Climate change: Its implications on urban and peri-urban agriculture in Dar es Salaam city, Tanzania

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ABSTRACT

Climate change is one of the challenges facing the world today. This study examined the impact of climate change on urban and peri-urban agriculture. Secondary data were collected through a literature survey and primary data were collected using structured and in-depth interviews, observations and focus group discussions. A total of 201 respondents who engaged in urban and peri-urban agriculture (UPA) in Dar es Salaam city were interviewed. The findings revealed that urban and peri-urban agriculture make a positive contribution to food security as 84% of the respondents claimed to engage in UPA for food and income. It was also observed that urban and peri-urban agriculture was affected by climate change, leading to drying of crops (41%), crop pests and diseases (28%), decrease in crop yields (13%), loss of soil fertility (8%), animal diseases (43%), drying of pasture lands (41%) and death of livestock (16%). It is evident that urban and peri-urban agriculture is severely affected by climate change. The study recommends that new farming systems such as vertical farming with the use of limited water resources should be adopted for better output.

Keywords: Climate change, climate variability, temperature, rainfall, urban and peri-urban agriculture, food security

Introduction

Climate change is one of the challenges facing the globe. Development efforts are threatened by climate change owing to its adverse impacts on various sectors including agriculture, health, the environment and infrastructure, especially in the least developed countries (IPCC, 2007; UNFCCC, 2007). Sub-Saharan Africa (SSA) is the region most vulnerable to the impact of climate change on agricultural production due to dependence on unpredictable rainfall which lowers production (IPCC, 2007; Cooper, 2002). The Tanzanian agricultural sector is key to economic development; several studies report that about 75% of the country's population works in the sector. However, its productivity is very low compared to other countries in Sub-Saharan Africa. Some of the major reasons for the low productivity is the dependence on unpredictable rainfall, poor seed and fertilizers, as well as low productivity of indigenous animal breeds (Baseka, 2016; Mbilinyi *et al*., 2013). In urban areas, vulnerability to climate change and variability is greatly influenced by the extent and quality of infrastructure, public services, economic conditions and institutional parameters (Satterthwaite *et al*., 2007, Roberts *et al*., 2011).

Around the world, food is produced within cities and areas immediately surrounding them, a practice which has become known as urban and peri-urban agriculture (UPA). Involvement in UPA is a result of fast urban growth in most cities caused in part by rural-urban migration. The activity encompasses some broad acre farmlands, diminutive community gardens, domicile gardens, fruit trees along wayside reserves and greenhouses (Pearson, 2007). In the past, agriculture was seen as a rural phenomenon, but currently it is an activity that is expanding rapidly to urban areas. Dramatic population increase in urban areas has been a reason for the extension of this originally rural phenomenon to cities as a way of coping with food insecurity (Baseka,

2016). Urban and peri-urban agriculture perform an essential function in providing varieties of food stuffs to the urban dwellers, along with ecological services in urban and peri-urban areas by greening the cities (Oyedipe, 2009; Mlozi *et al.*, 2014). Farming in and around the cities contributes positively to food security, i.e. food availability, accessibility, stability and utilization, leading to sustainable livelihood among the city dwellers.

The impact of climate change in cities ranges from sea level rise to floods, droughts and damage of infrastructures, with enormous effects on urban and peri-urban agriculture, i.e. crop production and animal husbandly (Rosenzweig *et al.*, 2011; Grimm *et al.*, 2008). According to IPCC (2001), there has been an unprecedented warming trend throughout the 20th century. The current average universal surface temperature of 15°C is nearly 0.6°C higher than it was in the past 100 years, and most of such increase has been due to human activities.

Agriculture has been identified as the second most vulnerable sector to the impacts of climate change, preceded only by the water sector (NAPA, 2006). Climate change-induced warmer temperatures, more extreme rainfall and more prevalent drought and flooding pose significant challenges for UPA in Dar es Salaam (Mlozi *et al.*, 2014). The total annual rainfall in Dar es Salaam city has decreased from about 1430.9mm in 1986 to 782.9mm in 2016, and the temperature has been increasing steadily from an average monthly minimum temperature of 20.7^{0}C in 1986 to the current 23.2^{0}C (TMA, 2017). These changes and variability in climate negatively affect the urban and peri-urban agriculture, which is very important for the people of Dar es Salaam. This sector ranks as Dar es Salaam's second largest employer and provides the city with a large quantity of food, e.g. 354,657 tons in 2004 (Ricci, 2012).

Most studies of climate change impacts on agriculture have focused on rural agriculture; very few recent studies have investigated the impact of climate change on urban and peri-urban agriculture. This study therefore intended to fill this gap in the body of knowledge.

Methods and Materials

The study was conducted in Dar es Salaam city in Tanzania. This area was selected because with about 5.5 million people (POD, 2017), Dar es Salaam is the most populous city in Tanzania and has the largest number of urban farmers. A total of 201 respondents from ten wards who engaged in urban and peri-urban agriculture were selected through stratified random sampling. The studied wards were Toangoma, Chamazi, Chanika, Kivule, Ukonga, Kipunguni B, Mbezi, Kisarawe II, Mabwepande and Mbweni.

