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Original research article

Impacts of climate variability on the vegetable production of urban farmers in the Addis Ababa metropolitan area: Nexus of climate-smart agricultural technologies

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ABSTRACT

This study was aimed at examining the impacts of climate variability on vegetable production and nexus climate-smart agriculture technologies. The study was conducted on vegetable farmers along the little Akaki River in Addis Ababa. Field data was collected from 156 randomly selected vegetable farmers via semi-structured survey questions. Climate data from 1996 to 2020 was analysed using qualitative and quantitative descriptive statistics methods. The results of monthly and annual precipitation variability indicated a coefficient of variation (CV) ranging from 23% to 73% and 49% to 98%, respectively. Seasonally, CV ranges between 34% and 99%, 50%–97%, and 20%–84% in Belg, Bega, and Kiremt, respectively. The results of respondents' perceptions indicated an increasing trend in temperature and precipitation variability. Vegetable urban farmers perceived an increase in the frequency of floods and rain falls (44.9%), drought frequency (13.5%), temperature (89.7%), and a decrease in the trend of vegetable productivity (86.5%) as the major impacts of climate variability. However, changing vegetable varieties (31.4%), early planting (26.9%), mixed farming (26.6%), late planting (5.1%), using agro-chemicals (4.5%), and agroforestry (1.9%) are the major on-farm climates where smart agriculture technologies were identified for adaptation. Shift occupation (37.8%), nonadaptation (36.5%), and non-farm activations (24.4%) were employed by the farmers as off-farm adaptation options. In addition, vulnerability analysis indicated that the absence of direct access to the market, inadequate access to weather information, land fragmentation, and tenure complications are the major determinants of being vulnerable. Finally, high precipitation and temperature variability affect vegetable productivity.

Practical Implications: Climate extreme phenomena are substantial pressures on urban agricultural production systems in risk-prone cities, where climate service challenges are rising globally (Sanfo et al., 2022; Kifle et al., 2022; Ebissa and Desta, 2022); besides, the requirement to produce more urban vegetables to feed residents, an ever-increasing and vulnerable group, is undeniable (Martinez et al., 2022). Additionally, climate variability and change threaten urban and pre-urban farmers' livelihoods and agricultural farming, particularly in semi-arid areas in Africa (Magesa et al., 2023). Furthermore, 64 % of the world's poorest people lived in sub-Saharan Africa in 2020, which strongly requires the implementation of Sustainable Development Goals 1 (no poverty), 2 (zero hunger) and 11 (make cities and human settlements inclusive, safe, resilient, and sustainable) in the region (Magesa et al., 2023; Chitakira and Ngcobo, 2021; Degefu et al., 2021c).

Thus, cities are exposure to compatible climate information services is vital for anticipating climate variability risks in vegetable production, optimizing the training of practitioners (urban farmers), and adapting to climate change through climate smart agriculture technologies (Degefu et al., 2021a; Chitakira and Ngcobo, 2021; Kifle et al., 2022). Moreover, it is compulsory to ascertain and analyze impact insights and their origins, vulnerabilities, and adaptive potential among urban farmers before beginning with the exercise of any given climate service to understand the demands of urban vegetable farmers and the possible exploitation of nexuses (Dendir and Simane, 2021).

Conversely, in Ethiopia, the agriculture sector is identified as one of the sectors most vulnerable to climate change and vulnerability (Kifle et al., 2022). On top of these, the productivity and the concern of urban

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agriculture (vegetable production) is highly ignored and reduced the potential, productivity and suitability of ecological land (Kifle et al., 2022; Degefu et al., 2021b; Degefu et al., 2021c). Besides, the combined effect of climate variability, population pressure, and urban ecosystem dynamics reduced urban vegetable production and leads the farming community into a viscous of poverty circle and worsens food security (Amberber et al., 2020; Degefu et al., 2021c).

However, previous studies have revealed that the effectiveness of climate information services on urban ecosystems depends on (i) the ability of urban farmers to access, understand, and overcome institutional constraints (Kiplagat et al., 2022) (ii) the capacity of end-users to translate the information and knowledge into effective decision-making options (Dendir and Simane, 2021), and (iii) the capacity of end-users to translate the information and knowledge into effective decision-making options (Martinez et al., 2022). To that end, the disparity between the awareness of urban farmers and policymakers towards the benefits of CSA and their practices implies that indigenous knowledge-based research on CSA farming and land management technology should be conducted. Therefore, it is crucial to appreciate the practices and adoption of CSA at the city level to realise triple-win outcomes: increased productivity, enhanced resilience, and mitigating climate variability and change.

1. Introduction

Climate change has substantial impacts on the socio-economic activity and environmental sustainability of countries with relatively low adaptive capacity (Bojago and Abrham, 2023; Magesa et al., 2023). Besides, climate vulnerability factors (exposure, sensitivity, and adaptive capacity) also affect the vegetable production and agricultural livelihoods of farmers in differing agro-ecological systems (Sanfo et al., 2022). According to Garrett et al. (2013) higher temperatures adversely reduce soil moisture, while prolonged droughts and increasing temperatures may help pests and diseases multiply, thereby reducing vegetable growth, productivity, and yields of crops in the agricultural system the yield of vegetable crops (Degefu et al., 2021c; Degefu et al., 2022; Kiplagat et al., 2022; Amberber et al., 2014) and become major threat to urban food security in many cities of the developing world (Hosseinpour et al., 2022). On the other hand, there are several possible pathways to decrease climatic risks and sustainably increase urban vegetable productivity, and enhance resilience in urban vegetable farming systems (Magesa et al., 2023; Kifle et al., 2022) for instance, climate-smart agriculture technologies (CSA) (Kifle et al., 2022; Khatri-Chhetri et al., 2017).

