Impacts of Climate Variability on Vegetable Production of Urban Farmers: Nexus Climate Smart Agriculture Technologies

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Abstract

This study was aimed to examine impacts of climate variability on vegetable production and farmer's prioritization of climate smart agriculture technologies and identification of vulnerable farmers. The study was conducted on vegetable farmers along the Little Akaki River in Addis Ababa. Field data were collected through semi structured survey questioner from randomly selected 156 vegetable farmers. Twenty years (1996-2016) climate data were analyzed with qualitative and quantitative descriptive statistics methods. The result of monthly and annual precipitation variability indicates a coefficient of variation (CV) ranging from 23% -73% and 49% - 98% respectively. Seasonally CV ranges between 34% - 99%, 50% - 97% and 20% - 84% in Belg and Bega and Kiremt respectively. The result of climate data and respondents' perception on local climate variability indicates an increasing trend in temperature and precipitation variability. Urban vegetable farmers perceived that increase in frequency of flood and rainfall (44.9%), drought frequency (13.5%) and increase in temperature (89.7%) and decrease in the trend of vegetable productivity (86.5%) as the major impact of climate variability. However, the changing vegetable variety (31.4%), early planting (26.9%), mixed farming (26.6%), late planting (5.1%), using agro chemicals (4.5%), and agro forestry (1.9%) were the major on-farm climates smart agriculture technologies identified to adaptation. Shift occupation (37.8%), non-adaptation (36.5%) and non-farm activates (24.4%) were employed as off farm adaptation option. In addition, result from vulnerability analysis indicates that the absence of direct access to markets, inadequate access to weather information, land fragmentation and tenure complications were the major vulnerable determinants. It is recommended that there should be market for selling vegetable products, accesses to weather information, and integration of indigenous and modern knowledge on climate variability adaptation should be addressed

Key words: climate smart, climate variability, Impact, urban farmers, vegetable.

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1. Introduction

Extreme climatic events such as floods and droughts have greater adverse effects on vegetable production (Bita and Gerats, 2013). Moreover, Garrett et al. (2013) reported that higher temperatures adversely affect soil moisture, while prolonged droughts and increasing temperatures may help pests and diseases to multiply, thereby, reducing the yield of vegetable crop. The overall effect of climatic variability is the reduction of vegetable growth, yields of crops and reiterate an overall decrease in yields of all the crops mostly maize, groundnut, yam (Deuter, 2008).

The magnitude of the impact of climate variability cannot be underestimated, as it has the propensity to affect the output of most agricultural crops, including vegetables (Lee et al. 2012; Kemausuor et al. 2011; Kotir, 2011). The fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC) has strongly given an indication to the effect that the changing climate is "explicit" and "extraordinary" since the mid-20th century (IPCC, 2014). Climate variability and change are major threats to food security in many regions of the developing world, which are largely dependent on rain-fed and labor-intensive agricultural production (IPCC, 2001).

The estimated impacts of both historical and future climate change 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 (Porter et al., 2014). The urban agriculture contributes a significant role in food supply, employment creation, income generation and environmental management. It is estimated that about 800 million people worldwide are engaged in urban agriculture (UNDP, 2011). It is thought that globally, the urban agriculture produces 15% of all food consumed in urban areas, and that this figure is likely to double within the next 20 years (Porter et al., 2014). Like other developing countries, Ethiopia is widely considered to be highly vulnerable to future climate change and variability (Conway and Schipper, 2011). According to UNDP (2011) the climate variability in Ethiopia could lead to extreme temperature and rainfall events, as well as more heavy and extended droughts and floods. Funk et al. (2005) reported that rainfall in Ethiopia is expected to decline in the future and it may also become more irregular. Accordingly, the country is highly dependent on the agricultural sector for income and food security, the erratic monsoon precipitation would adversely affect the lives of the majority of the populations (Haile, 2005).