Primary data were gathered by means of questionnaires, structured interviews and focus group discussions with agriculturalists and the local authorities in the study area. In addition, direct observations were conducted in the study area to identify different crops cultivated and livestock raised. Secondary data were collected through a literature survey. The study unit consisted of 201 urban and peri-urban farmers and 5 focus group discussions (FGDs) were conducted.

Results and Discussion

Profile of the respondents

The ages of the urban and peri-urban farmers in the study area ranged from 18 to 61+ years, averaging between 41 to 60 years (Table 1).

Table 1: Distribution of respondents by age and sex (%)

Age (Years)	Gender	
	Male	**Female**
18-30	61.5	38.5
31-40	44.4	55.6
41-60	43.9	56.1
Over 61	55.6	44.4
Mean	**45.8**	**54.2**

Urban and peri-urban agriculture in the study area

Urban and peri-urban agriculture involves both crop cultivation and animal keeping. In the study area, 61.7% of the respondents were engaged in crop cultivation only, mostly vegetables; 21.9% reported being involved in livestock keeping only; while 16.4% engaged in both livestock keeping and crop cultivation (Table 2).

Table 2: Agricultural activities performed in the study area

Activity	Frequency	Percentage
Crop cultivation only	124	61.7
Livestock keeping only	44	21.9
Both crop cultivation and livestock keeping	33	16.4
Total	**201**	**100**

Crops produced in the study area

Among the crops produced were vegetables. 76.1% of the respondents mentioned producing leafy vegetables including sweet potato leaves, amaranth, pumpkin leaves, okras and Chinese cabbage and 23.9% mentioned producing fruits. Other crops such as maize, cassava, tomatoes, carrots and potatoes were grown to an insignificant extent (Figure 1). Leafy vegetable production dominated in the study area because most of the crop growers had pieces of land which were too small to grow other crops such as cassava, fruits and rice which require large pieces of land. However, in the peri-urban areas some farmers had large pieces of land and thus it was possible for them to grow crops other than vegetables. Also, vegetables are perishable and therefore should be grown near to the market so that consumers can get them while they are fresh. These findings are in line with those of Mhache (2015) who also observed that common crops farmed in Dar es Salaam city were leafy vegetables.

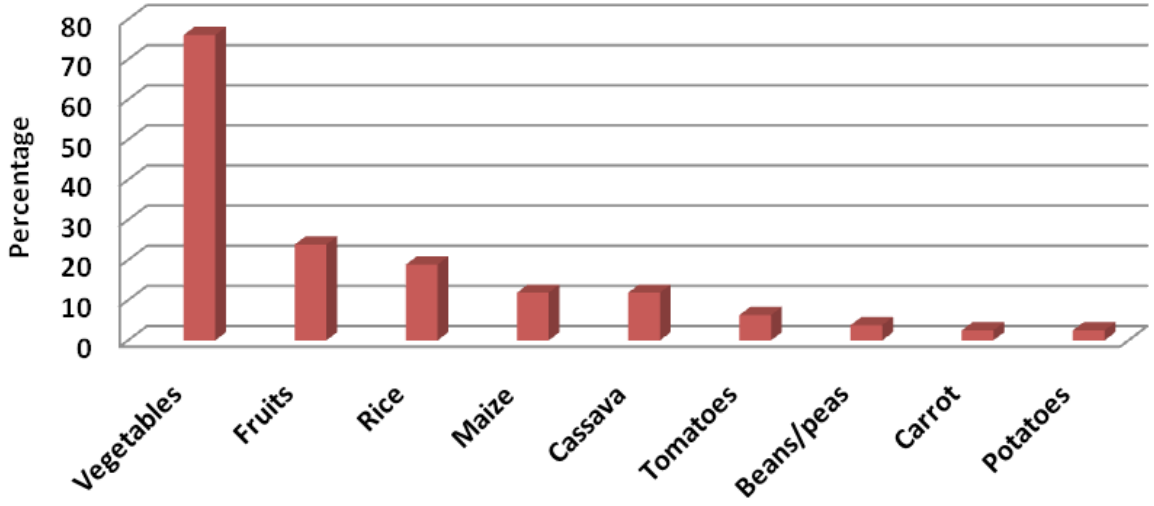


Fig. 1: Crops farmed in the study area

Livestock kept in the study area

About 33.3% of the respondents in the study area kept dairy cattle, followed by 16.7% who kept layers. Other livestock kept comprised goats, broilers, local fowls, pigs, ducks and beef cattle (Figure 2). The majority keep dairy cattle in enclosed places (zero grazing). The Von Thunen Theory suggests that due to the perishability of dairy cattle products, specifically milk, and the need to consume them while fresh, dairy cattle should be kept near the customers (Rodrigue, 2013). The low percentages for beef cattle in the city can be attributed to city regulations (Animal by-laws of 1982 of the Local Government Act, no. 8 section 80 of CAP 378) which stipulate direct zero grazing for all livestock, and the shortage of grazing land.

