Ethiopian Crops by Smallholder Farmers

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## Abstract

Fertilizer is one of the most important inputs for increasing crop yields and it has been utilized for decades in Ethiopia's agricultural sectors. The trends in fertilizer uses by smallholder farmers from 2004/05 to 2020/21 'Meher' cropping season for the field and horticultural crops at national and regional levels were assessed. Data on the total number of households, the number of households that applied each type of fertilizer, the area treated with each type of fertilizer (organic and inorganic), and the total area sown to each crop were obtained for each cropping season and each crop type from the annual report on farm management practices by the Central Statistical Agency (CSA) of Ethiopia. The compounded annual growth rate (CAGR) of fertilizer applicators and the area treated with fertilizer for each crop was estimated using the exponential trend model and a semi-logarithm trend function. The results revealed that the CAGRs for the number of households who applied inorganic fertilizers on each of the major cereal crops and the area of each particular crop treated with inorganic fertilizer, on most crops, were showed positive trends at national and regional levels, indicating an increasing trend in inorganic fertilizer application. At the national level, the number of households who applied inorganic fertilizer on major cereal (tef, wheat, sorghum, maize, and barley) crops increased with CAGR of 9.33 to 19.65% UREA, 7.35 to 18.96% DAP/NPS, and 10.90 to 17.34% DAP/NPS + UREA fertilizer. Similarly, areas fertilized with Urea, DAP/NPS, and combined use of DAP/NPS and UREA fertilizer had increases in CAGR of 6.14 to 20.38%, 6.94 to 21.64%, and 10.01 to 37.59%, respectively. Thus, large number of households and areas were fertilized with DAP/NPS + UREA fertilizer in wheat, tef and maize than barley and sorghum from 2004/05 to 2020/21. In contrast, the trend was decreased significantly for the number of households who applied organic fertilizer from 2004/05 to the 2020/21 cropping season. The CAGR for the household that applied organic and inorganic fertilizers and the area treated with those fertilizers were not evenly distributed among crops and regions; however, all types of fertilizer were applied almost in tef, wheat, sorghum, maize, and barley crops at regional levels. The proportion of households applying DAP/NPS + UREA fertilizer to the major cereal crops between 2004/05 to 2020/21 the cropping seasons was also higher than those applying organic, UREA, and DAP/NPS fertilizer alone. For instance, the average proportions of the households applying DAP/NPS + UREA to wheat, tef, and maize were greater than to barley and sorghum. In terms of region, it was observed that, the percentages of households who applied DAP/NPS + UREA for tef, wheat, and maize were higher in Tigray, followed by Amhara, SNNPR, and Oromia. In general, the application of inorganic fertilizer has increased, but not organic fertilizer despite the benefits of using organic fertilizer. Therefore, the paper gives insights into the trend of using more inorganic fertilizer than organic fertilizer based on the number of household and area coverage at the national and regional levels in Ethiopia.

**Keywords:** Compound annual growth rate, field crops, horticultural crops, organic fertilizer, inorganic fertilizer

## Introduction

Agriculture is the dominant and pertinent sector of Ethiopia's economy. It accounts for 33% of GDP, 66% of employment, and 76% of the exports of the country (ATI, 2022). The country comprises the crop, animal farming, forestry, and fishery sub-sectors, which account for 61.1%, 26.0%, 8.6%, and 0.2%, respectively, of the total agricultural production (NBE, 2021). Crop production had a lion's share in agriculture and the total land cultivated area reached 13.0 million hectares, of which cereals production accounted for 71.19% (CSA, 2020/21). Of the cultivated crops, five major cereals (Tef, Wheat, Maize, Sorghum, and Barley) are the core of Ethiopia's agriculture and food economy, accounting for about three-quarters of the total area cultivated, 29% of agricultural GDP and 14% of total GDP and about 64.5% of calories consumed (NBE, 2021).

Pulses are the second most important cultivated crop next to cereals in terms of area coverage. In the 2020/21 cropping season, a million holders produced pulses on 12.9% of the total area cultivated (CSA, 2021). Total pulse production averaged 1.6 million tons per year, which is 8.5% of total crop production. Oil seeds were the third most important crop cultivated on 5.9% total area of land by 3.1 million holders (CSA, 2021). They

produced an average of 0.5 million tons of oil seeds yearly i.e. three percent of total annual production in the season. In addition, horticultural crops like vegetables and root crops together were also cultivated on 281 thousand hectares, 2.6% of the area cultivated (CSA, 2021). Thus, field and horticultural crops are produced and critical to smallholder (a small farm operating farmers under a small-scale agriculture model) livelihoods in Ethiopia. Yet, the current productivity of both field and horticultural crops falls significantly below the potential yield (Diriba *et al.*, 2020; Gebissa, 2021). The productivity of wheat, maize, sorghum, and common bean in Ethiopia were about 26.8, 19.7, 29.3, and 35.5% of their potential under water-limited environment of Ethiopia in respective order (Belachew *et al.*, 2022).

In Ethiopia, soil nutrient deficiency was attributed for low yield potential of the crops. Studies showed that the majority of soils in smallholder fields are nutrient deplete (Amare *et al.*, 2005). There are several causes for soil nutrient depletion in Ethiopia including, limited application of organic fertilizers like crop residues and manure due to competitive uses of animal feed and household energy (Belachew and Abera, 2010; Elias, 2016). In the country, the amount of inorganic fertilizer applied per unit area in cereals is also very small (36.2 kg/ha) compared to Kenya (65.2

kg/ha), Latin America (86 kg/ha), South Asia (104 kg/ha), Southeast Asia (142 kg/ha) in Europe and USA (288 kg/ha) (FAO, 2020).

In many developing countries, agricultural development policies have resulted in increased use of inorganic fertilizers as a means to increase agricultural production (World Bank, 2009). Thus, inorganic fertilizers like UREA (46% N) and diammonium phosphate (DAP: 18% N, 46% P<sub>2</sub>O<sub>5</sub>) are primarily used in cereal production in Ethiopia. According to Central Statistical Agency report (CSA, 2004 and 2021), cereals account for 87% to 84.37% of the country's total inorganic fertilizer application. It is also used for pulse, oil seed, vegetables, and root crops and accounts for 3.7 to 3.44%, 2.7 to 4.98%, 1.6 to 0.75%, and 1.9 to 2.32%, respectively. But in Ethiopia, not only inorganic fertilizers but also, organic fertilizers, improved crop varieties, and agronomic practices are some of the dominant inputs that are used to increase crop production (Getachew and Aune, 2018).

The growing of fertilizer use was reported for more than four decades following the introduction of fertilizer under the *Freedom from Hunger* program in the late 1960s. The total amount of fertilizer used increased at decreasing rate in the early 1970, from 3,500 tons to only about 34,000 tons in 1985. In contrast, the trend was increasing from 140,000

tons in the early 1990s to about 650,000 tons in 2012 (Endale, 2010; Asfaw *et al.*, 2022). The recent increase in importing of inorganic fertilizer has been largely driven by the Growth and Transformation Program (Mideksa and Dessalegn, 2020). This was illustrated by the sharp increase in fertilizer imports, which jumped from 440,000 tons in 2008 to 890,000 tons in 2012 (Endale, 2010) although, the average fertilizer use per unit area in the country is still low. According to Shahidur *et al.* (2013), only 30-40 percent of Ethiopian smallholder farmers use about 37-40 kilograms per hectare, which was below the recommended rates (Endale, 2010).