The estimated impacts of both historical and future climate change and variability on cereal crop yields in different regions indicate that the yield loss can be up to −35 % for rice, −20 % for wheat, −50 % of sorghum, −13 % for barley, and −60 % for maize depending on the location, future climate scenarios and projected year (Campbell et al., 2016; Porter et al., 2014). Besides, about 800 million people worldwide are engaged in urban agriculture (Appeaing Addo, 2010) and contributes in food supply, employment creation, income generation and environmental management (Wadumestrige Dona et al., 2021). For example, globally, the urban agriculture produces 15 % of all food consumed in urban areas, and it will be double within the next 20 years. Conversely, the magnitude of the impact of climate variability and the contribution of CSA cannot be underestimated, as it has the propensity to affect the output of most agricultural crops, including urban vegetables (Tanimonure and Naziri, 2021; Hilemelekot et al., 2021).

In response, climate-smart agriculture (CSA) is one of the solutions that simultaneously addresses the issues of climate variability and change adaptation and mitigation as well as food security (Kifle et al., 2022; Khatri-Chhetri et al., 2017) and includes, rainwater harvesting, use of improved seeds, ICT based agro-advisories and crop/livestock insurances and residue incorporation can improve crop yields, water and nutrient use efficiency and reduce Greenhouse Gas (GHG) emissions from agricultural activities (Khatri-Chhetri et al., 2017; Ghosh, 2021). Moreover, it is important to assimilate indigenous and modern technologies and services that are pertinent for a specific place to adapt to climate change and variability (Khatri-Chhetri et al., 2017; Corner-Dolloff et al., 2015). Therefore, identifying and prioritizing locally appropriate CSA technologies will need to address the context-specific, multi-dimensional complexity of urban agricultural systems (Mwongera et al., 2017). Hence, like other developing countries, the practice of climate-smart agricultural strategies in Ethiopia, particularly in Addis Ababa, is in its infant stage (Bojago and Abrham, 2023).

Furthermore, agriculture and climate change nexus studies are not new to Ethiopia. However, studies are spatially limited and concentrated on specific crop-based agricultural systems (Mihiretu et al., 2023; Obsi Gemeda et al., 2023; Dendir and Simane, 2021). Studies on the impact of urban vegetable farming practices, the effect of the climate variability nexus, and the response of CSAs have seldom been attempted in Ethiopia, particularly in Addis Ababa, Even though there are few practices related to urban agricultural productivity and challenges in the Addis Ababa farming system (Ghosh, 2021; Kingsley et al., 2021; Gebremichael et al., 2014; Kifle et al., 2022). To this end, in the present study, we assessed the response of urban farmer-level empirical evidence in analysing the impacts of climate variability on vegetable production and farmers' prioritisation of climate-smart agriculture technologies along the little Akaki River in Addis Ababa, Ethiopia. Hence, the city is becoming the epicentre of active socioeconomic growth and is among the most dynamic cities in the country. In order to contribute to the knowledge gaps pertaining to the understanding of complex relationships among urban agriculture, the effect of climate variability, and CSA, we first assessed the perceptions of vegetable farmers about climate variability and then examined the major impacts of climate variability on vegetable production. Second, we identified the CSA adaptive technologies of farmers to the impacts of climate variability on vegetable production. Third, to assess the vulnerable farmer groups in the study area, we, therefore, attempted to answer the following research questions:

- What is the perception of urban farmers, and how do farmers perceive climate variability?
- What are the major impacts of climate variability on vegetable production?
- What are the possible CSA adaptive strategies taken by the farmers?
- Which groups of farmers are affected or vulnerable to climate variability, and to what extent?

2. Materials and methods

2.1. Description of the study area

This study was conducted along the Akaki River catchment, part of the Awash River watershed in Addis Ababa, Ethiopia (Fig. 1). The catchment is geographically located between 8°50′01′N and 9°13′10′N latitude and 38°43′42′E and 39°00′26′E longitude, with elevation ranges between 2033 and 3217 m above mean sea level (Maru et al., 2023). Moreover, the topography undulates the catchment's northern, western, and southwestern parts and creates a plateau. Rolling plains, steep river banks, valleys, hills, and mountains make up the physiographic elements of the area (Maru et al., 2023; Tolera and Chung, 2021). The southern and southeastern parts of the catchment have gentle morphology and flat land regions (Tolera and Chung, 2021). Besides, the study area daily maximum temperature range is between 17.1 °C and 36.3 °C, whereas the daily minimum temperature range is 0.6 °C to 26.1 °C. The average annual precipitation in the catchment ranges from 800 to 1400 mm, depending on the elevation difference (Maru et al., 2023). The major rainy season lasts from June to September and accounts for over 70 % of the annual total precipitation (Tolera and Chung, 2021).

Furthermore, the Little Akaki River can be segmented into three parts. The upper catchment of Little Akaki comprises small streams that drain from different parts of Mount Entoto (Mengesha et al., 2023). It is dominated by eucalyptus trees and residential settings (Degefu et al., 2023). The middle catchment includes the full course of the river inside the city, traversing through highly populated and commercial sections of the city. Besides, in this part of the catchment, urban farmers grow vegetables by irrigating with river water (Maru et al., 2023). The lower catchment of Little Akaki traverses through the rural parts of the city and finally enters the Aba-Samuel dam. This was why we conducted the study on middle-catchment urban farms along the little Akaki River (Fig. 1).

Research design

A cross-sectional individual vegetable farmer household level and at organizational level from subcity urban agricultural office and meteorological agency officer's survey was conducted using a structured questionnaire and interviews. Both quantitative and qualitative data were collected through household questionnaire survey and key informant interviews. List of questionnaires were adapted from the most related studies (Gebrehiwot and van der Veen, 2013; Obsi Gemeda et al., 2023).