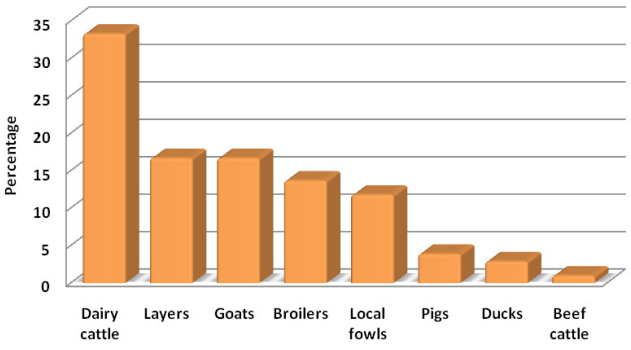


Fig. 2: Livestock kept in the study area

Contribution of urban and peri-urban agriculture to food security in the study area

The practice of urban and peri-urban agriculture has contributed positively to the four pillars of food security, i.e. food accessibility, availability, stability and utilization. A cross-tabulation was done to investigate the relationship between the highest level of education attained by the household head and participation in crop production in urban and peri-urban area. The results showed that 84% engaged in crop production for purposes of home consumption and generating income (Table 3). The results showed a significant positive relationship between reasons for crop production and education level of the farmers, at X^2=19.64; P Value =0.02.

Table 3: Cross-tabulation between education status and reasons for crop production.

Education Level	Reasons for Crop Production (%)			
	To get food	To get income	Lack of other job	Both income and food
No formal education	25.0	00.0	00.0	75.0
Primary education	03.5	03.5	05.3	87.7
Secondary education	06.7	00.0	20.0	73.3
Tertiary education	08.7	13.0	00.0	78.3
Mean	**05.6**	**04.4**	**05.6**	**84.4**
X^2=19.64; P Value=0.02				

People's perception of climate change in the study area

Climate change has been considered as the most serious environmental threat facing the world today. However, the extent of knowledge on climate change and variability is not similar among communities. In the study area, our findings showed that the majority of urban and peri-urban farmers (98%) perceived climate change and variability while only 2% claimed they had not perceived any climatic changes. The finding implies that from the farmers' point of view, climate change is a reality in Dar es Salaam city. The extent of variation between farmers on the perception and awareness of climate change in the study area was due mainly to differences in households' socio-economic characteristics. These findings support the general perception that climate change is felt more by the poor people, who rely greatly on the natural resource base for their livelihoods, than by those who are economically well off (Melilo *et al.*, 2014; Crimmins *et al.*, 2016). Many other studies have documented similar observations in different parts of Tanzania including Kangalawe *et al.* (2009), Mlozi *et al.* (2014), and Mwamfupe (2014) in Kasulu, Dar es Salaam and Rufiji districts respectively.

Local indicators of climate change in the study area

The earth's climate is changing as various climatic elements such as temperatures and rainfall patterns are changing and more extreme climate events like heavy rainstorms, rising sea water levels and melting snow are already being recorded. In the current study, people perceived climate change in various ways including increased temperatures, shift in the rain season, decrease in rainfall, flooding, reduced rainfall duration and drought (Figure 3).

Temperatures

Temperature is a crucial environmental factor that directly influences growth and development of plants and animals. In this study 45.9% of the respondents mentioned increased temperatures as an indicator of the changing climate in their areas (Figure 3). This was also evidenced from the data obtained from Tanzania Meteorological Agency (TMA) (1986-2016) which showed that there have been variations in average minimum and maximum temperature over the past 30 years. While in 1986 the average annual minimum temperature was 20.7°C, this had increased to 23.2°C by 2016. The trend line shows that the average annual minimum temperature in Dar es Salaam city is increasing at the rate of 0.064 each year, R^2=0.804 (Figure 4).

Also, the average annual maximum temperature in the study area has increased, from an average maximum temperature of 31°C in 1986, to 31.3°C in 2016. The trend line shows that the average annual maximum temperature in the study area is increasing at the rate of 0.046 each year, R^2=0.465 (Figure 5). These findings are in line with those observed by Mwamfupe (2014) in Rufiji district where the majority mentioned increased temperatures as an indicator of climate change in their areas. However, it has been reported that mean global temperature has increased by 0.76°C since the 1850s owing to the emission of greenhouse gases (GHGs) provoked by industrial revolution during the second phase, and has been predicted to rise by 1.8–4.0°C between 1990 and 2100 (IPCC, 2007).