In terms of the application of fertilizer rate per hectare of cultivated lands, the period (2004/05 to 2020/21) showed an increasing trend. For instance, at the national level application of Urea, DAP/NPS, and Urea + DAP/NPS fertilizers on tef, wheat, maize, sorghum, and barley crops increased by more than 50%. Although the application rate per hectare indicated remarkable increases, still lower than the research recommendation for all major crops. According to (Asfaw *et al.*, 2022) the reported that the application of fertilizer has shown a steady upward increase since the year 2012 for most cereal crops. Fertilizer application rate has increased by 64%, 52%, 44%, 40%, 32%, and 8% for rice, maize, wheat, teff, finger-millet and barley respectively over the period

from 2015 to 2020. On the other hand, the application of fertilizer has decreased by 38%, 6% for sorghum and oats respectively. These increases could arise because farmers stagnated in the monoculture cropping system. Thus, farmers have been forced to shift from cereal-legume-based cropping to cereals-cereals and cereals-bulb crops such as tef-wheat, tef-maize, wheat-onion, and tef-onion rotation systems. These cereals and bulb crops are more utilized soil nutrients and leading to deficient soil nutrients. As a result of these, farmers are used more chemical fertilizers. These facts raise concerns in the public and highlight the need to examine trends in fertilizers usage, which have not been assessed before at both national and regional levels.

This study sought to fill this information gap by answering the following question: how can the trends of organic fertilizer and inorganic fertilizer uses and give direction for sustainable and improved organic fertilizer and inorganic fertilizers uses. Therefore, the objective of this study was to assess the trend of organic fertilizer and inorganics fertilizers used during Meher season in the field and horticultural crops grown by smallholder farmers in Ethiopia

## Materials and Methods

### Description of Administrative Regions and Crop Growing Seasons

Ethiopia is administratively divided into four levels: regions, zones, woredas (districts), and kebeles (wards) (Mulatu, 2017; Mapp, 2019). As of 2022, the country comprised of twelve regions and two city administrations. Among all four regions of the country namely; Tigray, Amahara, Oromia and South Nation Nationality, and Peoples (SNNP), which reflects about 95 to 99% cereals, pulse, oil seed, vegetables, and root crops produced of the country, were considered to conduct the study for major crops. Both organic fertilizer (farmyard manure and wood ashes) and inorganic fertilizers DAP (Di-Ammonium phosphate) and/or NPS and Urea (Ammonium Nitrate) were considered for the study.

In Ethiopia, most crops are grown primarily during a longer rainy season (*Meher*) which usually starts in (June to August and is harvested time from September to February). The short rains *Belg* (sowing time February to March and harvesting time June to September) are less reliable to grow crops in most parts of the country. Because of this, trends in fertilizer use for *Belg* season were not analyzed. Thus, in this study, only the rainy (*Meher*) season fertilizer application by smallholder farmers (a small farm operating farmers under a small-scale

agriculture model) was considered. Besides, the analysis focuses solely on fertilizers applied to major field crops (Tef, wheat, sorghum, maize and barely) at both national and regional levels because of consolidated national and regional data. However, pulse crops, oil seeds, vegetables, and root crops were analyzed solely at national bases because data at regional levels were not consolidating. In the application of fertilizer to fields and horticultural crops in Ethiopia, the entire DAP/NPS fertilizer was applied full dose at sowing, whereas nitrogen fertilizer was applied in two splits (1/3 at sowing and 2/3 at tillering about 21 to 30 days after sowing) through the application of Urea. The application of organic fertilizers was applied 20 to 30 days before crop sowing.

### **Data Collection Approach and Analysis**

Data on the total number of households, the number of households who applied organic and inorganic fertilizers, the total area sown, and the area treated with natural, inorganic and mixed fertilizers used at both national and regional level were obtained from the Central Statistical Agency (CSA, 2004/05 to 2020/2021) of Ethiopia. Each datum set was graphed to generate a time plot to visualize and investigate if there is any pattern that exists over time. In addition, Durbin-Watson Statistic was used as a criterion to detect serial autocorrelation. These preliminary

analyses revealed the presence of first and second-order serial autocorrelation (regardless of the significance level) and a non-linear relationship between time and all the variables mentioned above. Consequently, the compounded annual growth rate (CAGR) of fertilizer use was estimated by transforming the exponential trend model ( $Y_i = i^{x_i}$ ) to a semi-logarithm trend function, which is  $\text{Log}_{10} Y_i = b_0 + b_1 X_i$ .

Where  $Y_i$  = a number of households, households who applied fertilizer on a particular crop, the area under a particular crop or area treated with fertilizer in year  $X_i$ ;  $b_0$  is the mean number of households, households who applied fertilizer, the area under a particular crop or area treated with fertilizer in the 2004/05 crop season;  $b_1$  the parameter that measures the CAGR per annum. A trend is detected when the  $b_1$  is significantly different from zero (Gerrodette, 1987). Since the exponential trend model was used,  $b_1$  was converted to CAGR (%) as  $(10^{b_1} - 1) \times 100$ . As indicated before, because of the presence of variable levels of first and second-order serial autocorrelation, each datum set was analyzed using Proc Autoreg of SAS. Furthermore, the percentage of the area treated with or the percentage of households who applied fertilizer in any one year was calculated as  $100 * (\text{total cropped area treated or total households who applied fertilizer}) / (\text{total cropped area or a total number of households who grow that$

particular crop). In some cases, particularly for pulse crops, vegetables, oil crops, and root crops, data at regional levels were unavailable for some years because of the high coefficient of variation and missed. In such cases, the CAGR was estimated only in the national wide.

## Results

### Trends in Fertilizer Use on Major Cereal Crops

The major cereal crops produced in almost all regions of the country were tef (*Eragrostis tef.*), wheat (bread and durum wheat types), sorghum (*Sorghum bicolor*), maize (*Zea mays*), and barley (both the variety which can be used for food and malt processing), despite the variation in the volume of production and productivity. Between the 2004/05 and 2020/21 cropping seasons, the total number of households that grew and the total area under each major cereal crop had significantly increased at both national

and regional levels (Tables 1 and 2). However, the number of barley grower households at national, and the total area under barley both at regional and national levels and sorghum at SNNPR region were showed a decreasing trend (Tables 1 and 2). At the national level, maize grower households and the area sown to maize was greater than tef, wheat, and sorghum and exhibited an increasing trend (Table 1 and 2). Likewise, at regional levels, maize grower households and the area sown to maize increased in Oromia and followed by Amhara regions. Similarly, between 2004/05 and 2020/21 crop season, the total number of households who grew tef, sorghum, and barely and the total area sown to tef, wheat sorghum and barely had greater in the Oromia region. However, the total number of households who grew wheat was more significantly higher in the Amhara region (Tables 1 and 2) than other regions.

Table 1. Number of households who grew major cereal crops in 2004/05 and 2020/21 crop seasons in the main crop producer regions of Ethiopia

Region/ National	Tef		Wheat		Sorghum		Mazie		Barley	
	2004/05	2020/21	2004/05	2020/21	2004/05	2020/21	2004/05	2020/21	2004/05	2020/21
Tigray	395681	633525	287946	386778	270380	558917	394632	835782	370776	419786
Amhara	1839987	2703282	1252127	1906639	895059	1191608	1780595	2978454	1475667	1290159
Oromia	1822436	2861364	1722661	1832546	1782165	2321488	3089557	5205203	1427362	1509055
SNNP	767677	1224860	626620	761835	549905	562834	1199744	1372318	597800	789117
Ethiopia	4857682	6866855	3937682	4579491	3674865	4323086	6677356	10189355	3902139	3738220

Table 2. Area (ha) sown to major cereal crops in 2004/05 and 2020/21 cropping seasons in main crop producer regions of Ethiopia

Region/ National	Tef		Wheat		Sorghum		Maize		Barley	
	2004/05	2020/21	2004/05	2020/21	2004/05	2020/21	2004/05	2020/21	2004/05	2020/21
Tigray	137360	188392	87785	102258	142038	232636	47200	80152	95453	85432
Amhara	852307	1086375	392722	641170	411949	597441	285242	595086	375912	311401
Oromia	918461	1393456	765528	996364	522499	676075	791686	1371868	532141	440702
SNNP	210055	234351	131485	147641	92009	62926	207410	313799	84936	75440
Ethiopia	2135553	2928206	1398215	1897405	1253620	1679277	1392916	2526212	1095436	926107

## Organic Fertilizer Use Trends on Major Cereal Crops

According to the Central Statistical Agency of Ethiopia (CSA) definition, organic fertilizer is characterized as the fertilizer that consists of the farm yard manure and wood ashes (CSA, 2004 to 2021). At national level, the CAGRs for the number of households who applied organic fertilizer on each of the major cereal crop and the area coverage with organic fertilizer were positive; indicating that the trend was increased for the major crops (Table 3).