2.3. Sampling procedure and sample size

In this study, we used the multi-stage sampling technique to select the required sample size. Initially, four sub cities, namely: Gulela, Kolfa Keraniyo, Nifas Silk-Lafto, and Akaky Kaliti, were purposively selected from the Akaki River catchment in Addis Ababa based on urban agricultural practices and socio-economic importance in prior perceptions of vegetable farmers about climate variability and CSA adaptive technologies in urban river-fed agriculture. Secondly, Nifas Silk-Lafto and Akaky Kaliti were selected in consultation with the stakeholders based on climate change sensitivity and the potential occurrence of climate extremes. And thirdly, the most susceptible four (3, 4, 5, and 6) were purposefully selected based on stakeholders' consultation with farmers, woredas, and sub-city urban agricultural experts, physical observation, and the presence of wider vegetable production practices. After study woredas were identified, we adopted a proportional sample to the population size using the Yamane (1967) sample size determination at a 95 % confidence level with a 5 % margin error to select 156 urban farmers, as shown in Eq. (1). Finally, the respondents were randomly selected from four purposefully identified woredas.

$$n = \frac{N}{1 + N(e)^2} \tag{1}$$

Where n is the sample size, N is the population size (653), and e is the level of precision (0.05). Exact the sample size of the study was 156 vegetable farmers in the study area.

2.4. Data collection

During data collection, We provide a list of closed-ended survey questionnaires for vegetable farmers because it would enable them to collect data on the general backgrounds of household characteristics and farms, the impacts of climate variability on vegetable production, their knowledge of climate variability, and their CSA adaptive strategies along the little Akakai River. Besides, the degree of importance of given CSA adaptation technologies and climate variable perceptions was investigated through direct face-to-face interviews with key informants. The researcher were adequately manage and supervise the data collection process and check the quality of the returns to avoid bias and errors on the spot. Conversely, Secondary data on climatic issues of the past 20 years (temperature and rainfall 1996 to 2020) were collected by the National Metrology Agency (NMA, 2020).

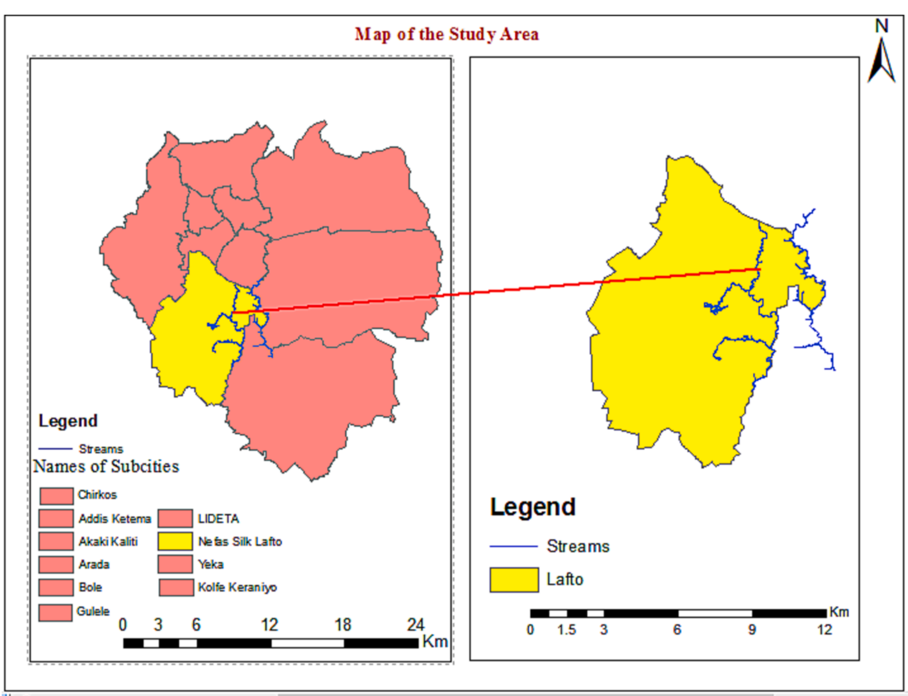

Fig. 1. Location Map of the Study Area.

2.5. The engagement of the surveyors

There were 156 respondents or households who were selected from four Woreda to administer the survey questionnaire. Thus, 3 field surveyors (senior urban agricultural experts and 2 Woreda Developmental Agents (DAs) of Nefasilik Lafto sub-city) were purposefully selected. They are purposefully selected for the following reasons: (i) for their better expertise on the subject; (ii) for their experience conducting surveys; and (iii) for their knowledge about the local community, including culture and communication. In addition, during the field survey for direct observation and photography of the vegetable farm land along the little Akaki River, two Woreda Developmental Agents (DAs) were purposefully selected. The selection criteria were based on their 'experience, performance, technical skill, and ability to speak the local language. Hence, these field surveyors were given training about the concept of this particular study and data collection methods. Besides, preliminary field visitation and orientation were given before the field surveyors left to collect the data. In all cases, monitoring was performed to ensure the data's reliability.

2.6. Data analysis

The collected quantitative data were summarized using Statistical Package for Social Science (SPSS) version 20 and Microsoft Excel. Descriptive statistics methods, which include frequency distribution, percentage present demographic, socio-economic, and CSA adaptive technologies, Besides, coefficients of variation were used to analyze the variation (how the individual data points vary from the mean value) of monthly, seasonal, and annual rainfall and temperature data from meteorology records of stations found in Addis Ababa (Eqs. (2)–(4). A higher value of CV is an indicator of greater spatial variability, and vice versa (Tofu and Mengistu, 2023; Issahaku et al., 2016). Conversely, qualitative data obtained through key informant interviews and field observation were analyzed using the thematic content analysis method (Yue et al., 2002).

$$Variance(\delta^2) = \frac{\sum(x-x)^2}{(n-1)} \tag{2}$$

$$StandardDevation(\delta) = \sqrt{\delta^2} \tag{3}$$

$$CV(\%) = \frac{SD}{Mean}*100 \tag{4}$$

Furthermore, climate variability trend analysis was performed through non-parametric tests. The advantage of non-parametric statistical tests over parametric tests is that the former is more suitable for non-normally distributed, outlier, censored, and missing data, which are frequently encountered in hydrological time series (Issahaku et al., 2016; Asfaw et al., 2018; Murray et al., 2016). As a result, we used the Kendall (MK) test to detect trends in meteorological variables, which tests for a trend in a time series without specifying whether the trend is linear or non-linear (Yue et al., 2002). Trend analysis has been carried out on an annual basis as well as for the "bega" (October to January), "belg" (February to May), and "kiremt" (June to September) seasons.