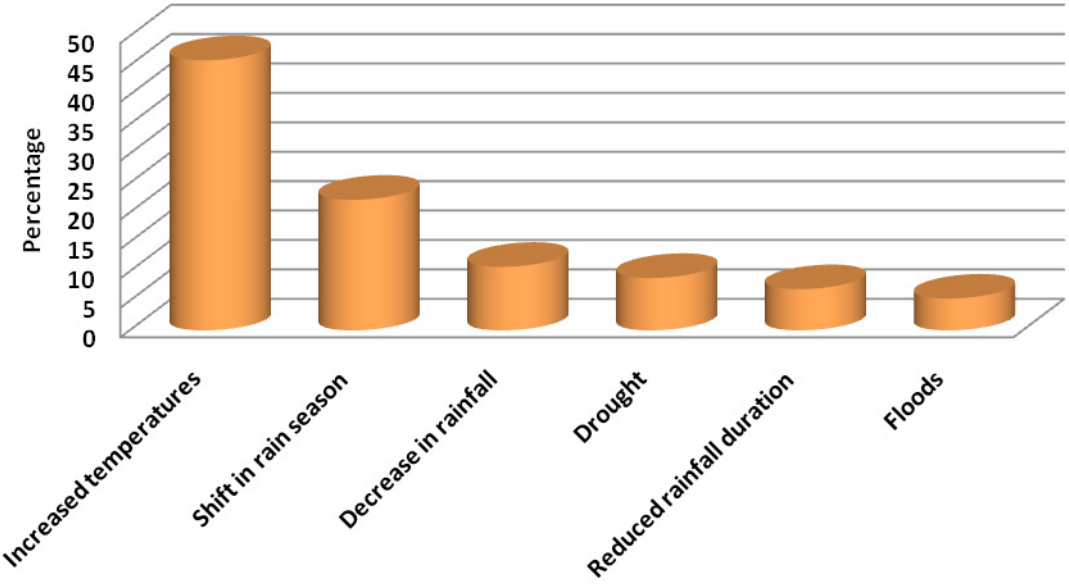


Fig. 3: Local indicators of climate change in the study area (%).

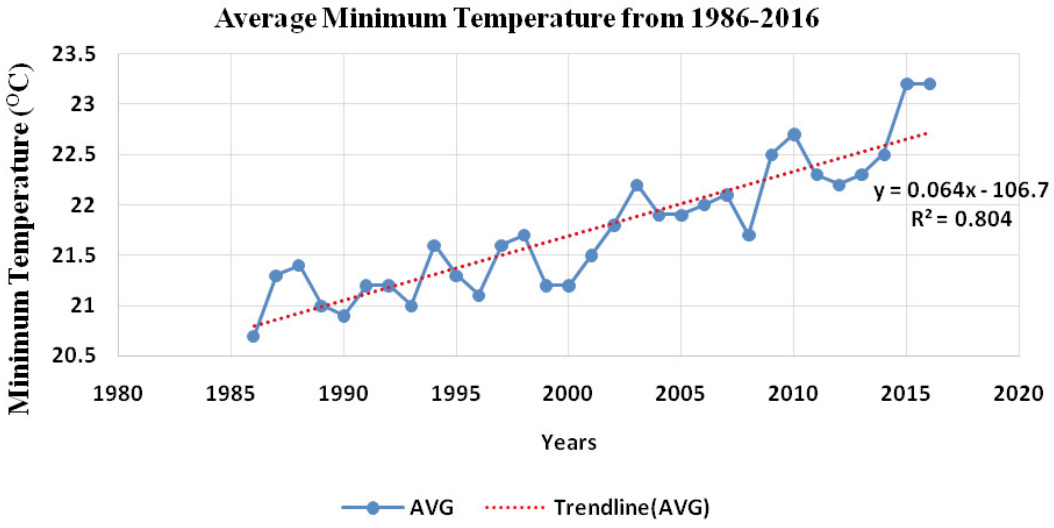


Fig. 4: Average annual minimum temperature (°C) from 1986-2016 in Dar es Salaam city
Source: Tanzania Meteorological Agency

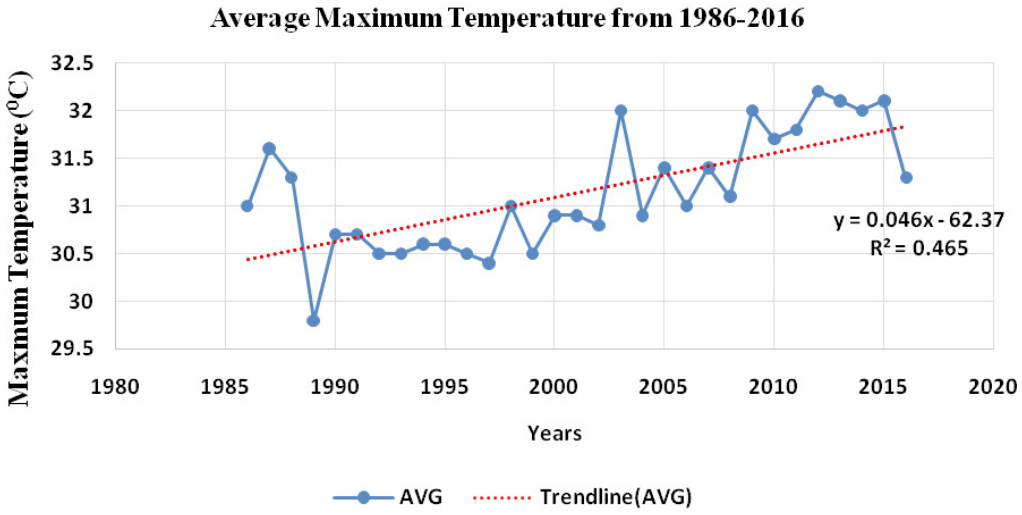


Fig. 5: Average Maximum temperature (°C) from 1986-2016 in Dar es Salam city
Source: Tanzania Meteorological Agency

Shift in rain season

The findings from the study area revealed that about 22.2% of respondents reported experiencing erratic and delayed start of rainfall as an indicator of climate change in their areas (Figure 3). They recalled that there used to be a clear cut bimodal rainfall, with a short rain season from November to December followed by heavy rainfall from March to May. But in recent years there has been a considerable shift in rainfall patterns, so that sometimes the rains start early but at other times they start late compared to the previous years. One respondent in the study area had this to say:

"The climate has changed as evidenced by the changed seasons of rainfall. Sometimes rains come early and

sometimes late. Sometimes we experience normal rainfall pattern sometimes not. In the previous years the rainfall seasons was fixed but currently the climate has changed thereby affecting our farming practices"

Decrease in rainfall totals

Decrease in rainfall was one of the climate change indicators mentioned by 10.8% of the respondents (Figure 3). This is because rainfall is the most important source of water for crop production as well as livestock keeping. The climatic data from Tanzania Meteorological Agency (TMA) for the years 1986-2016 showed that there had been a decrease in rainfall over the past 30 years. While the annual rainfall in 1986 was 1430.9mm, this had dropped to 782.9mm in 2016. The trend line shows that the average annual rainfall in Dar es Salaam city is decreasing at the rate of -9.703 each year R^2=0.115 (Figure 6). Also, the annual average relative humidity in the study area has been changing; while the average annual relative humidity in 1986 was 82%, it had dropped to 81% in 2016 (Figure 7).

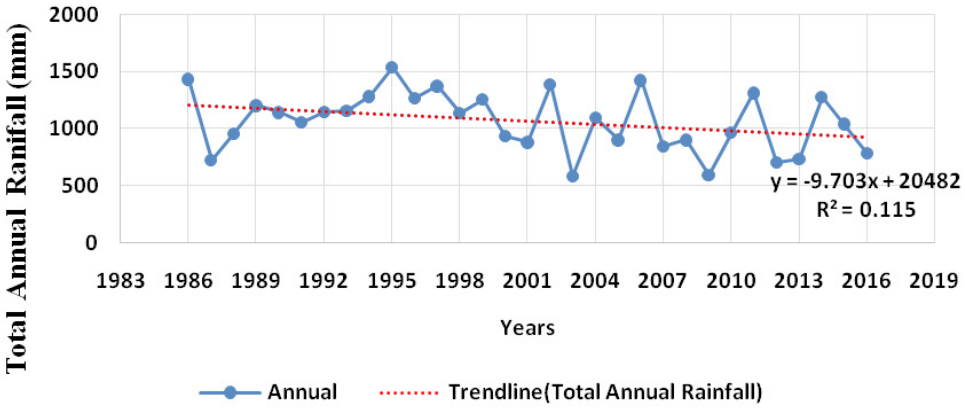


Fig. 6: Total annual rainfall (mm) from 1986-2016 in Dar es salaam city
Source: Tanzania Meteorological Agency

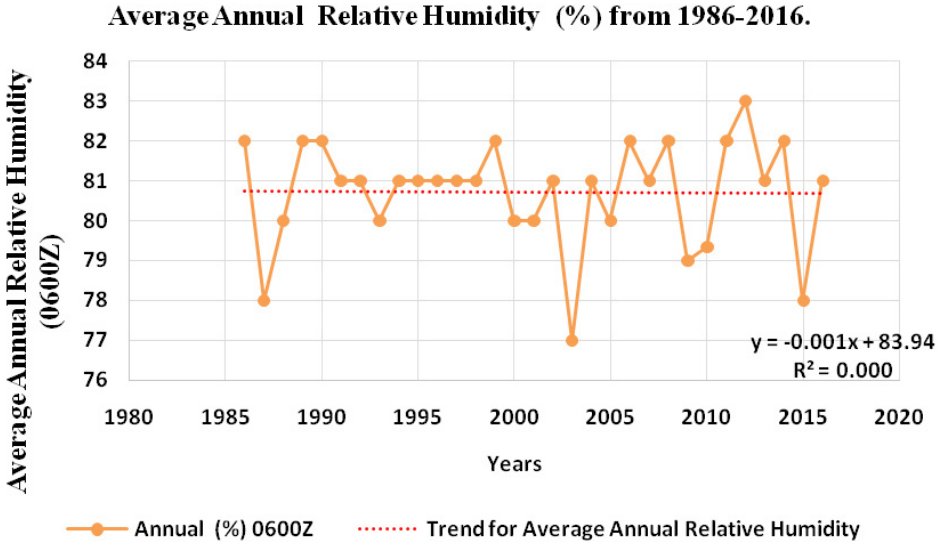


Fig. 7: Average Annual Humidity (0600Z) from 1986-2016 in Dar es Salaam city
Source: Tanzania Meteorological Agency

Drought

Drought is an environmental stress which is characterized by periods of limited or no soil moisture during the growing season. In this study, it was revealed that drought was reported to be among the climate change indicators (Figure 3). Drought resulted from increased temperatures and decrease in rainfall as well as increased water use. The Dar es Salaam Water and Sewerage Corporation (DAWASCO) estimates that the daily water demand in the city is at least 450,000 m^3, but the maximum daily production is just 300,000 m^3 (Smiley, 2016). These results concur with those of Jacob *et al.* (2000) in Dar es Salaam city which revealed that water was a scarce commodity during the dry season, as the public water-supply system can hardly keep up with the requirements of the population which is said to be increasing by 5.6% per year (URT, 2012). Access to a reliable source of water, which varied tremendously between wards, determines the potential of the agricultural enterprise. Where there is no water supply to irrigate, farmers cultivate and produce only under rain fed conditions, which are not predictable.