In Ethiopia, vegetable crops are produced in different agro-ecological zones by commercial as well as smallholder farmers as a source of their income and food season (Deribie, 2015). However, due to perishable and biological nature of the vegetable production process, the vegetable production is a risky practice (Alamerie et al. 2014). Gebremichael et al. (2014) reported the urban farming is practiced in all 10 sub-cities of Addis Ababa. In the city, the vegetables are produced on more than 300 hectares of land area. There are 6454 vegetable producers and 5765 livestock/dairy owners, with one livestock and 9 vegetable cooperatives in the city (Gebremichael et al. 2014). There are 461 micro- and small-enterprises of farmers, particularly of women, youth and elderly people, engaged in livestock, vegetable and mushroom production. Under the Akaki Small Scale Irrigation scheme, various households have been producing vegetables like lettuce, Swiss charade, carrot, kale, cabbage, potato, cucumber, cauliflower, beans, tomato, pepper and onion along River Akaki. These farmers have supplied about 30% of the vegetable demand of Addis Ababa city. This is done by the farmers even when they face challenges of frequent floods during rainy season (Deribie, 2015).

There are several potential adaptation options to reduce moderate to severe climatic risks in urban agriculture. Adaptation options that sustainably increase productivity, enhance resilience to climatic stresses, and reduce greenhouse gas emissions are known as climate-smart agricultural (CSA) technologies, practices and services (FAO, 2010). Many agricultural practices and technologies such as minimum tillage, different methods of crop establishment, nutrient and irrigation management and residue incorporation can improve crop yields, water and nutrient use efficiency and reduce Greenhouse Gas (GHG) emissions from agricultural activities (Sapkota et al., 2015). Similarly, rainwater harvesting, use of improved seeds, ICT based agro-advisories, and crop/livestock insurances can also help farmers to reduce the impact of climate change and variability (Altieri and Nicholls, 2013).

In Ethiopia, urban climate change and variability related studies and documentation of urban vegetable production are very few and have been focused on impacts of climate variability on crop farming system and farmer perceptions about climate variability (Gebrehiwot and van der Veen, 2013). However, there is no study available on the impact of climate variability on vegetable production and climate smart agriculture technologies in Addis Ababa city. Hence, the present study is initiated to examine the impacts of climate variability on vegetable production and farmer's prioritization of climate smart agriculture technologies adaptive strategies along the Little Akaki River of Addis Ababa.

2. Materials and Methods

2.1 Description of the Study Area

This study was conducted in Addis Ababa on urban farms along the Little Akaki River (Figure 1)

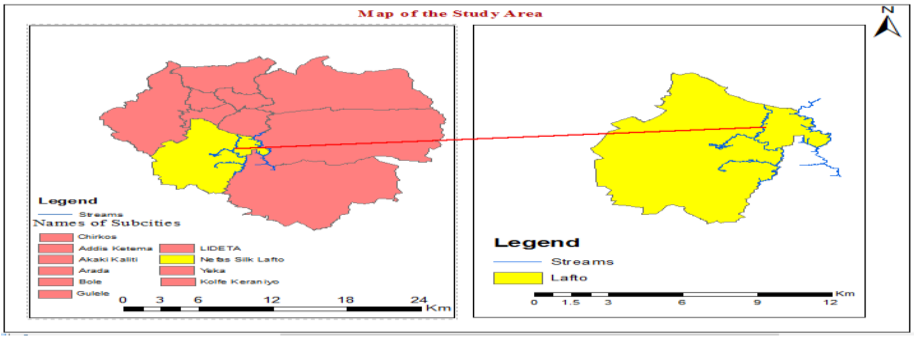


Figure: 1 Location Map of the Study Area

3. Selection of Study Sites and Informants

During a reconnaissance survey of the study area, overall information was obtained. Consequently, two sub-cities (Akaki and Nifasilik Lafto) and four Woredas (3, 4, 5 and 6) were purposively selected due to the presence of wider vegetable production practices (observation and discussion with farmers, Woreda and sub-city urban agricultural experts). Yamane (1967) approach was used to determine sample size after realizing the total urban farmers of the study area. Based on the formula a total of 156 urban farmers were selected for primary data collection. Finally the respondents were randomly selected from purposely identified four Woredas.