Overall, an increasing trend was observed on average number of households who applied organic fertilizer for maize and sorghum than tef, wheat, barley crops from 2004/05 to 2020/21 crop season (Table 4). Similarly, the area coverage of sorghum and maize treated with organic fertilizer were more than tef,

wheat and barley between 2004/and 2020/21.

Nationally the CAGRs for the number of household and use of organic fertilizer per unit were increased in all region of the country (Table 3). Between 2004/05 and 2020/21 crop season, the proportion of organic fertilizer applicator households and the proportion of organic fertilizer treated area on major cereal crops were decreased in all regions and in the country (Tables 4 and 5). With the only exception of these decreasing, the proportions of organic fertilizer treated area were positive and increasing of tef area in the Tigray region (Table 5). Generally, between 2004/05 and 2020/21 crop season, larger proportions of households who grew cereal crop and area treated with organic fertilizer in the regions and in the country were decreased use of organic fertilizer on major cereal crops.

Table 3. Compounded annual growth rate (%) of households who applied organic fertilizers on and organic fertilizer treated area of major cereal crops between 2004/05 and 2020/21 cropping seasons in different regions of Ethiopia

Region/ National	Tef		Wheat		Sorghum		Maize		Barely	
	HWNF	ATNF	HWNF	ATNF	HWNF	ATNF	HWNF	ATNF	HWNF	ATNF
Tigray	5.63	-0.99	2.32	0.87	6.89	3.89	8.18	6.54	-6.11	-7.87
Amhara	10.46	5.37	5.74	4.39	9.77	9.07	7.49	5.53	6.29	5.97
Oromia	8.31	5.26	5.79	5.55	10.99	8.11	9.45	7.68	7.98	5.78
SNNP	6.39	2.19	2.11	-0.69	8.68	7.05	7.14	5.06	-2.12	-5.74
Ethiopia	4.94	2.97	4.32	1.76	8.11	7.68	6.25	5.12	5.04	3.53

HWNF= Holders who applied natural fertilizer, ATNF= Area treated with natural fertilizer



Table 4. Proportion (%) of households who applied natural fertilizer on major cereal crops in 2004/05 and 2020/21 crop seasons

Region/ National	Tef		Wheat		Sorghum		Maize		Barely	
	2004/05	2020/21	2004/05	2020/21	2004/05	2020/21	2004/05	2020/21	2004/05	2020/21
Tigray	1.08	2.61	21.27	8.55	29.82	18.17	73.51	39.51	28.17	13.66
Amhara	6.17	2.06	10.83	3.02	9.93	9.65	37.00	10.02	18.73	15.12
Oromia	2.62	2.40	3.51	1.36	13.22	12.65	23.95	13.25	9.35	6.78
SNNP	2.54	2.49	10.93	7.20	10.30	8.31	17.70	15.78	22.59	14.00
Ethiopia	4.58	2.45	7.53	2.80	13.31	11.16	26.98	13.17	15.32	10.77

Table 5. The proportion of area of major cereal crops treated with organic fertilizer in 2004/05 and 2020/21 crop season

Region/ National	Tef		Wheat		Sorghum		Maize		Barely	
	2004/05	2020/21	2004/05	2020/21	2004/05	2020/21	2004/05	2020/21	2004/05	2020/21
Tigray	18.80	5.74	40.45	16.29	45.17	26.71	74.88	46.61	45.23	22.11
Amhara	13.52	5.01	25.35	8.46	18.94	17.39	65.47	31.64	35.13	26.06
Oromia	17.56	5.36	12.12	5.05	22.60	20.48	47.01	33.99	21.75	20.53
SNNP	6.25	6.51	18.39	9.50	23.44	22.32	45.71	28.02	30.02	20.64
Ethiopia	10.53	5.99	19.52	8.56	23.14	22.43	23.15	20.44	52.84	35.50

### Urea Fertilizer Use Trends on Major Cereal Crops

Consumption of Urea is one of the vital inputs in increasing crop productivity and its utilization should be carried out at the farm level. Between 2004/05 and 2020/21 crop season, the result of CAGRs showed that the number of households who applied Urea for the major cereal crop and the area coverage of crops fertilized in Urea was positive at both national and regional levels (Table 6). There was a decreasing and negative trend in the use of Urea on barley in the SNNP region (Table 6). At the national level, the amount of Urea used on tef, wheat, maize and barely was more than the rate for sorghum at household level (Table 6). The amount of Urea applied for wheat and maize

were higher than tef, sorghum and barley (Table 6).

At regional level, large amount of Urea per household per unit area were applied in Tigray region which was higher compared to the national average. It was followed by Amhara, Oromia and SNNP (Table 6). Besides on crops, the CAGR for Urea per households per unit area were greater in wheat and maize than tef, sorghum and barley crops in Tigray region (Table 6). Similarly, the CAGRs of Urea utilization was per households was greater for tef and wheat in Amhara, and maize in Oromia regions (Table 6).

Besides, between 2004/05 and 2020/21 of cropping season, on average, the proportion of households

who applied Urea fertilizer and the proportion of area treated with Urea fertilizer on tef, wheat and maize in Oromia and SNNP were greater than Tigray and Amhara regions (Tables 7 and 8). But, in terms of crop, the proportions of the area treated with Urea fertilizer were greater on

sorghum and maize than tef, wheat and barley crops in Tigray region (Table 6). On the other hand, the proportion of households who applied Urea fertilizer and the proportion of area treated by the households with Urea fertilizer in each of major cereal crop were negligible (Tables 7 and 8).

Table 6. Compounded annual growth rate (CAGR) (%) of households who applied Urea fertilizers applied on crops and the total area treated with Urea fertilizer on major cereal crops between 2004/05 and 2020/21 cropping seasons

Region/ National	Tef		Wheat		Sorghum		Maize		Barely	
	HWAF	ATUF	HWAF	ATUF	HWAF	ATUF	HWAF	ATUF	HWAF	ATUF
Tigray	16.29	15.58	26.80	27.05	19.35	16.49	24.47	20.79	19.37	15.36
Amhara	13.84	7.12	20.28	24.40	8.99	6.66	6.08	1.26	8.15	24.03
Oromia	9.94	9.83	19.94	20.52	7.55	6.26	14.00	12.59	8.21	6.28
SNNP	6.92	4.78	9.11	26.98	2.43	10.03	7.12	4.46	-4.94	4.00
Ethiopia	19.65	9.53	18.72	20.38	9.33	6.14	15.69	14.44	13.59	13.28

HWUF= Holders who applied Urea fertilizer, ATUF= Area treated with Urea

Table 7. Proportion (%) of households who applied inorganic (Urea) fertilizer on major cereal crops in 2004/05 and 2020/21 crop seasons

Region/ National	Tef		Wheat		Sorghum		Maize		Barely	
	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21
Tigray	2.33	2.17	4.00	6.85	1.36	7.17	1.56	2.61	4.52	8.28
Amhara	5.52	8.12	5.20	3.62	0.04	1.53	9.70	1.28	4.34	6.46
Oromia	13.63	7.84	45.52	25.70	1.40	4.46	8.38	14.18	3.42	3.67
SNNP	25.77	25.92	40.86	5.37	2.46	2.42	22.46	7.72	2.35	1.22
Ethiopia	3.09	3.16	2.33	2.37	0.75	3.95	1.44	2.95	0.61	2.72