3. Results and discussion

3.1. Socio demographic status of the respondents

Out of the total respondents (156) in the study area, 105 (67.3 %) were males and 51 (32.7 %) were females. Moreover, 62.2 % of the respondent's age was categorised as greater than 41 years, while only 4.5 % were categorised as 20–30 years old. Besides, 85.3 % of the respondents were married; 9.0 %, 3.2 %, and 1.4 % were single, divorced, and widowed, respectively. Therefore, vegetable production in the little Akaki River is dominated by married farmers, and it is more sustainably practiced to support their families. This finding agrees with the findings of Birhan and Tekalign (2022) that agriculture is strongly practiced by married people to meet family needs. In addition, 96 (61.5 %) of farmers had more than 21 years of farming experience, 54 (34.6 %) were 11–12 years old, and 6 (3.8 %) of the respondents had been farming for <10 years in the district. Age is the determinant factor for farmers' perception of climate change, which can target old and experienced farmers because they are better at distinguishing climate change from merely inter-annual variations in weather scenarios (Birhan and Tekalign, 2022; Batungwanayo et al., 2023; Ishaya and Abaje, 2008).

3.2. Trend analyses of climatic variables

3.2.1. Trend of temperature variability

Table 1 depicts the monthly and annual temperature and its trend in the period under examination. The mean temperature in the study area ranges from 23 °C (minimum) to 29.9 °C (maximum annual average temperature of 24.03 °C). This indicated the high variability of temperature in the study area. Moreover, using a linear regression model,the rate of change is defined by the slope of the regression line (Fig. 2), which in this case is about 0.16 °C and 0.07 °C per decade for the minimum and maximum temperature, respectively, during the period of 1996–2020 (Fig. 2). The result obtained in this study agrees with the findings by Alemu and Dioha (2020) that in Ethiopia, the mean annual temperature increased by 1.4 °C over the past few decades and has been increasing annually at a rate of 0.2 °C. Besides, the MK trend test result revealed that mean and minimum average temperatures have been increasing or decreasing over time. The trend for monthly maximum temperature showed a non-significant increasing trend (except for the months of October, April, and August), while a significant increasing trend for minimum monthly temperature was obtained for the November, December, March, April, May, and June months (Table 1). The empirical result agrees with the views of respondents and the findings of Alemu and Dioha (2020); Asfaw et al. (2018); Murray et al. (2016) where the increasing trends in the Tmin series were higher than those in the Tmax series.

3.2.2. Annual and seasonal rainfall trend and variability

The total annual rainfall of the study area ranged between 732 mm and 1552.3 mm. The mean annual rainfall of the area during the study period was 1007.86 mm, with 167.46 mm of standard deviation and 16.62 % of CV. Besides, using a linear regression shows that the amount of total annual rainfall declined from 1996 to 2020 (Fig. 3). The rate of change is defined by the slope of the regression line, which shows the decreasing trend as −3.081 mm per year, −1.868 mm per year, and −6.2651 mm per year for annual, belg, bega, and kiremt rainfall, respectively (Fig. 4).

Furthermore, as depicted in Table 2-3, the declining trend of belg and bega rainfall is not statistically significant; the average CV (89.37) and CV (47.41) are higher than those of kiremt rainfall (17.24), which implies more interannual variability of belg rainfall than belg and kiremt. The result agrees with the findings of (Tofu and Mengistu, 2023; Asfaw et al., 2018) where more variability in Belg rainfall than in Bega and Kiremt rainfall in most parts of Ethiopia. Morover, according to Issahaku et al. (2016) CV is used to classify the degree of variability of rainfall events as less (CV < 20), moderate (20 < CV < 30), high (CV > 30), very high CV > 40 % and CV > 70 % indicate extremely high inter-annual variability of rainfall. Based on this, the five year interval of annual precipitation coefficient of variation for the study area was summarized in Table 2. The result revealed that the degree of variability falls on extremely high inter-annual variability of rainfall.

The MK test for the trend analysis has been done for the Belg, Bega, and Kiremt seasons and the whole year. The results show that the April precipitation had a statistically significant decreasing trend. Conversely, a statistically significant increasing trend was observed for December.

Table 1
Monthly and MK results for temperature (1996–2020) based on NMA temperature data.

Month	Mean	Std. deviation	T_{min} MK	P-value	Sen's slope	T_{max} MK	P-value	Sen's slope	T_{Mean} MK	P-value	Sen's slope
Oct	25.084	2.294	0.261	0.071	0.105	0.261	**0.035**	0.105	0.261	**0.012**	0.105
Nov	24.662	2.338	0.192	**0.001**	0.192	0.192	0.208	0.080	0.167	**0.011**	0.246
Dec	24.022	1.916	0.245	**0.029**	0.101	0.245	0.977	0.001	0.245	**0.005**	0.100
Jan	23.540	1.818	0.084	0.713	0.026	0.084	0.057	0.026	0.084	**0.000**	0.026
Feb	23.518	1.664	0.017	0.401	0.004	0.017	0.109	0.004	0.017	**0.000**	0.004
March	23.591	1.779	0.003	**0.000**	0.000	0.003	0.315	0.000	0.003	0.269	0.000
April	23.743	1.703	−0.077	**0.030**	−0.025	−0.077	**0.041**	−0.025	−0.077	0.080	−0.025
May	23.751	1.433	−0.167	**0.002**	−0.002	−0.024	0.153	−0.002	−0.024	**0.006**	−0.002
Jun	23.762	1.911	0.266	**0.009**	0.107	0.266	0.104	0.107	0.266	**0.016**	0.107
July	23.845	1.926	0.272	0.295	0.116	0.272	0.413	0.116	0.272	**0.009**	0.116
Aug	24.305	1.964	0.198	0.164	0.116	0.198	**0.003**	0.073	0.198	**0.002**	0.073
Sep	24.572	2.075	0.407	0.269	0.140	0.407	0.295	0.140	0.407	0.055	0.140
Average	24.033	0.851	0.138	**0.000**	0.441	0.205	0.164	0.091	0.161	**0.023**	0.029

Authors construction from NMA data.