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

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

3.1 Data Collection and Analysis

In this research, both primary data (from vegetable farmers along the Little Akaki River) and secondary data (from urban agricultural office of the selected sub-city and National Meteorological Agency) were used as data source. Primary data were collected by using close ended and semi structured interviews, field observation methods (Martin, 1995; Cotton, 1996). Interviews and discussions were conducted in Amharic using a checklist of topics. Secondary data on climatic issues of the past 20 years (temperature and rainfall 1996 to 2016) were collected from the National Metrology Agency. Other published and unpublished materials and different websites were also used. The collected data were analysed and summarized using Statistical Packaging for Social Science (SPSS) version 20 and Microsoft Excel.

4. Result and Discussion

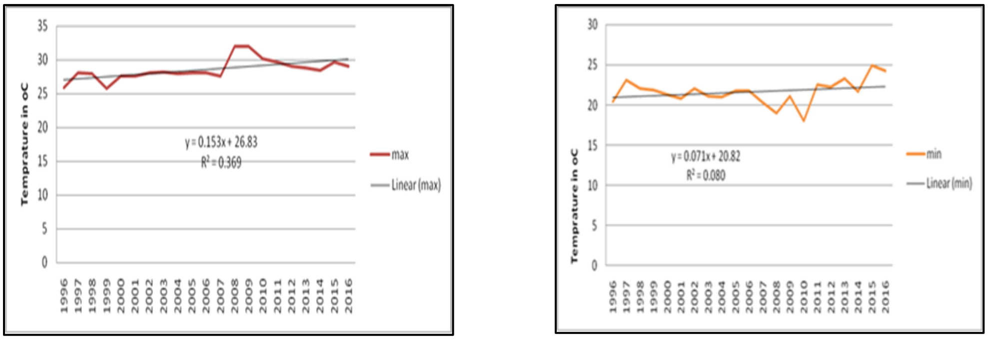
4.1 Socio Demographic Status of the Respondents

Out of the total respondents (156) of the study area 105 (67.3%) were males and 51 (32.7%) were females. Moreover, 62.2% of the respondent's ages were categorized in groups of greater than 41 years. While, only 4.5% were categorized between 20-30 years. About 85.3% of the respondents were married, while 9.0%, 3.2% and 1.4% were single, divorced and widowed respectively. Therefore, the vegetable production in the Little Akaki River was dominated by married farmers and it was more sustainably practiced to support their family. This finding agrees with the findings of Soyebo et al. (2005) that agriculture is very much practiced by married people to make ends meet and provide for their children. In addition, 96 (61.5%) farmers had more than 21 years of farming experience, 54 (34.6%) were 11-12 years and 6 (3.8%) respondents were experienced for <10 years in the district. Ishaya and Abaje (2008) reported that age is the determinant factor for farmers' perception of climate change that can target old and experienced farmers because they are better at distinguishing climate change from merely inter-annual variety of weather scenarios.

4.2 Trend Analyses of Climatic Variables

4.2.1 Trend of Temperature Variability

The annual average minimum and maximum temperature record of the study area were 23^0C and 29.9^0C, respectively. While, the annual average maximum temperature range was between 25.7^0C and 32^0C. Accordingly, the annual minimum temperature was between 18^0C and 24.9^0C in the past two decades and it is presented in Figure 2 below. This indicates the existence of high variability of temperature in the district. The average annual maximum temperature and annual minimum temperature had been changed by a factor of 0.157 and 0.071 respectively as per the trend line (Figure 2). McSweeney et al. (2008) reported that in Ethiopia the mean annual temperature increased by 1.3°C between 1960 and 2006, at an average rate of 0.28°C per decade.