Table 8. The proportion of area of major cereal crops treated with inorganic (Urea) fertilizer in 2004/05 and 2020/21 crop season

HWDF= Holders who applied DAP/NPS fertilizer, ATDF= Area treated with DAP/NPS

Region/ National	Tef		Wheat		Sorghum		Maize		Barely	
	HWDF	ATDF	HWDF	ATDF	HWDF	ATDF	HWDF	ATDF	HWDF	ATDF
Tigray	16.43	18.08	16.49	10.83	37.67	34.47	29.26	26.93	19.10	14.24
Amhara	38.08	48.29	11.23	6.36	30.24	36.71	21.76	21.01	22.28	23.11
Oromia	13.98	15.11	8.55	7.86	14.35	22.14	11.22	14.22	7.99	2.47
SNNP	13.68	16.51	3.57	1.00	26.98	15.64	12.00	14.62	4.55	5.90
Ethiopia	9.77	9.96	8.88	6.94	18.96	21.64	13.44	13.61	7.35	12.30

### DAP/NPS Fertilizer Use Trends on Major Cereal Crops

The CAGR's of the number of households who applied DAP/NPS fertilizer on each of major cereals (tef, wheat, sorghum, maize and barely) and the proportions of the area of each of these crops treated with DAP/NPS fertilizer are presented in Table 9. Thus, between 2004/05 and 2020/21 crop season, the CAGRs for the number of households who applied DAP/NPS fertilizer on each of the major cereal crop and the area of each particular crop treated with DAP/NPS fertilizer showed positive trends at both national and regional levels, which indicate an increasing DAP/NPS fertilizers use trends in the production of these major cereal crops (Table 9). At national level, the CAGRs for the number of households who applied DAP/NPS fertilizer and area treated by this fertilizer on sorghum was greater than tef, wheat, maize and barely crops (Table 9). However, DAP/NPS fertilizer user households and area treated with DAP/NPS fertilizers of tef, sorghum and barely in the Amhara region,

maize and wheat in the Tigray and were greater than the national average and the corresponding CAGR values Oromia and SNNP regions (Table 9).

The proportion of households who applied DAP/NPS fertilizer in each major cereals crop had increased (Table 10). Thus, at national level, between 2004/05 and 2020/21 cope season, the proportions of DAP/NPS user households on tef, wheat and maize, and barely on the average, were greater than the proportions of DAP/NPS user households on sorghum (Table 10). However, the proportion of DAP/NPS treated area were on the average greater on barely than tef, wheat, sorghum and maize crops (Table 11). These indicate that, larger proportions of barely area were treated with DAP/NPS fertilizer than which inorganic fertilizer. On the other hand, at regional level, the proportion of households who applied DAP/NPS fertilizer in each major cereals crop and the proportions of the area of each of these crops treated with DAP/NPS fertilizer were negligible (Tables 10 and 11).

Table 9. Compounded annual growth rate (%) of households who applied DAP/NPS fertilizers on and DAP/NPS fertilizer treated area of major cereal crops between 2004/05 and 2020/21 cropping seasons in different regions of Ethiopia

Region/ National	Tef		Wheat		Sorghum		Maize		Barely	
	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21
Tigray	0.69	0.96	0.96	1.04	0.39	6.20	1.26	5.73	2.49	5.33
Amhara	2.55	1.35	1.00	0.54	0.47	6.21	6.13	2.37	0.63	4.35
Oromia	0.79	1.40	0.90	1.43	1.99	2.62	8.36	2.37	1.26	2.70
SNNP	0.27	0.65	0.22	0.05	0.18	1.20	3.16	1.16	1.10	1.25
Ethiopia	20.48	17.91	30.61	15.98	0.97	3.99	10.19	9.35	20.36	23.01

Table 10. Proportion (%) of households who applied DAP/NPS fertilizer on major cereal crops in 2004/05 and 2020/21 crop seasons

Region/ National	Tef		Wheat		Sorghum		Maize		Barely	
	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21
Tigray	4.38	3.92	3.28	6.12	0.39	6.20	1.26	5.73	2.49	5.33
Amhara	6.13	5.50	3.92	3.45	0.47	6.21	2.37	8.36	0.63	4.35
Oromia	2.22	3.71	2.50	3.76	1.99	2.62	2.37	3.16	1.26	2.70
SNNP	1.43	2.25	1.79	3.51	0.18	2.30	1.16	2.04	1.10	1.25
Ethiopia	21.17	22.48	21.97	16.19	1.89	6.45	8.99	11.63	16.08	21.30

Table 11. The proportion of area of major cereal crops treated with DAP/NPS in 2004/05 and 2020/21 crop season

Region/ National	Tef		Wheat		Sorghum		Maize		Barely	
	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21
Tigray	5.86	9.27	5.34	6.48	2.06	8.91	1.23	2.95	3.45	6.62
Amhara	13.15	20.80	15.77	30.06	0.73	1.88	6.37	11.85	5.13	6.61
Oromia	26.74	32.10	13.97	28.27	1.65	6.63	8.20	16.97	27.61	30.79
SNNP	35.24	23.48	8.78	18.58	5.92	5.87	8.89	10.37	24.04	14.16
Ethiopia	3.68	4.58	2.90	3.58	1.30	4.41	2.10	4.98	1.11	3.69

## DAP/NPS Combined with Urea Fertilizer Use Trends

Both at national and regional levels, between 2004/05 and 2020/21 crop seasons, the number of households who applied DAP/NPS + Urea fertilizers on each of the major cereal crop (tef, wheat, sorghum, maize and barely) and the area of each those particular crops treated with DAP/NPS

+ Urea is presented in Table 12. Thus, the CAGRs for the number of households who applied DAP/NPS + Urea fertilizer on major cereal crops and the area of each particular crop treated with these fertilizers were positive at both national and regional levels, which indicate an increasing trend (Table 12). Although, in the SNNP region, for all major cereal

crops, the CAGRs for DAP/NPS + Urea fertilizer user households and the area treated with these fertilizers was greater than the national average and

the corresponding CAGR values in Tigray, Amhara and Oromia regions except area treated on tef at national level (Table 12).

Table 12: Compounded annual growth rate (%) of household who applied DAP/NPS + Urea fertilizer application and DAP/NPS + Urea fertilizer treated area of major cereal crops between 2004/05 and 2020/21 cropping seasons in different regions of Ethiopia

	Tef		Wheat		Sorghum		Maize		Barely	
	HWBF	ATBF	HWBF	ATBF	HWBF	ATBF	HWBF	ATBF	HWBF	ATBF
Tigray	12.91	12.85	16.92	16.98	24.10	28.39	21.28	19.85	16.00	14.59
Amhara	12.55	13.09	14.01	12.88	21.26	31.07	12.27	11.37	18.77	20.12
Oromia	13.36	12.10	10.36	11.77	14.30	17.31	15.81	18.16	3.90	10.15
SNNP	21.86	21.80	20.37	18.02	24.43	36.10	22.48	24.19	23.19	26.55
Ethiopia	12.12	37.59	10.90	10.01	17.34	18.49	13.11	14.51	14.48	13.51

HWBF= Holders who applied both DAP/NPS + Urea fertilizer; ATBF= Area treated with both (DAP/NPS +Urea fertilizers)

Between 2004/05 and 2020/21 crop season, the proportion of households who applied DAP/NPS + Urea fertilizer in each major cereals crop had increased (Table 13). Although, the proportions of DAP/NPS + Urea user households on wheat, tef and maize, on the average, were greater than the proportions of DAP/NPS + Urea users on barely and sorghum at regional and national levels (Table 13). It means larger proportions of households in the Tigray, Amhara, Oromia, SNNP and in the country at large were applied DAP/NPS + Urea on wheat, tef, and maize than barely and sorghum. However, at the regional level, the rate at which DAP/NPS + Urea fertilizer applicator household for wheat in SNNP, for tef in Amhara, and for maize in Oromia region were greater than the rate at which for tef in

Tigray, Oromia, SNNP, for wheat in Tigray, Oromia, SNNP and for maize in Tigray, Amhara, and SNNP, the rate at which DAP/NPS + Urea fertilizer applicator household on these three crops.