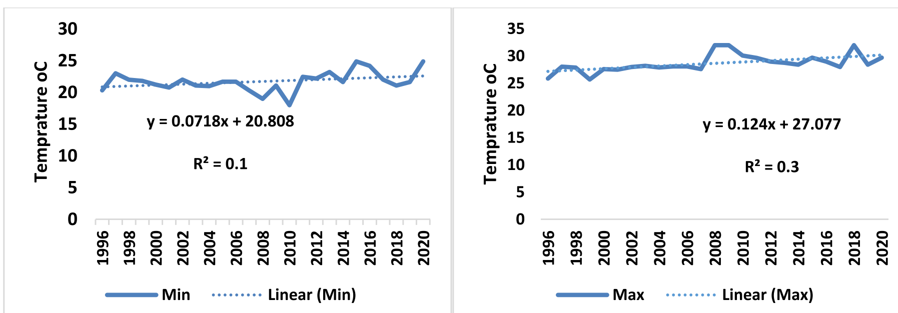

Fig. 2. Trend of annual maximum and annual minimum temperature variability.

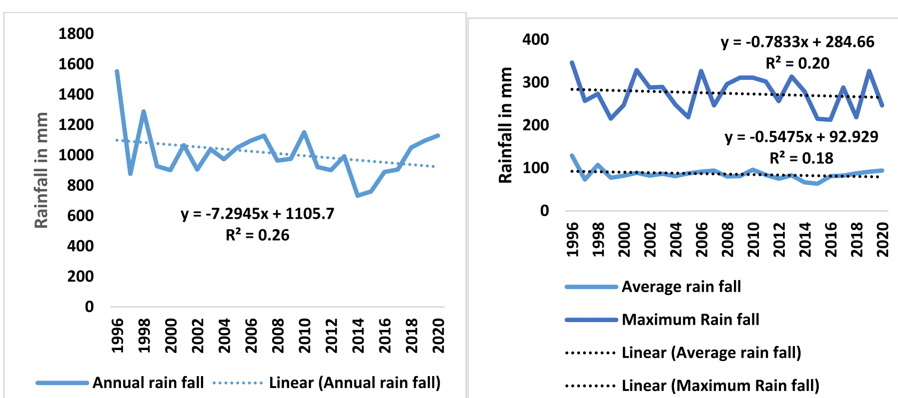

Fig. 3. Trend of annual, average and maximum rainfall variability.

The remaining months have a non-significant decreasing or increasing trend. A statistically significant decreasing trend was obtained for the Kiremt season and for the yearly average (Table 3). The output agrees with the result reported by Asfaw et al. (2018); Obsi Gemeda et al. (2023) of decreasing kiremt rainfall in different parts of Ethiopia, including the central highlands. Additionally, a significantly or non-significantly decreasing trend of belg rain through time was obtained, which coincides with Alemayehu and Bewket (2017) where belg rainfall showed a significant decreasing trend, and Asfaw et al. (2018) variability in belg rainfall. Besides, the statistical test result accords with the report obtained from interviews with urban farmers.

3.3. Farmers' perception in terms of temperature and precipitation variability

3.3.1. Farmers' perception on temperature variability

Eighty nine present of farmers were perceived an "increase" in temperature, and 0.6 % of respondents perceived "no change" in temperature in the past decades (Fig. 5). This result is alien with tamprature data analysised (Table 1 and Fig. 2). According to the farmers, the reasons for the increase in maximum temperature in the district were due to the extent of city expansion coupled with deforestation, industrialization, population increment, and global warming. Moreover, respondents listed the manifestations of increment and variability associated with undetermined patterns of daily and monthly temperature, rainfall deficit, crop productivity loss, early onset of the rainy season, and delayed onset of the rainy season. This result is in line with

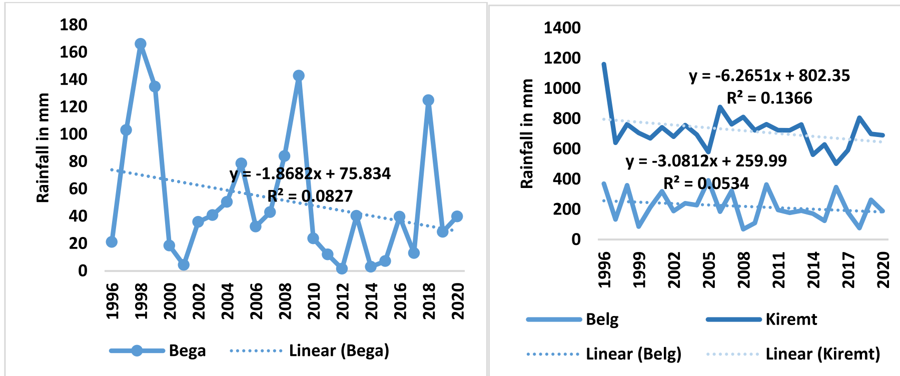

Fig. 4. Bega, Belg and Kiremte rainfall trends and variability respectively.

Table 2
Trends in annual rainfall variability within five year intervals.

Year category	Mean annual rainfall	SD	CV	Degree of variability according to Issahaku et al. (2016)
1996——2000	102.11	83.39	83 %	Extremely high inter-annual
2001——2005	96.28	64.32	68 %	Very high inter-annual
2006——2010	100.57	86.93	87 %	Extremely high inter-annual
2011——2015	74.07	63.83	74 %	Extremely high inter-annual
2016–2020	89.20	71.23	80. %	Extremely high inter-annual

Authors construction from NMA data.

the reports of Asfaw et al. (2018)in northcentral Ethiopia;Tofu and Mengistu (2023)in west Shewa, Ethiopia;and Obsi Gemeda et al. (2023) Southwestern parts of Ethiopia.