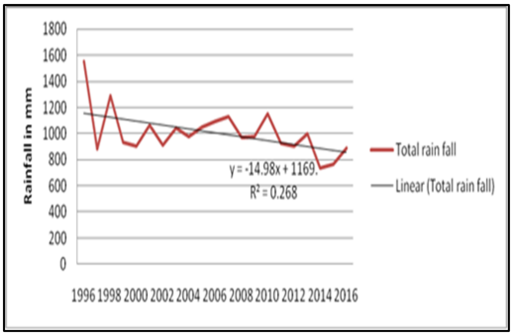
Annual Maximum **Annual Minimum**

Figure 2 Trends of Annual Maximum and Annual Minimum Temperature Variability

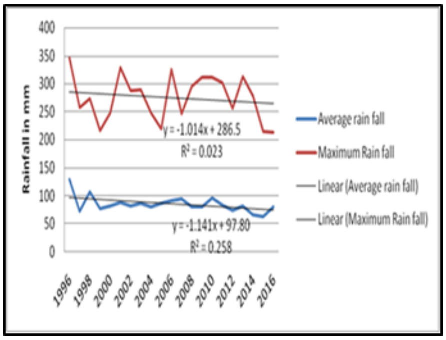
3.2.2 Annual and Seasonal Rainfall Trend and Variability

Trend of Annual Rainfall and Variability

Total annual rainfall of the study area ranged between 732 mm and 1552.3 mm. The linear trend shows that the amount of total annual rainfall declining from 1996 to 2016. Annual maximum and minimum precipitation change from the mean average has to be 286.5 mm by -1.014 and 97.80 mm by -1.141 changing factors respectively (Figure 3).



Maximum Rainfall



Minimum Rainfall

Figure 3 Annual Rainfall, Maximum and Minimum Precipitation Trend and Variability

The average annual precipitation coefficient of variation range of each year was from 49% – 98%. According to W. Hare (2003) 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% indicates extremely high inter-annual variability of rainfall. Based on this, five year interval of annual precipitation coefficient of variation of the study area is summarized in Table 1.

Table 1 Trends in Annual Rainfall Variability within Five Year Intervals

Year category	Mean annual rainfall	SD	CV	Degree of variability according to W. Hare (2003)
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 - 2016	74.07	63.83	74%	Extremely high inter-annual

Seasonal Rainfall Trends and Variability

Bega rain fall season shows a declining trend by 3.24 mm per year over the past two decades (1996-2016). On the other hand, Belg and Kiremt rain was declining by 2.57 mm and 9.14 mm per from 1996-2016 (Figure 4).