Similarly, to that of the proportion of households who applied DA/NPS + Urea fertilizers, the proportion of DAP/NPS + Urea treated area were on the average greater on wheat, tef and maize than barely and sorghum crops both at national and regional levels (Table13). For example, the highest proportion of area of wheat treated in SNNP and, tef and maize areas treated in Oromia region (Table 14). This indicate that, in SNNP and Oromia regions, large proportion of wheat, tef and maize area were treated with DAP/NPS + Urea fertilizer than

sorghum and barely crops. Moreover, at national level, the proportion of wheat, tef and maize area treated with DAP/NPS + Urea fertilizers were

greater than sorghum and barely area treated with DAP/NPS + Urea fertilizer (Table 14).

Table 13. Proportion (%) of households who applied DAP/NPS + Urea fertilizer on major cereal crops in 2004/05 and 2020/21 crop seasons

Region/ National	Tef		Wheat		Sorghum		Maize		Barely	
	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21
Tigray	28.85	39.75	22.26	39.19	2.35	11.15	11.79	37.24	21.07	30.32
Amhara	23.65	36.81	32.98	48.39	2.00	2.78	34.87	27.76	3.37	18.29
Oromia	29.69	41.12	23.20	57.35	2.13	3.51	15.66	53.20	7.55	19.23
SNNP	9.45	40.47	21.48	66.10	0.99	10.17	7.63	36.76	3.33	38.03
Ethiopia	25.13	39.83	25.60	54.89	1.32	4.92	17.74	44.31	6.92	22.65

Table 14. The proportion of area of major cereal crops treated with DAP/NPS + Urea in 2004/05 and 2020/21 crop season

Region/ National	Tef		Wheat		Sorghum		Maize		Barely	
	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21	2004/ 05	2020/ 21
Tigray	22.38	55.78	27.89	43.22	4.59	8.75	9.92	24.66	22.44	35.75
Amhara	33.45	45.16	24.24	45.33	2.60	4.28	18.84	36.98	4.71	19.79
Oromia	20.29	36.96	22.18	50.28	2.86	6.15	12.77	41.91	7.98	19.03
SNNP	19.86	37.27	17.85	63.93	2.13	2.52	7.16	37.72	4.82	40.43
Ethiopia	19.64	42.23	22.38	55.78	2.23	10.56	12.89	36.43	7.58	29.07

## Trends in Fertilizer Use on Food legume Crops

The major food legume crops cultivated in Ethiopia include faba bean (*Vicia faba* L.), field pea (*Pisum sativum* L.), chickpea (*Cicer arietinum* L.), lentil (*Lens culinaris* Med.), haricot bean (*Phaseolus vulgaris* L.) and fenugreek (*Trigonella foenum-graecum*). Between 2004/05 and 2020/21 crop season, the total number of households who produced chickpea, faba bean and haricot bean (*Phaseolus*

*vulgaris* L.) and the total area sown to chickpea, faba bean and haricot bean had increased significantly at the national level (Table 15). Conversely, the number of faba bean and haricot bean producer households and the area sown to both crops were on the average greater than chickpea (Table 15). On the other hand, within the same time span, number of households who grew field pea, lentil and fenugreek and only area sown on field pea were decreased (Table 15).

Table 15. Number of households who grow food legume crops and the total area (ha) sown to major pulse crops between 2004/05 and 2020/21 cropping seasons in Ethiopia

	Number of households		Area (ha) sown	
	2004/05	2020/21	2004/05	2020/21
National				
Chickpea	666100	935307	167569	220719
Field-pea	1604211	1599356	254365	219928
Haricot bean	2353250	2998746	245597	311584
Faba-bean	3358747	4159404	463174	504570
Lentil	643636	374545	76642	84512
Fenugreek	479676	419222	16325	42344

In the country, CAGRs for both organic and inorganic fertilizer applicator households on faba bean, field pea, chickpea, lentil, fenugreek and haricot bean and the CAGRs for area of each legume crop treated with organic and inorganic fertilizer were positive (Table 16), which indicates increasing fertilizer use trend in the production of these legume crops. On the average, lentil, fenugreek and chickpea had comparable but greater CAGRs for organic fertilizer applicator households than field pea, faba bean and haricot bean (Table 16). However, haricot bean and fenugreek had comparable but greater CAGRs for organic fertilizer treated area than lentil, chickpea, field pea and faba bean.

Similarly, between 2004/05 and 2020/21 crop seasons, the number of Urea fertilizer applicator households and the area treated with this fertilizer on fenugreek, lentil and haricot bean had exhibited greater CAGR than chickpea, field pea and faba bean (Table 16). However, the proportion of Urea fertilizer applicator households

and area treated with Urea fertilizer on haricot bean, faba bean, field pea, chickpea, lentil and fenugreek were negligible. Thus, between 2004/05 and 2020/21, legume crops were rarely treated with Urea fertilizer in the country.

The number of households who applied DAP/NPS fertilizer on fenugreek and haricot bean had increased at CAGRs of 17.39% and 16.23%, respectively, and the area treated with DAP/NPS fertilizer on haricot bean and fenugreek had increased at CAGR of 40.59% and 20.19%, respectively. However, the proportion of DAP/NPS fertilizer applicator households and the proportion of DAP/NPS fertilizer treated area were on the average similar for haricot bean, faba bean and field pea. Thus, between 2004/05 and 2020/21 crop seasons, the proportion of DAP/NPS fertilizer applicator households on haricot bean ranged from 6.83 to 17.26%, 6.82 to 16.47% on faba bean, 7.23 to 15.84% on field pea. The corresponding values for the proportion of area of each crop treated

with DAP/NPS fertilizer were 8.8 to 16.13%, 6.15 to 18.27% and 7.56 to 16.04%. Conversely, the number of households who applied DAP/NPS and the area treated with this fertilizer type on chickpea, lentil and fenugreek crops were negligible. Thus, between 2004/05 and 2020/21, legume crops like chickpea, fenugreek and lentil were rarely treated with DAP/NPS fertilizer in the country.

In Ethiopia, DAP/NPS combined with Urea types of fertilizers are applied on most field and horticultural crops by smallholders' farmers. Thus, the number of DAP/NPS + Urea fertilizer user households and the legume crops area treated with these fertilizers had positively and significantly (Table 16). For example, lentil, fenugreek, faba bean and haricot bean had comparable but greater CAGRs for DAP/NPS + Urea fertilizer applicator households than field pea and chickpea (Table 16). The corresponding values for the proportion of area of lentil, fenugreek, faba bean and haricot bean treated with DAP/NPS + Urea fertilizers were also comparable but greater than field pea; however, proportion of area of chickpea treated with DAP/NPS +

Urea fertilizer was the highest CAGR (Table 16).

Moreover, the proportion of DAP/NPS + Urea fertilizer applicator households on fenugreek ranged from 3.53 to 15.00%, 2.94 to 9.32% on faba bean, 3.74 to 9.05% on lentil and 3.44 to 8.90% on haricot bean. Similarly, the proportion of area treated with DAP/NPS + Urea fertilizer on fenugreek, faba bean, lentil, haricot bean had comparable and the value ranged from 6.29 to 7.62%, 1.79 to 7.45%, 3.18 to 8.04% and 2.87 to 10.56%, respectively. Conversely, the proportion of DAP/NPS + Urea fertilizer applicator households on chickpea and the area treated with DAP/NPS + Urea fertilizer on chickpea was negligible. Thus, between 2004/05 and 2020/21 crop season, the proportion of DAP/NPS + Urea fertilizer applicator households and the area treated with these fertilizer type on chickpea ranged from 0.85 to 2.7%, and 0 to 1.24%, respectively. Generally, large number of households who grown chickpea and chickpea planted area were rarely applied with DA/NPS + Urea fertilizer compared to other legume crops.