3.3.2. Farmers' perception on precipitation (rainfall) variability

Most of the vegetable farmers perceived rainfall variability in terms of manifesting cause-and-effect variability: flood frequency, drought frequency, surface water availability, and irrigation water availability in the study area. The perception coincides with the study's findings, which were conducted in different parts of Ethiopia (Obsi Gemeda et al., 2023; Tofu and Mengistu, 2023; Asfaw et al., 2018) and other developing countries (Mavhura et al., 2022; Dayrit et al., 2018; Issahaku et al., 2016). Specifically, out of the total 156 valid cases, 64.7 % of urban farmers perceived an increase in precipitation, followed by 33 (21.2 %) respondents who felt a decrease in the amount of rainfall, and

Table 3
Basic statistics and MK trend analysis of rainfall (1996–2020).

Month	Minimum	Maximum	Mean	Std. deviation	CV	MK test	Sen's slope
Oct	0	134.80	29.56	39.78	134.57	−0.09	−0.01
Nov	0	53.50	4.90	10.99	224.00	0.12	0.00
Dec	0	77.90	8.58	21.86	254.64	**0.19***	0.00
Jan	0	68.50	14.89	18.42	123.73	−0.14	−0.06
Feb	0	85.30	18.94	24.23	127.95	0.11	0.01
March	0	162.10	58.91	42.41	72.00	**−0.15**	−1.06
April	0	149.80	75.09	44.64	59.45	**−0.03***	−0.17
May	13.3	184.00	76.71	52.31	68.19	0.01	0.02
Jun	0	290.20	129.54	59.07	45.60	**−0.28**	−3.02
July	132.8	346.30	243.64	61.19	25.11	**−0.13***	−0.13
Aug	101.1	326.40	223.00	61.38	27.52	**−0.09**	−0.95
Sep	43.8	278.70	124.10	50.94	41.05	0.05	0.35
Annual	732.9	1552.50	1007.86	167.46	16.62	**−0.11**	−4.01
Bega	0	166.10	57.94	51.78	89.37	**−0.05**	−0.33
Belg	68.8	391.80	229.65	108.88	47.41	**−0.11**	−1.89
Kiremt	502.2	1160.60	720.27	124.19	17.24	**−0.14***	−2.27

Note: Bolded values (*) indicate statisticaly significant at 0.1 alpha levels.
Authors construction from NMA data.

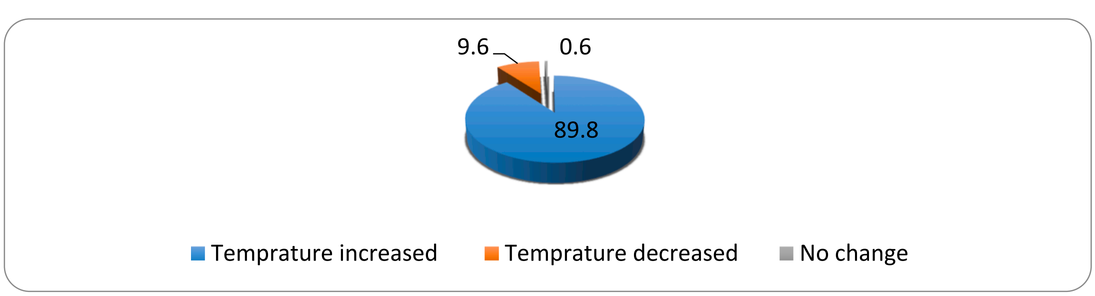

Fig. 5. Farmers' Perception of Temperature variability (Source: Filed survey (2019)).

22 (14.1 %) of the respondents perceived that there has been no change in rainfall amount in the last decades (Table 4). Moreover, about 71.3 % of the respondents observed the late start of rainfall from the normal date, and 91.3 % of the respondents approved the early termination of the rainy season from the normal date. Besides, there was an inconsistent and unconditional amount of rainfall in the timing of the rains, with rain coming either earlier or later than expected and with rain withdrawing or offsetting before the normal time.

Furthermore, 108 (69.2 %) of the respondents noticed an increase in flood frequency, while 16 (10.3 %) recognized a decrease in flood frequency, and 32 (20.5 %) of them perceived no change in flood frequency. Regarding availabilityof the surface water, 61 (39.1 %) respondents perceived that the increment in surface water availability was associated with the increase in rainfall, while 21 (13.5 %) noticed that the surface water availability of the farm was decreasing. However, 74 (47.4 %) of the respondents perceived that there was no change and were not aware of the trend of surface water availability during the study period (Table 4). The response of urban farmers was different from the result of trend analysis, particularly for the Belga and Bega rainfall patterns, which proved the incorporation of the actual experience of farmers while analyzing trends in meteorological variables.

3.4. Climate smart agriculture technologies for adaptation to climate variability

3.4.1. On-farm adaptation mechanisms to climate variability

The effect of Climate Variability (temperature and rainfall) on vegetable production will depend on effective management and adaptive practices at the farm and off-farm levels. Climate smart agriculture adaptive technologies are context, site specific and cover various biophysical and agronomic practices. For instance, water smart (rainwater harvesting, covercrop method,) nuterinat smart (green manure, inter cropping, agrochemical), carbon smart (integrated past mangemnt, agroforestery, homegardening), weather smart and knowledge smart (Kifle et al., 2022; Magesa et al., 2023; Mwongera et al., 2017; Khatri-Chhetri et al., 2017). In Ethiopia various CSA technologies have been implementing under the broader framework of integrated watershed management level (Kifle et al., 2022). Out of the total 49.10 % of respondents who had knowledge of smart technology, 32.10 % had knowledge of nutrient smart technology, 13.80 % had knowledge of water smart,and 3.0 % had knowledge of carbon smart, which were found to be practices of urban farmers to offset the impacts of climate variability shocks (Table 5). Besides, the sample urban farmer response to the introduction of CSA was also sustained by key focus group discussion participants reporting that farmers practiced CSA technologies in the bega and belge seasons due to shortages of water and increments in temperature. However, the preferences of urban farmers for technologies varied according to fame size, economic status, awareness, and the knowledge of experts. This finding agrees with the results of farming systems and practices identified in City of Tshwane Metropolitan Municipality (Chitakira and Ngcobo, 2021); Central highland of Ethiopia (Kifle et al., 2022).