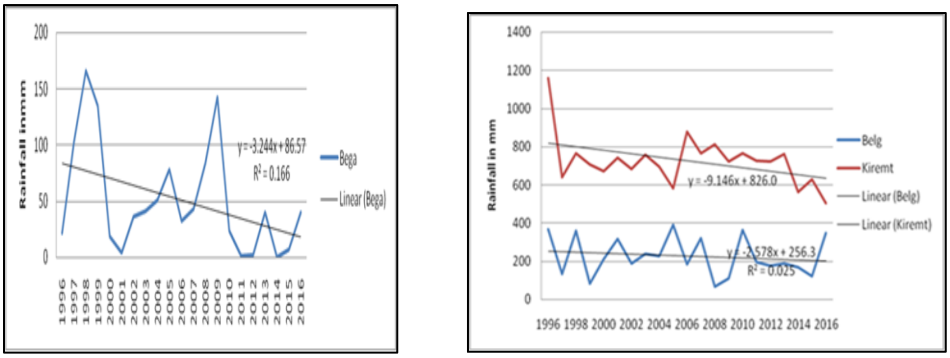


Figure 4 Bega, Belg and Kiremt Rainfall Trends and Variability Respectively

Based on the analysis, the ranges of coefficient of variation (CV) of each year seasonal rainfall were 34%-99%, 50%-97% and 20%-84% in Belg, Bega and Kiremt seasons respectively. This, except in Kiremt season, shows high rainfall variability in all the cases of the year [1996 (20%), 1999 (24%) and 2007 (29%)]. The highest rainfall variability was observed in Belg season of the past 20 years with coefficient of variation above 60%, followed by the Bega season with coefficient of variation (CV) 50% and above. Moreover, the result of Kiremt season CV (20% - 84%) range indicated that low and very high rainfall variability occurred in the past two decades. On the other hand, the range of coefficient of variation (CV) of monthly precipitation was between (23% and 73%). In addition, the coefficient of variation of the five year interval seasonal rainfall shows that in Bega and Belge the range was between 56%-84.04%, while in Kiremt it was less than 53%.

Table 2Trends in Seasonal Rainfall Variability within Five Year Intervals

Year	Belg seasons			Bega seasons			Kiremt seasons		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
1996 - 2000	32.38	20.00	63%	58.31	43.73	81%	197.18	71.85	36%
2001 - 2005	12.87	16.48	77%	68.43	58.93	87%	172.76	79.44	46%
2006 - 2010	19.96	15.52	76%	53.80	31.17	67%	196.93	84.31	47%
2011 – 2016	5.93	3.68	56%	35.34	35.14	69%	169.20	84.09	53%

3.3 Farmers’ Perception in terms of Temperature and Precipitation Variability

3.3. 1 Farmers’ Perception on Temperature Variability

Eighty nine percent of the farmers perceived an “increase” in temperature, and 0.6% of the respondents perceived “no change” in temperature in the past two decades (Figure 5). This result is alien with climate data analysis of the past two decades (McSweeney et al. 2008). The reason for the increase in maximum temperature in the district, as perceived by the farmers, was partly due to the extent of city expansion coupled with deforestation.

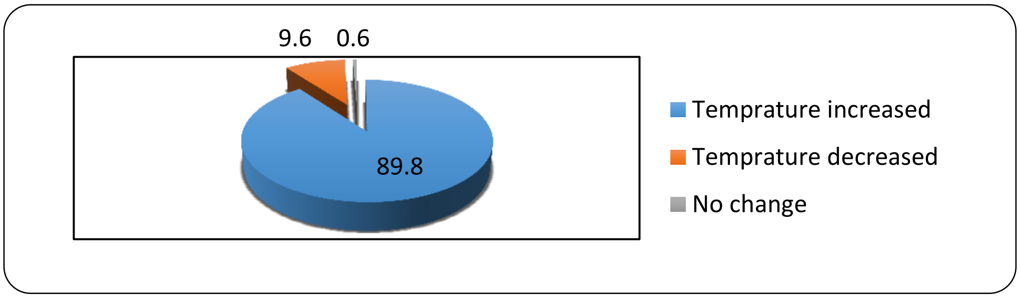


Figure 5 Farmers' Perception of Temperature Variability

3.3.2 Farmers' Perception on Precipitation (Rainfall) Variability

Out of the total 156 valid cases 101 (64.7%) farmers perceived an increase in the precipitation followed by 33 (21.2%) respondents who felt a decrease in the amount of rainfall, and 22 (14.1%) respondents perceived that there was no change in the amount of rainfall in the last 20 years. The farmers' main evidences for the rainfall variability were the increasing frequency of flood, drought and the decreasing surface of water availability, and irrigation water availability.

3.4 Climate Smart Agriculture Technologies for Adaptation to Climate Variability

3.4.1 On-Farm Adaptation Mechanisms to Climate Variability

Out of the total 156 valid cases, 49.10% of urban farmers exercised knowledge smart technology, followed by 32.10% farmers adopted nutrient smart technology to offset the impacts of these shocks (see in Table 3).