Table 16. National compounded annual growth rate (%) for organic and inorganic fertilizers applicator households and fertilizer treated area of legume crops between 2004/05 and 2020/21 crop season

Region/ National	Organic fertilizer		Urea		DAP/NPS		DAP/NPS + Urea	
	HWOFF	ATOF	HWUF	ATUF	HWDF	ATDF	HWBF	ATBF
Chickpea	11.08	5.97	9.27	10.20	9.96	9.98	5.28	15.07
Field pea	9.46	5.98	8.86	7.87	7.79	5.77	5.77	5.77
Haricot bean	9.46	8.09	14.08	11.60	16.23	40.59	10.07	12.93
Faba bean	6.23	5.29	8.57	9.11	9.21	8.14	11.35	11.65
Lentil	13.86	4.29	15.32	15.74	7.44	11.99	12.28	14.16
Fenugreek	12.36	6.93	18.38	12.88	17.39	20.19	11.14	13.27

HWOFF, HWUF, HWDF and HWBF= Holders who applied organic, Urea, DAP/NPS and both (DAP/NPS + Urea) fertilizer; ATOF, ATUF, ATDF and ATBF= Area treated with organic, Urea, DAP/NPS and both (DAP/NPS + Urea) fertilizer

### Trends in Fertilizer Use on Oil seed Crops

The major oilseed crops cultivated by smallholders in Ethiopia include noug (*Guzotia abyssinica*), linseed (*Linum usitatissimum*), rapeseed (*Brasica carinata*), groundnut (*Arachis hypogaea*), sesame (*Sesamum indicum*) and safflower (*Carthamus tinctorius*). However, fertilizers use data are available only for linseed,

sesame and rapeseed. Between 2004/05 and 2020/21 crop season, the total number of households who produced linseed, sesame and rapeseed had decreased significantly at the national level (Table 17). Conversely, the area sown to sesame crops were increased significantly (Table 17). On the other hand, within the same time span, the area sown to rapeseed was decreased (Table 17).

Table 17. Number of households who grow and area (ha) sown to oilseed crops between 2004/05 and 2020/21 cropping seasons in Ethiopia

National	Number of households		Area (ha) sown	
	2004/05	2020/21	2004/05	2020/21
linseed	1267738	606911	250702	78921.37
Sesame	463741	309622	169897.3	369897.3
Rapeseed	816876	423273	41881	7917.47

At the national level, the CAGRs for organic fertilizer user households on each of the three oils seed crops and the organic fertilizer treated area only sesame crop was positive, which indicates an increasing trend (Table 18). However, the CAGRs, for the organic fertilizer treated area on

linseed and rapeseed crops were negative, which indicated a decreasing trend (Table 18). On the other hand, between 2004/05 and 2020/21 crop season, the proportions of organic fertilizer applicator households on linseed, sesame and rapeseed and the proportions of each crop area that was

treated with organic fertilizer were decreased. Thus, the proportions of organic fertilizer applicator households on linseed value ranges from 7.22 to 1.89%, 8.37 to 0%, on sesame 5.76 to 3.40%, on rapeseed. The corresponding values for the proportion of area of each three crop, 21.96 to 6.76, 41.67 to 3.46% and 30.47 to 28.72%.

At national level, between 2004/05 and 2020/21 crop season, the CAGR for the number of households who applied Urea fertilizer on linseed, sesame and rapeseed was positive (Table 18). However, the proportion of households who applied Urea fertilizer and the proportion of linseed, sesame, and rapeseed area treated with Urea fertilizer were very small. In general, the proportion of households who applied Urea fertilizer and the proportion of area treated with Urea fertilizer on these three oilseed crops did not show distinct trend. Similarly, between 2004/05 and 2020/21 crop season, the CAGR for the number of households who applied DAP/NPS fertilizer and area applied with this fertilizer type on only sesame was

positive (Table 18). Thus, households who applied DAP/NPS fertilizer and area treated with DAP/NPS fertilizer on sesame increased at CAGR of 8.68% and 17.64%, respectively (Table 18). On the other hand, the proportion of households who applied DAP/NPS fertilizer and the proportion of area treated with DAP/NPS fertilizer on linseed and rapeseed were negligible (Table 18).

The CAGRs for households who applied DAP/NPS + Urea fertilizer on linseed, sesame and rapeseed was positive (Table 18), which indicates increased use of DAP/NPS + Urea fertilizer on these crops. Consequently, 14.51 to 17.40% and 2.70 to 5.23% the households had applied DAP/NPS + Urea fertilizer and area treated with this fertilizer on rapeseed, 0.98 to 0.26% the households had applied DAP/NPS + Urea fertilizer on linseed. For the sesame crop, the households had applied DAP/NPS + Urea fertilizer and area treated with this fertilizer was highly variable among crop seasons (the estimates had very high coefficient of variation).

Table 18. National compounded annual growth rate (%) for organic fertilizer and inorganic fertilizers applicator households and fertilizer treated area of oilseed crops between 2004/05 and 2020/21 crop season

Region/ National	Organic fertilizer		Urea		DAP/NPS		DAP/NPS + Urea	
	HWOFF	ATNF	HWUF	ATUF	HWDF	ATDF	HWBF	ATBF
Linseed	0.11	-2.16	9.15	13.57	-0.49	-5.45	6.90	5.92
Sesame	5.08	4.25	7.78	18.13	8.68	17.64	15.59	19.59
Rapeseed	4.98	-4.98	4.09	1.74	-8.72	-12.79	2.70	5.23

HWOFF, HWUF, HWDF and HWBF= Holders who applied organic, Urea, DAP/NPS and both (DAP/NPS + Urea) fertilizer; ATOF, ATUF, ATDF and ATBF= Area treated with organic, Urea, DAP/NPS and both (DAP/NPS + Urea) fertilizer

## Trends in Fertilizer Use on Fruit Vegetable Crops

The important fruit vegetable crops in Ethiopia are tomato, green pepper, red pepper, egg-plant are probably the most widely cultivated crops in the country. Nationwide hundreds of thousands of households are involved in beet root, carrot and yam production each on an area less than 5600 ha.

Moreover, fertilizers use data are available only for green pepper and red pepper. Thus, the number of households who grow green pepper and red pepper, and the corresponding area for these two crops had significantly increased between 2004/05 and 2020/21 crop season (Table 19).

Table 19. Number of households who grow and area (ha) sown to red pepper and green pepper between 2004/05 and 2020/21 cropping seasons in Ethiopia

	Number of households		Area (ha) sown	
	2004/05	2004/21	2004/05	2020/21
National				
Green pepper	794229	1219649	4783	14690.91
Red pepper	1540837	1936607	56991	168345.57

At the national level, the CAGRs for households who applied organic fertilizer and inorganic fertilizer on green pepper and red pepper was positive (Table 20), which indicates increased use of organic fertilizer and inorganic fertilizer on these crops. Between 2004/05 and 2020/21 crop season, the proportion of organic fertilizer and inorganic fertilizer applicator households and the proportion of organic fertilizer and inorganic fertilizer treated area were on the average similar for these two fruit vegetable crops. Thus, between 2004/05 and 200/21 crop seasons, fertilizer applicator households on green pepper ranged organic fertilizer from 6.81 to 7.41%, Urea from 0.47 to 1.49%, DAP/NPS from 0.87 to 1.56%, DAP/NPS + Urea from 0.96 to 3.74% and on green pepper, organic fertilizer applicator households ranged from 5.98 to 15.00%, Urea from 5.58 to 18.93%, DAP/NPS from 3.32 to 7.40% DAP/NPS + Urea from 8.95 to 9.96%. Moreover, the proportion of area of green pepper treated with organic fertilizer were 5.34 to 9.82%, 0 to 1.48% Urea, 3.05 to 2.46% DAP/NPS, and 0 to 15.02% DAP/NPS + Urea. Similarly, the proportion of area of red pepper treated with organic fertilizer were 2.61 to 8.44%, Urea from 10.12 to 16.36, DAP/NPS from 10.84 to 6.91% and DAP/NPS + Urea fertilizer from 18.86 to 38.47%. As a result, the proportions of fertilizer applicator households and area treated with organic fertilizer and inorganic fertilizer were negligible. However, the proportions of area treated with DAP/NPS + Urea fertilizer on red pepper was highest than other fertilizer type.