3.4.2. Off-farm adaptation mechanisms of farmers to climate variability

According to the responses of urban farmers and FGD, farmers exercised different off-farm adaptation mechanisms to tackle climate variability in the study area (Fig. 6). From the total number of respondents, 37.8 % exercised shift occupation, 36.5 % ignored the climate variability issue or did not practice it, and 24.4 % diversified into a variety of non-farm activities such as trading (29.5 %), rearing farm animals (14.1 %), and carpentry (6.4 %), among others (Fig. 7). The reason may be attributed to the greater losses vegetable farmers experienced during the major seasons (bega and belg) of the year, where most of them could not break even. The finding is in line with the fact that tomato farmers in the study communities employed both on-farm and off-farm adaptive strategies in response to the effects of climate variability on tomato production in Offinso North District, Ghana (Guodaar et al., 2017). However, it is important to note that some of these off-farm activities may not necessarily be sustainable (Guodaar et al., 2017; Kifle et al., 2022; Khatri-Chhetri et al., 2017; Tanimonure and Naziri, 2021).

Table 4
Farmers' Perception on climate variability in the study area.

Farmer's perception	Increased	Decreased	No change
Precipitation /amount rain fall	101 (64.7 %)	33 (21.2 %)	22(14.1 %)
Flood frequency	108 (69.2 %)	16(10.3 %)	32(20.5 %)
Drought frequency	67(42.9 %)	16(10.3 %)	73(46.8 %)
Surface water availability	61(39.1 %)	21(13.5 %)	74(47.4 %)
Irrigation water availability	48(30.8 %)	31(19.9 %)	77(49.4 %)

Source: Filed survey (2019).

Table 5
On farm climate smart technology for adaptation to climate variability.

Climate smart technologies	Farmer exercised technologies	Percentage	Total
Water smart	Rainwater harvesting	6.10 %	13.80 %
	Cover Crops Method	7.80 %	
Nutrient smart	Green manure	11.00 %	32.10 %
	Inter-cropping / mixed with legumes	16.60 %	
	Agro-chemical	4.50 %	
Carbon smart	Integrated past management	1.10 %	3.0 %
	Agroforestry	1.90 %	
Weather smart	Weather based advisory	2.20 %	2.20 %
	Vegetation Insurance	0 %	
Knowledge smart	Improve/ changing variety	20.60 %	49.10 %
	Late planting	5.10 %	
	Early planting	18.90 %	
	Switching to non-vegetables crops	4.50 %	

Source: Filed survey (2019).

3.5. Impacts of climate variability in vegetable production and farmer's income

The research examined how the respondents perceived climate variability's impacts on their vegetable production and farmer's income. Respondents were asked to indicate to what extent rainfall variability and high temperatures affected their vegetable production and revenue. The frequencies of responses are reported in Fig. 7. The respondents had different perceptions of climate variability's impacts. Fourty-five percent (45 %) of respondents reported negative impacts of climate variability on their vegetable production, 25 % reported negative impacts on their household revenue, and 30 % reported the effect observed on both. This might be due to the landscape and topography of the farm area and high rainfall variability. The findings of Ado et al. (2019) and Guodaar et al. (2017) support our discussion by arguing that any significant change in climate variables in combination with other socio-environmental changes will negatively affect productivity and farmers income.

3.5.1. Trend of productivity of vegetable in the study area

A total of 86.5 % of the respondents reported that the trend of vegetable productivity had decreased due to the impact of climate variability (Fig. 8a-b). While 2.6 % reported no change in productivity and 10.9 % reported an increase in the productivity of vegetables in the last decade, These results also agree with the reports of Guodaar et al. (2017) who found that climate variability; especially temperature and rainfall variability, causes a reduction in tomato yield. Moreover, the most commonly produced leafy vegetables in the study area were kosta (Beta vulgaris), yabshagomen (Brassica carinata), and slata (Lactuca

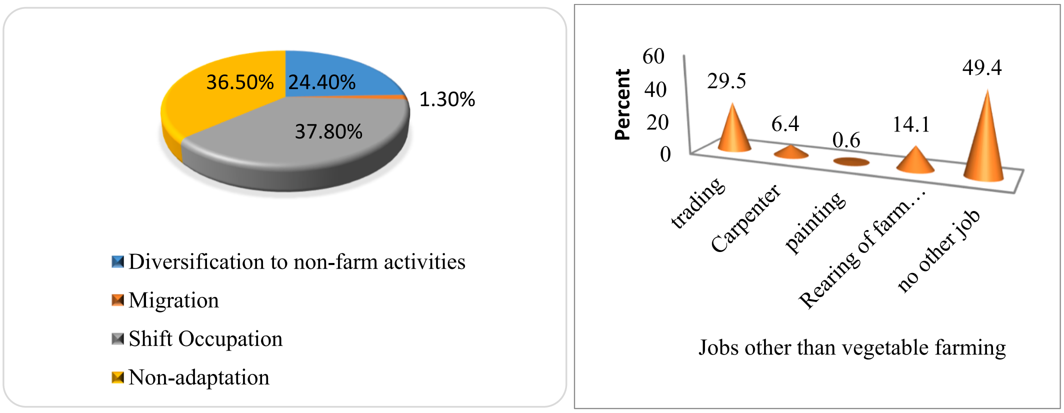

Fig. 6. Off farm farmer's adaptation mechanism of climate variability. Source: Filed survey (2019).