Table 3 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%	

Climate Smart Technologies	Farmer Exercised Technologies	Percentage	Total
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%	

3.4.2 Off-farm Adaptation Mechanisms of Farmers to Climate Variability

37.8% of the respondents exercised shift occupation, 36.5% didn't practice anything, and 24.4% adopted climate variability effect by diversification in non-farm activates (Figure 6) to tackle climate variability off-farm.

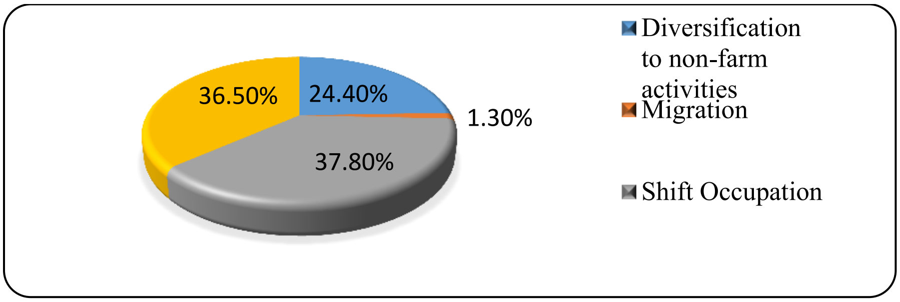


Figure 6 Off- Farm Farmer's Adaptation Mechanism of Climate Variability

3.5 Impacts of Climate Variability in Vegetable Production and Farmer's Income

The impact of climate variability on vegetable productivity is summarized in Figure 7. According to the respondents, the vegetable productivity was affected by the frequent flood (25%) and high rainfall (44.9%). This was due to the landscape and topography of the farm area (Figure 7).

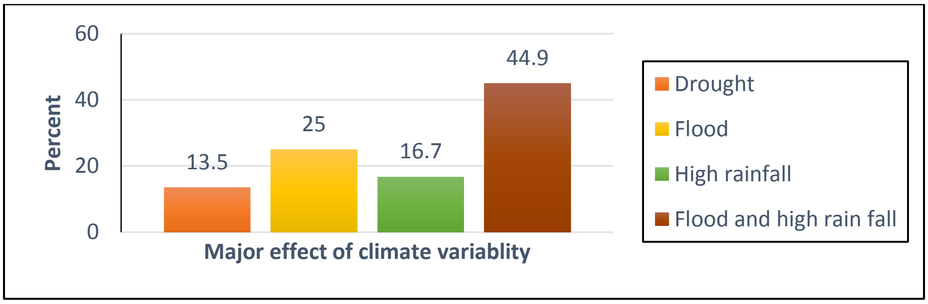
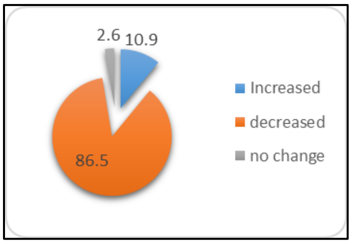


Figure 7 Major Effect of Climate Variability Listed by Farmers

3.5.1 Trend of Productivity of Vegetable in the Last 20 Years

A total of 86.5% of the respondents reported that the trend of vegetable productivity decreased due to the impact of climate variability (Figure 8). While 2.6% reported that there was no change in productivity, and 10.9% reported increased productivity of vegetable in the last 20 years respectively.

These results also agree with the reports of Kalibbala (2011). He found that climate variability, especially temperature and rainfall variability cause a reduction in vegetable yield. The most commonly produced leafy vegetables in the study area were [kosta (*Beta vulgaris*), Yabshagomen (*Brassica carinata*), Selata (*Lactuca sativa*)] that are very sensitive to the climate variability (both temperature and rainfall variations). Moreover, a total of 60.3% of farmers stated that the income earned from vegetable production decreased. While 39.1% of farmers reported that there was increasing income from vegetable production and 6% of the respondents stated as no change on income earned from vegetable farming (Figure 8).