Table 20. National compounded annual growth rate (%) for organic fertilizer and inorganic fertilizers applicator households and fertilizer treated area of green pepper and red pepper crops between 2004/05 and 2020/21 crop season

National	Organic fertilizer		Urea		NPS/DAP		Urea + NPS/DAP	
	HWOFF	ATNF	HWUF	ATUF	HWDF	ATDF	HWBF	ATBF
Green pepper	5.20	2.30	10.44	5.57	12.06	9.51	8.95	9.96
Red pepper	1.31	1.22	6.78	5.79	4.21	3.80	7.18	6.73

HWOFF, HWUF, HWDF and HWBF= Holders who applied organic, Urea, DAP/NPS and both (DAP/NPS + Urea) fertilizer; ATOF, ATUF, ATDF and ATBF= Area treated with organic, Urea, DAP/NPS and both (DAP/NPS + Urea) fertilizer

## Trends in Fertilizer Use on Root and Bulb Crops

### Root Crops

The important root crops in Ethiopia are beet root, carrot, sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*) and Anchote (*Coccinia abyssinica*), while the economical tuber crops are potato (*Solanum tuberosum*) and yam (*Dioscorea* sp.). However, due to the disaggregated of fertilizer data for beet root, carrot, cassava, Anchote and yam crops were

unusable to estimate CAGRs and proportion of fertilizer applicator households and area treated with fertilizers. As a result, estimated only for sweet potato and potato crops. Thus, the number of households who grow sweet potato and the corresponding area for potato and sweet potato crops had significantly increased between 2004/05 and 2020/21 crop season (Table 21). But, the number of households who grow potato crop had decreased (Table 21).

Table 21. Number of households who grow and area (ha) sown potato and sweet potato between 2004/05 and 2020/21 cropping seasons in Ethiopia

National	Number of households		Area (ha) sown	
	2004/05	2020/21	2004/05	2020/21
Potato	1171582	1038881	51698	85988
Sweet potato	1087638	2171800	45474	62117

Moreover, the CAGRs for households who applied both organic fertilizer and inorganic (Urea, DAP/NPS and DAP/NPS + Urea) fertilizers on sweet potato and potato had positive and significantly increased (Table 22). Similarly, the CAGRs for sweet potato and potato area treated with organic fertilizer and inorganic fertilizers had

also positive and significantly increases (Table 22). The proportion of households who applied organic fertilizer on sweet potato ranges from 5.89 to 4.57%, Urea from 0.94 to 0.69%, DAP/NPS from 1.45 to 1.52% and DAP/NPS + Urea from to 1.19 to 1.04%. Similarly, the proportion of households who applied organic

fertilizer on potato ranges from 5.47 to 3.31%, Urea from 2.03 to 2.48%, DAP/NPS from 14.41 to 23.94% and DAP/NPS + Urea 5.70 to 9.68%. Moreover, the proportion of potato treated area with fertilizers ranges from 12.42 to 18.64% natural, from 2.79 to 2.73 Urea, from 14.28 to 16.02% DAP/NPS, 19.81 to 29.88% DAP/NPS + Urea fertilizer; however,

the proportion of sweet potato area treated with organic fertilizer and inorganic fertilizer were negligible. Thus, between 2004/05 and 2020/21 crop seasons, large number of sweet potato cultivated area had not treated by both organic fertilizer and inorganic fertilizer; however, potato planted field were treated but, more by DAP/NPS + Urea fertilizer type.

Table 22. National compounded annual growth rate (%) for organic fertilizer and inorganic fertilizers applicator households and fertilizer treated area of potato and sweet potato crops between 2004/05 and 2020/21 crop season

National	Organic fertilizer		Urea		DAP/NPS		DAP/NPS + Urea	
	HWOFF	ATNF	HWUF	ATUF	HWDF	ATDF	HWBF	ATBF
Potato	1.33	2.70	5.62	8.41	2.50	10.80	9.60	12.58
Sweet potato	4.52	1.06	6.29	5.14	9.20	4.52	8.40	5.35

HWOFF, HWUF, HWDF and HWBF= Holders who applied organic, Urea, DAP/NPS and both (DAP/NPS + Urea) fertilizer; ATOF, ATUF, ATDF and ATBF= Area treated with organic, Urea, DAP/NPS and both (DAP/NPS + Urea) fertilizer

## Bulb crops

In Ethiopia, onion (*Allium cepa* L.), shallot (*A. ascalonicum* auct. hort.), garlic (*A. sativum* L.) and leek (*A. porrum* L.) are the important bulb crops. However, onion and garlic are probably the most widely cultivated

bulb crops in the country. Thus, the area sown for onion and garlic crops had significantly increased between 2004/05 and 2020/21 crop season (Table 23). However, the number of households who grow these bulb crops had decreased (Table 23).

Table 23. Number of households who grow and area (ha) sown for onion and garlic between 2004/05 and 2020/21 cropping seasons in Ethiopia

National	Number of households		Area (ha) sown	
	2004/05	2020/21	2004/05	2020/21
Onion	951709	702181	17980	38953
Garlic	1902636	1328146	13657	15980

Because of both organic fertilizer and inorganic fertilizer use data are available only for garlic and onion, to estimate CAGRs and proportion of fertilizer applicator households and

area treated with fertilizers. Thus, the CAGRs for organic fertilizer and inorganic fertilizers user households and the fertilizer treated area on each of the two crops were positive, which

indicates an increasing trend in fertilizer use on bulb crops production (Table 24). Moreover, between 2004/05 and 2020/21 crop seasons, the proportion of households who applied organic fertilizer and inorganic fertilizer on onion and garlic were positive. Thus, the proportion of households who applied organic fertilizer ranges from 5.46 to 2.24%, from 2.89 to 12.46% Urea, from 2.97 to 10% DAP/NPS and from 3.50 to 13.32% DAP/NPS + Urea. Similarly, the proportion of households who applied organic fertilizer on garlic ranges from 6.63 to 4.76%, Urea from 1.52 to 2.49%, DAP/NPS from 1.76 to 0% and DAP/NPS + Urea from 2.46 to 6.58%. The proportion of onion and garlic treated area with fertilizers had also positive. Thus, the proportion of

onion area treated with fertilizers ranges from 1.83 to 5.49% natural, 4.52 to 12.57% Urea, 7.01 to 12% DAP/NPS and 18.34 to 38.91% DAP/NPS + Urea. Moreover, the proportion of garlic area treated with fertilizers ranges from 9.71 to 21.90%, 4.51 to 7.45%, 2.54 to 6.55% and 7.46 to 28.04% natural, Urea, DAP/NPS and DAP/NPS + Urea fertilizer, respectively.

Generally, in Ethiopia, onion and garlic growers had been used different fertilizer type and level of area treated with fertilizer mainly DAP/NPS + Urea fertilizer. However, households who applied natural, Urea and DA/NPS fertilizers on onion and garlic and treated area by these types of fertilizers were negligible.