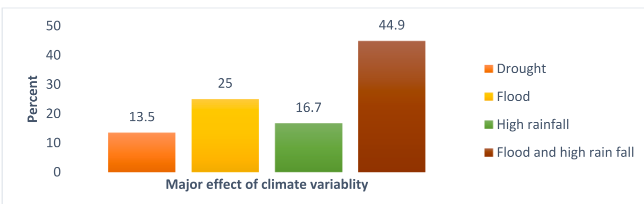

Fig. 7. Major effect of climate variability listed by farmers. Source: Filed survey (2019).

sativa), which are very sensitive to climate variability (temperature and rainfall variations). Besides, a total of 60.3 % of farmers stated that the income earned from vegetable production decreased. While 39.1 % of farmers reported that there is an increase in income from vegetable production, 6 % of the respondents stated that there is no change in income earned from vegetable farming (Fig. 8a- b).

3.5. Vegetable farmers vulnerability to climate variability

According to the survey result, farmers whose land was vulnerable to the impact of climate variability where their farm land topography was sloppy, those with smaller farmland, and those who did not have access to weather information in the district were highly vulnerable (Table 6). Based on the result, out of the total respondents, 50 % reported that their land is highly vulnerable to climate variability in terms of flood occurrence, 38.5 % indicated that their land is moderately vulnerable, and 11.5 % of the respondents reported that their land is not exposed to climate variability. This finding shows that most of the vegetable farmers in the study area have farmland vulnerable to climate variability in general. On the other hand, 40.4 % of the farmers responded that they have access to early warning information, 41.7 % of them have no access to early warning information, and 17.9 % of the respondents have no idea about early warning information. In addition, out of 156 vegetable farmers, 59.6 % were those who held sloppy land topography and were most vulnerable to climate impacts, specifically flooding, which occurs in every rainy season, compared to those who held flat farm land topography, which accounted for 40.4 % of the total respondents (Table 6).

3.6. Climate services and practical implications

Climate information plays a foundational role in achieving a green recovery and climate neutrality in the developing world and is a central one for the climate resilience of Ethiopian cities. This character can show up if climate change information is delivered appropriately and used effectively. According to the authors, this study is implicit in the provision of climate information for use by Addis Ababa city decision-makers and has been created to provide climate information addressing aspects of climate variability. Moreover, climate services are adopting strategies to increase agricultural productivity, enhance sustainable development, and adapt to unavoidable climate variability. However, for climate services to be effective, they must be accessible and suitable for user needs.

4. Conclusion and recommendation

Assessing the impacts of climate variability on the vegetable production of urban farmers: Nexus climate smart agriculture technology practices are necessary to ensure farmers' sustainability. The results show that the majority of the farmers have perceived changes in rainfall and experienced the impacts of changing variability over a period of decades. The results of the monthly and annual CV confirmed the existence of high rainfall variability, with ranges between 23 % and 73 % and 49 % and 98 %, respectively. Seasonally, the highest rainfall variability was observed in Belg, with a CV between 34 % and 99 %, followed by a Bega CV range of 50 % and 97 %, and in Kiremt, rainfall variability indicated a coefficient of variation range between 20 % CV and 84 % CV. Due to this, vegetable production and the income of farmers have been adversely affected. The farmers applied different climate-smart agriculture technologies, like knowledge-smart (49.0 %) and nutrient-smart (32.10 %), to offset the impacts of these shocks as farm adaptive mechanisms. Shift occupation (37.8 %) and diversifying into non-farm activities (24.4 %) were used as off-farm adaptive mechanisms. Based on the results, most urban vegetable farmers were

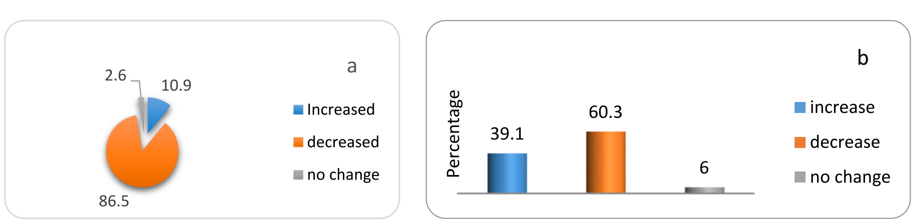

Fig. 8. Trend of the of vegetable productivity (a) and income (b) in the study area. (Source: Filed survey (2019)).

Table 6
Farm land vulnerability, access to early warning information, size and topology of farm.

Farm land vulnerability	Frequency	Percent
Highly	78	50.0
Moderately	60	38.5
Not exposed	18	11.5
Total	156	100.0
Early warning information		
Access to early warning information	Frequency	Percent
Yes	63	40.4
No	65	41.7
No idea	28	17.9
Total	156	100.0
Farm land information		
Size of Farm Land	Frequency	Percent
>1000 m^2	83	53.2
1000 m^2	55	35.3
500 m^2	9	5.8
<500 m^2	9	5.8
Total	156	100.0
Land topography information		
Farm land topography	Frequency	Percent
Sloppy	93	59.6
Flat	63	40.4
Total	156	100.0

vulnerable to climate variability impacts due to farmland topology and other factors. Thus, this study recommends putting in place sensitization CSA programmes regarding urban agriculture and the relative impact associated with the studied practices. Further, to increase the adoption rate of CSA practices among farmers, the national government, through agricultural and climate-related institutions, needs to put in place urban farmer-friendly policies and a strategic plan, such as land tenure, access to credit, and training and extension through services, to improve urban farmers' adaptive capacity and vegetable productivity. Besides, the establishment of the market will provide an outlet for the farmers to be able to produce more vegetables in the city and the country at large. Again, it will motivate most of the youth to venture into the vegetable market, which will help reduce unemployment among the youth in the area.

CRediT authorship contribution statement

Mekonnen Amberber Degefu: Conceptualization, Methodology. **Fantu Kifle:** Conceptualization, Methodology, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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