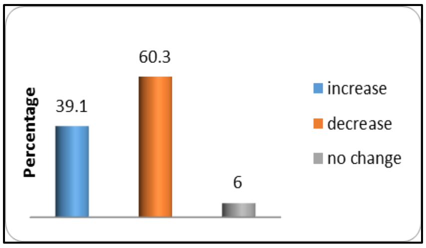


Figure 8 Trend of the of Vegetable Productivity and Income in the Last 20 Years Respectively

3.5 Vegetable Farmers Vulnerability to Climate Variability

According to the survey result, farmers whose land was exposed to the impact of climate variability, their farm land topography was sloppy, and those farmers with smaller farmland, and those who didn't have access to weather information in the district were highly vulnerable to climate changeability. Similarly, out of the total respondents, 50% of them reported that their land was highly vulnerable to climate variability in terms of flood occurrence, 38.5% indicated that their farmland was moderately vulnerable, and 11.5 % of the respondents reported that their land was not exposed to the climate variability. This finding shows that most of the vegetable farmers in the study area were exposed to climate variability in general. On the other hand, 40.4% of the farmers responded that they had access to early warning information, 41.7% of them had no access to early warning information and 17.9% of the respondents had no idea about early warning information. In addition, out of 156 vegetable farmers, 59.6% of them hold sloppy land and were most vulnerable to climate impacts, specifically flooding which occurred in every rainy season compared to those who had owed a flat farm land which accounted 40.4 % of the total respondents.

Conclusion and Recommendations

Conclusions

The results show that the majority of the farmers had perceived changes in rainfall and experienced the impacts of a changing variability over a period of two decades. The result of monthly and annual CV confirmed that the existence of high rainfall variability was between (23% and 73%) and (49% and 98%) respectively. Seasonally, the highest rainfall variability was observed in Belg with CV between 34% and 99%, followed by a Bega CV range of 50% and 97%, and in Kiremt season rainfall variability indicated a coefficient of variation between (20% CV up to 84% CV). Due to this, the vegetable production and the income of farmers were adversely affected.

The farmers applied different climate smart agriculture technologies such as: knowledge smart (49.0%), nutrient smart technology (32.10%) to offset the impacts of these shocks as on farm adaptive mechanism. While, shift occupation (37.8%), diversify into non-farm activates (24.4%) were used as off farm adaptive mechanism. Based on the result, most of the urban vegetable farmers were vulnerable to climate variability impacts. This was due to farm land topology.

Recommendations

- The city administration and any other concerned body in the city should develop climate smart urban agriculture strategic plan and act on it.
- Land tenure, access to credit, as well as training and extension through services should be considered to improve their adaptive capacity and vegetable productivity of urban farmers
- The establishment of the market will provide an outlet to the farmers to be able to produce more vegetable 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.

Reference

Alamerie, K. Ketema, M. and Gelaw, F. (2014), Risks in Vegetables Production from the Perspective of Smallholder Farmers: The Case of Kombolcha Woreda, Oromia Region, Ethiopia, Agriculture, Forestry, and Fisheries, Special Issue: Agriculture Ecosystems and Environment. Vol.3, No.6-1,

Altieri, M.A., Nicholls, C.I., (2013). The Adaptation and Mitigation Potential of Traditional Agriculture in a Changing Climate: Clim. Change

Bita, C. E. and Gerats, T. (2013), “Plant Tolerance to High Temperature in a Changing Environment: Scientific Fundamentals and Production of Heat Stress-Tolerant Crops”, Frontiers in Plant Science, Vol. 4, pp. 273.

Conway, D. and Schipper, ELF. (2011). Adaptation to Climate Change in Africa: Challenges and Opportunities Identified from Ethiopia. Global Environ. Change 21:227-237.

Deribie, M. (2015) Impact of Akaki Small-scale Irrigation Scheme on Household Food Security. J. Account Mark 4: 140. DOI:10.4172/21689601.1000140

Deuter, P. (2008). "Defining the Impacts of Climate Change on Horticulture in Australia", Report Prepared for the Garnaut Climate Change Review, Canberra.