Table 24. National compounded annual growth rate (%) for organic fertilizer and inorganic fertilizers applicator households and fertilizer treated area of root and bulb crops between 2004/05 and 2020/21 crop season

National	Organic fertilizer		Urea		DAP/NPS		DAP/NPS + Urea	
	HWOFF	ATNF	HWUF	ATUF	HWDF	ATDF	HWBF	ATBF
Onion	3.31	6.13	5.17	10.39	7.78	17.11	7.05	11.03
Garlic	0.29	1.67	7.80	10.02	5.99	13.87	6.46	10.04

HWOFF, HWUF, HWDF and HWBF= Holders who applied organic, Urea, DAP/NPS and both (DAP/NPS + Urea) fertilizer; ATOF, ATUF, ATDF and ATBF= Area treated with organic, Urea, DAP/NPS and both (DAP/NPS + Urea) fertilizer

## Discussion

Trends of organic (farmyard manure and wood ashes) fertilizer uses on cereals, pulse, oil seed, fruit vegetables, root, and bulb crops have increased over the period from 2004/05 to 2020/21 at the national level. However, between the 2004/05

and 2020/21 crop seasons, compared to pulse and oil seed crops, a higher amount of organic fertilizer was applied to cereals (maize, tef, wheat, sorghum). This could be associated with the crop return per hectare, a high level of organic fertilizer is applied to a higher crop return per hectare than smaller crop returns (Pender and Gebremedhin, 2007; Kassie *et al.*,

2011; Tewodros *et al.*, 2020). Among the cereal crops, larger proportions of households and the area treated with organic fertilizer were more significant for maize and sorghum than tef, wheat, and barley crops. These might be associated with the crop type, (Hailu, 2010; Zelalem, 2019; Mitiku *et al.*, 2022), more organic fertilizer is applied for higher plants, while less amount of organic fertilizer is applied for smaller plant types, because farmers, they are getting better yield without lodging problem in the smaller crops.

Regardless of the difference in the proportions of organic fertilizer applicator households and the proportion of organic fertilizer treated area on major cereals, pulse, oil seed, fruit vegetables, root, and bulb crops except for potato and green pepper, which increasing trend, the change is negligible, where decreased in all regions and in the country. This result is supported by Mengistu *et al.* (2011) and Gedefaw and Sisay. (2019). The reasons for decreased use of organic fertilizer on crops in Ethiopia are the following reasons: **i)** Limited sources of materials for organic fertilizers' preparation: this includes low availability of biomass overall due to low productivity, and competing uses for this biomass (dung used as fuel and crop residues used as feed), **ii)** Large-sized plots and plots located far from the farmers' homes discourages the application of manure. This is because they are labor-intensive due to

transportation and the addition of manure which is bulky in nature (Waithaka *et al.*, 2007; Giller *et al.*, 2006), **iii)** Insecurity in land rent limits the adoption of manure and residue management: rental is less secure than ownership and that limited rental periods shorten a farmer's planning horizon. Moreover, land-rented farmers may decide to adopt inorganic fertilizers, which require less labour compared to organic fertilizer and provides nutrients faster than organic fertilizer, which is long-term (Leonhardt *et al.*, 2019).

Inorganic fertilizer uses trends over the period of 2004/05 to 2020/21 increased and concentrated on cereals and root and bulb crops. Trends at the national and regional levels more households and more areas treated with inorganic fertilizers on tef, wheat, and maize fields than barley and sorghum crops. Combined use of DAP/NPS and Urea fertilizers were used more than solely Urea and DAP/NPS. On the other hand, low households and low areas were treated on sorghum and barley crops. This might be due to fertilizer uses could be correlated with the other input (improved seed, pesticide, and irrigation), agroecology (sorghum is usually grown in areas with less rainfall), there are a few improved varieties available, these crops have received little attention until recently and therefore, there is seemingly a lower return to fertilizer use (Endale, 2010; Asfaw *et al.*, 2022).

In terms of the application of fertilizer rate per hectare of cultivated lands, the period (2004/05 to 2020/21) showed an increasing trend. For instance, at the national level application of Urea, DAP/NPS, and Urea + DAP/NPS fertilizers on tef, wheat, maize, sorghum, and barley crops increased by more than 50%. Although the application rate per hectare indicated remarkable increases, still lower than the research recommendation for all major crops. These changes could arise because farmers stagnated in the monoculture cropping system. According to Misgana (2017) and Adane (2019), the area sown to legumes in Ethiopia had declined over time due to new and re-emerging viruses and fungal diseases. Thus, farmers have been forced to shift from cereal-legume-based cropping to cereals-cereals and cereals-bulb crops such as tef-wheat, tef-maize, wheat-onion, and tef-onion rotation systems. As a result, fertilizer utilization increased. In addition to the monoculture cropping system, farmers often do not have enough amount of crop residue returns on their farms to be used as organic fertilizers, because crop residues are used more as firewood and animal feed than as a fertilizer (Birhanet *et al.*, 2017). Consequently, most agricultural lands are poor soil fertility, low soil structures, and low productivity. On pulse crops, more proportion of households and more areas were treated with DAP/NPS fertilizer than sole Urea and combined use of

DAP/NPS and Urea fertilizers. This could be because yield response to phosphorus fertilizer is more for of pulses crops (Solomon *et al.*, 2022). On the crop bases, the haricot bean crop on average was treated with more DAP/NPS fertilizer than the other pulse crops. This could be because haricot bean is often cultivated on marginal lands and among producers and the crop needs additional nutrients (Ermias and Fanuel, 2020; Alemayehu *et al.*, 2022).

Owing partly to the attention given to cereal production to achieve food security, most fertilizer use in Ethiopia has been on cereal crops. At national levels, the amount of fertilizer used for pulse, vegetables and oils crops were increased from 2004/05 to 2020/21. For example, the increase was two-fold for onion and potato and a large proportion in the cropping season, probably due to high crop return per unit area (Endale, 2010; Asfaw *et al.*, 2022).

In SNNP region more proportion of households and more proportion of crop area was applied both inorganic and organic fertilizers mainly on major crops treated than the other regions. Although the exact reason why crop producers in SNNP region use more inorganic and organic fertilizers than the other region has not been investigated scientifically, however; fertilizer use is associated with the land size, the smaller land owners, the more fertilizer application. For instance, the average farm size of more



densely population areas like SNNP regions, average farm size is 0.5 ha (Tafesse *et al.*, 2013). According to Gabriel and Demeke (2001) the study showed that size of land is the major determinant of fertilizer use.

## Conclusion

A significant increasing trend has been observed in the use of inorganic fertilizer since 2004/05 though the amounts used varied crop based and regions. Cereal took the largest share across crops in Tigray, followed by Amhara, SNNP, and Oromia across region. Based on the number of households and areas coverage, with organic fertilizer Oromia and Amhara regions used the largest proportion than Tigray and SNNP regions. The current study points out that on average amount of inorganic fertilizers used were relatively higher than organic fertilizer. Based the relative advantage and accessibility, it is suggested that optimizing organic and inorganic fertilizer use into crop production is beneficial from the point of sustainability and climate change impact adaptation.

Among the problems are limited sources of materials for organic fertilizers' preparation because of competing uses for this material (dung used as fuel and crop residues used as feed), plots located far from the farmers' home state, and fragmented farmland and insecurity in land

tenure are limits to the adoption of organic fertilizer in the country. As far as the use of organic fertilizer in Ethiopia is concerned, the recommendation could be illustrated in to the following manner. *First*, researchers need to look into the huge amount of organic fertilizer required per unit area associated to cost and difficulty for transportation. *Second*, legal regulations to maximize rental periods between landowners and farmers those who rented land may be an option to increase the use of organic fertilizer. *Third*, the mechanization researchers will develop and provide organic fertilizer transport equipment at an affordable price to smallholder farmers. *Fourth*, extension workers should focus on rising awareness about the importance of organic fertilizers to encourage or expand their use among smallholder farmers. In addition to the above recommendation, it is necessary to reduce the pace at which inorganic fertilizer used through the provision of safe and effective fertilizer management, including increased fertilizer use efficiency. Therefore, developing technologies and alternative options for increasing the use of organic fertilizer on the one hand, and reducing inorganic fertilizer, on the other hand are focus areas of intervention in the future.

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