Drying of crops

An increase in temperature adversely affects crops as excessive heat is a limiting factor of production. In the current study, 41% of the farmers reported that their crops were adversely affected by average temperature changes and drought (Table 4). The farmers also reported that they were experiencing delays in the start of rainfall, thus leading to poor germination of seeds, specifically of rice seeds. These findings indicate that changes in climatic conditions affect the production of crops. This tallies well with what was found by Kasimba (2012) in Zimbabwe, that an increase in temperature poses a threat to the growth of crops as they end up drying.

Crop pests and diseases

In the study area, 28% of the farmers reported that there has been an increase in pests such as aphids and leaf chewing larvae as a result of climate change (Table 4 and figure 8). Several major crop pests and diseases were identified during the questionnaire survey. Several other studies have reported that climate change has led to the prevalence of crop pests and diseases which put agricultural systems at risk. Crop diseases such as anthracnose most often affect tomatoes, cucumbers, melons and beans. Other vegetables are affected by bacterial leaf spot, club root, downy mildew, late blight, mosaic virus, and powdery mildew which are often spread through an insect vector.

Fig. 8a: Okras and Amaranth plants attacked by Aphid pests in Mpiji river valley-Mbezi.

Fig. 8b: Okras and Amaranth plants attacked by Leaf chewing larvae in Mabwepande.

Decrease in Crop Yields

In the study area 23% of the farmers reported that there has been a decrease in crop yields due to increased temperatures, water scarcity and shift in rainfall duration (Table 4). Rainfall has become unpredictable in the study area; this has affected farmers' plans for their activities. Also, lack of capacity for farmers to make proper plans on what to produce, when and how to produce, has led to crop failure and thus decrease in crop yields. This conception is also shared by farmers in the Niger Delta of Nigeria as observed by Nzeadibe *et al.* (2011). This confirms that the majority of farmers associate climate change with crop failure. Similar results were also observed by Kikoyo (2013) whose study in Uganda revealed that climate change and variability led to a decrease in crop yields. In the current study, the farmers reported a decrease in crop yields compared to the previous years when the farmers obtained larger yields because the temperature was moderate and there was stable rainfall.

Table 4: Farmers' perception of the impact of climate change and variability on crop production.

Response	Percentage
Drying of crops	41
Crop pests and diseases	28
Decrease in crop yields	23
Loss of soil fertility	8
Total	**100**

Loss of soil fertility

In the study area, 8% of the crop growers reported a decrease in soil fertility in their areas due to excessive rainfall and resultant floods, or a decrease in rainfall which can result in drought, thus affecting the soil quality. Similar results were also reported by Nutall (2007) who observed that climate change negatively affects the functioning of agricultural soils making them unproductive. It is evident from the results that climatic elements, specifically temperature and rainfall, impact for soil fertility. During this study, it was reported that when there is excessive rainfall, it affects the soil quality.

Impact of climate change on livestock keeping in the study area

In developing nations, livestock keeping plays a major role in the agricultural sector in particular, and economic development in general. It has been reported that there is an expanding demand for foods of animal origin (FAO, 2009). The impact of climate change on agricultural production is not limited to crops, but also affects livestock keeping. Heat agony suffered by animals will decrease the pace of animal feed intake and affect their regular growth (Rowlinson, 2008).

Animal diseases

Variations in temperature and rainfall are the most major climatic variables distressing livestock and leading to disease outbreaks. In the study area 43% of the respondents reported that climate change had led to increased animal diseases. Increased temperatures make livestock such as dairy cattle susceptible to diseases such as bluetongue (bovine anaemia, calf diphtherias), blackleg and anthrax. Also, poultry is affected by diseases such as bacteria (salmonella), mycoplasma, viruses (new castle disease, influenza, infectious bronchitis, infectious laryngotracheitis, avian encephalomyelitis, egg drop syndrome) and parasites. These animal diseases lead to loss of livestock, 16% of the respondents in the study area mentioned that their livestock were dying due to climate change (Table 5).

Drying of pasture lands

Scarcity of good pasture is a major problem for the livestock keepers. Due to climate change and variability, the green nature of the ground fades, leaving it bare or with dry grasses which are not suitable for grazing. In the study area, 41% mentioned that drying of pasture lands was one of the impacts of climate change they felt (Table 5). The increased temperatures and decrease in rainfall have dried up various areas where they used to get grasses for feeding their livestock, leading to reduced livestock outputs. Also, the expansion of agriculture has reduced the grazing land as the farmers' shift to those areas which have water for irrigating their fields, thus diminishing the grazing land.

Table 5: Farmer's perception of the Impact of Climate Change and Variability on Livestock keeping.