Deressa, T. Hassan, R.M., Alemu, T., Yusuf, M., Ringler, C. (2008) Analyzing the Determinants of Farmers’ Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia. IFPRI Discussion Paper 00798

FAO (2010), Climate Smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Funk, C, Senay G, Asfaw A, Verdin J, Rowland J, Korecha D, Eilerts G, Michaelsen J, Amer S, Choularton. R. (2005) Recent Drought Tendencies in Ethiopia and Equatorial/Subtropical Eastern Africa FEWS NET Report Number 01/2005

Garrett, K. A., Dobson, A. D. M., Kroschel, J., Natarajan, B., Orlandini, S., Tonnang, H. E. Z., and Valdivia, C. (2013) "The Effects of Climate Variability and the Color of Weather Time Series on Agricultural Diseases and Pests, and on Decisions for Their

Management", Agricultural and Forest Meteorology, Vol.170, pp. 216–227.

Gebrehiwot, T., van der Veen, A. (2013). Climate Change Vulnerability in Ethiopia: Disaggregation of Tigray Region. *Journal of East African Studies*, 7, 607-629

Gebremichael, D., A.T., Worku, A., Abshare, M.W. Habtemariam, Y.M., Balcha, G. and Gebremichael, D. (2014), Building Urban Resilience: Assessing Urban and Peri-urban Agriculture in Addis Ababa, Ethiopia. (Padgham, J. and J. Jabbour (eds.) United Nations Environment Programme (UNEP), Nairobi, Kenya

Haile, M. (2005) Weather Patterns, Food Security and Humanitarian Response in Sub-Saharan Africa Phil. Trans. R. Soc. B. 360:2169-2182

IPPC, (2007) Climate Change 2007: The Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

IPCC, (2014) Summary for Policy Makers. In Stocker, T. F., Qin, D., Plattner, G. K.,

Tignor, M., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V. and Midgley, P.M. (Eds.), (2013) "Climate change: The Physical Science Basis", Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Ishaya, S. and Abaje, I.B. (2008) Indigenous People's Perception on Climate Change and Adaptation Strategies in Jema'a Local Government Area of Kaduna State, Nigeria Georg. Reg. Plan. 1(8):138-143.

Kemausuor, F., Dwamena, E., Bart-Plange, A. and Kyei-Baffour, N. (2011) "Farmers" Perception of Climate Change in the Ejura-Sekyedumase District of Ghana", ARPN Journal of Agricultural and Biological Science, Vol. 6, No.10, pp. 26-37.

Kotir, J. H. (2011). Climate Change and Variability in Sub-Saharan Africa: A Review of Current and Future Trends and Impacts on Agriculture and Food Security‟, Environment, Development and Sustainability, Vol. 13, No. 3, pp. 587–605.

Lee, J., Nadolnyak, D. and Hartarska, V. (2012) "Impact of Climate Change on Agricultural Production in Asian Countries: Evidence from

Panel Study", Department of Agricultural Economics and Rural Sociology, University of Auburn, Auburn

Porter, J.R., Xie, L., Challinor, A.J., Cochrane, K., Howden, S.M., Iqbal, M.M., Lobell, D.B., Travasso, M.I., (2014). Food Security and Food Production Systems: In Field, Et Al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Cambridge University Press, Cambridge, UK and New York, USA, pp. 485–533

Sapkota, T.B., Jat, M.L., Aryal, J.P., Jat, R.K., Khatri-Chhetri, A., (2015), Climate Change Adaptation, Greenhouse Gas Mitigation and Economic Profitability of Conservation Agriculture: Some Examples from Cereal Systems of Indo-Gangetic Plains. J. Integr. Agric. 14 (8), 1524–1533

UNDP (2011), India Factsheet: Economic and Human Development Indicator. United Nations Development Programme (UNDP), New Delhi, India

Yamane, T. (1967), Statistics: An Introductory Analysis 2nd Ed., New York: Harper and Row.