Response	Percentage
Animal diseases	43
Dying of livestock	16
Drying of pasture lands	41
Total	**100**

Climate change was reported to affect farmers negatively, but lack of land for farming was also reported to affect farming activities. In areas close to the city, urban agriculture occupies small areas compared to peri-urban areas where bigger parcels of land can be accessed and used for agricultural activities. In the study area most of farmers had small parcels, with 61.3% having an area ranging between 0.2-0.1 hectare and only 0.4% having more than 4.05 hectares (Figure 9). Thus, most farmers in urban settings have smaller plots for farming and most of these plots are either rented or open spaces owned by the government. The same was observed in Kenya by Ogendi *et al.* (2014) who also revealed that people involved in UPA normally use small farm sizes because most areas are built up, as opposed to rural areas where large farm sizes can be found. Studies by Mhache (2015) also revealed that about 50% of the crop growers in Dar es Salaam city had small farm sizes ranging from 0.1-0.5 hectare.

Furthermore, Geographic Information Systems (GIS) analysis using land sat images used to map the spatial and temporal land cover changes over the years (1981-2016) showed that there was a significant change in agricultural land due to urban sprawl. Available data show that in 1981 the agricultural land in Dar es Salaam city was 65,960 hectares, and in 2016 it shrank to 51, 287 hectares. On the other hand, built up area had expanded from 13,939 hectares in 1981 to 45, 467 hectares in 2016 (Figure 10).

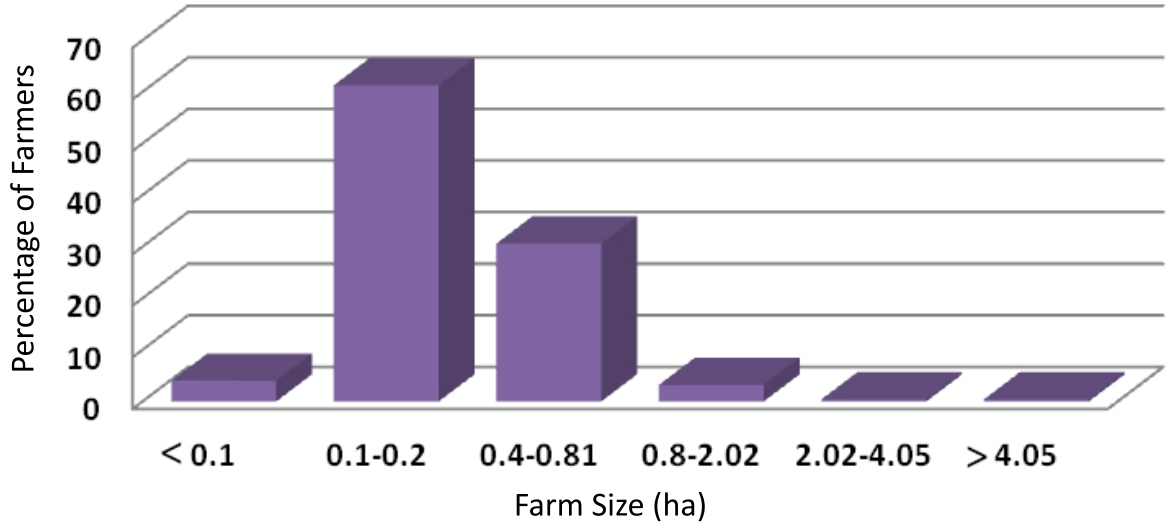
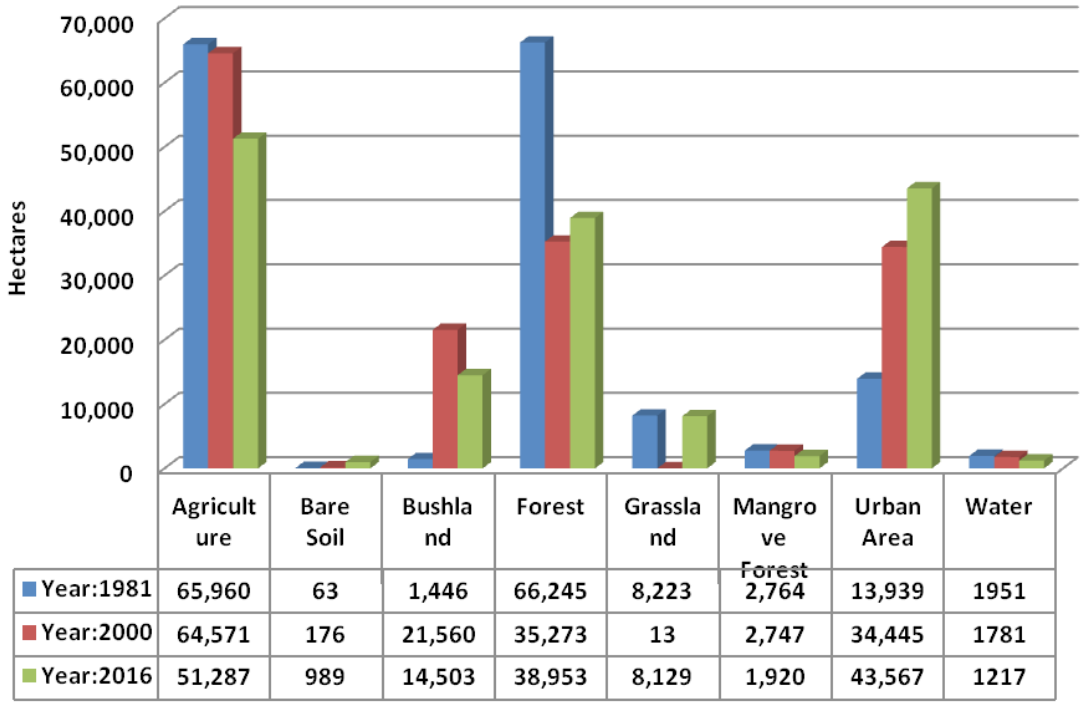


Fig. 9: Farm sizes for crop production in the study area (%)



	Agriculture	Bare Soil	Bushland	Forest	Grassland	Mangrove Forest	Urban Area	Water
Year:1981	65,960	63	1,446	66,245	8,223	2,764	13,939	1951
Year:2000	64,571	176	21,560	35,273	13	2,747	34,445	1781
Year:2016	51,287	989	14,503	38,953	8,129	1,920	43,567	1217

Fig. 10: Dar es Salaam Land cover types from 1981-2016

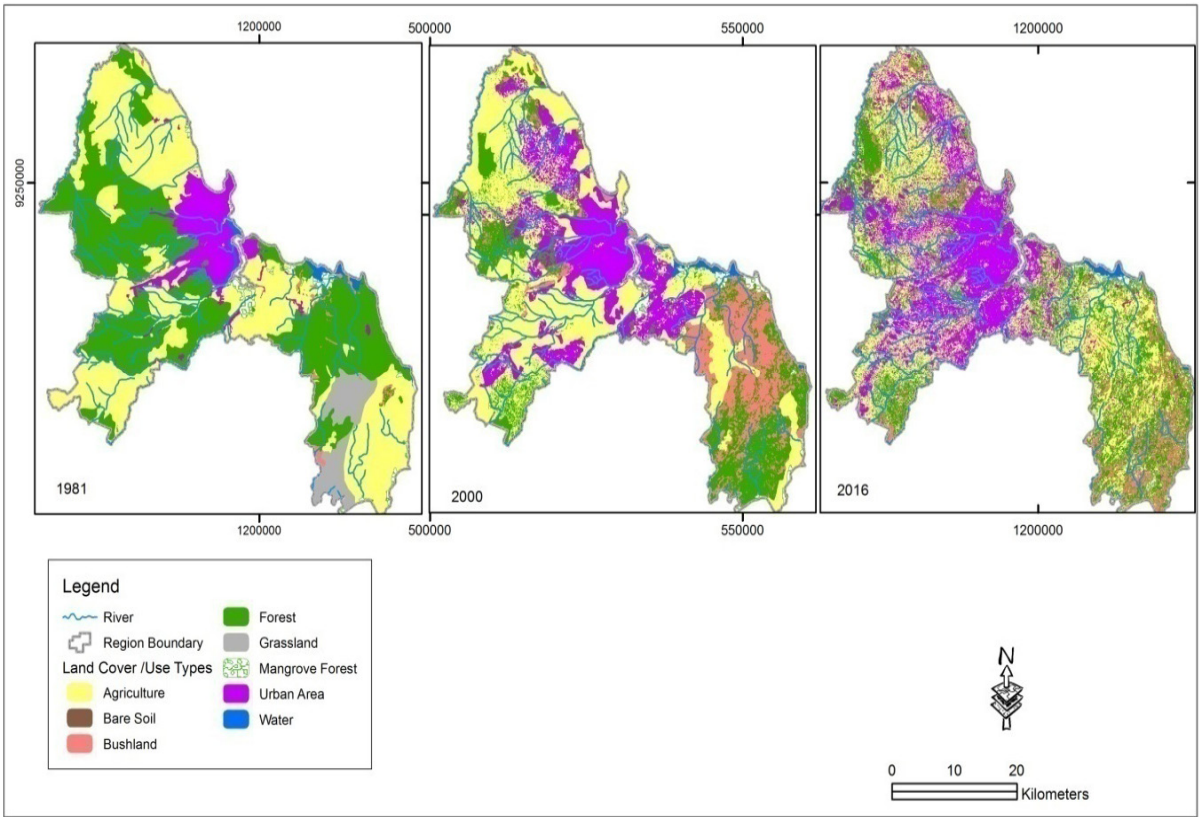


Fig. 11: Land cover/use types in the study area in 1981, 2000 and 2016.

In 1981 most parts of Dar es Salaam city were covered by agricultural lands and forests, and only small parts were built up, specifically in the city centre. In 2000, agricultural land continued to diminish as built land expanded and by 2016, most parts of Dar es Salaam city had changed into built settlements, thus substantially diminishing agricultural lands (Figure 11).

Conclusion

Based on the findings, it is evident that crop production and livestock keeping in urban and peri-urban areas of Dar es Salaam city were highly affected by increasing temperatures, decrease in rainfall totals, drought, shift in rain season and floods, leading to increased crop pests and diseases, drying of crops, decrease in crop yields and loss of soil fertility, as reported by the farmers and evidenced in the agricultural fields. Also, climate change had negative impacts on animal husbandry, leading to dying of livestock, drying of pasture lands and animal diseases. We recommend the adoption of vertical farming systems which use limited water resources while giving large amount of yields, instead of depending on unpredictable rainfall.

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