ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 1 January 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2019; 19(1):14010-14042 DOI: 10.18697/ajfand.84.BLFB1017

Borlaug LEAP Paper

Climate Change Effects on Crop Production in Yatta sub-County: Farmer Perceptions and Adaptation Strategies

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ajfand SCHOLARLY, PEER REVIEWED
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Volume 19 No. 1
January 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Abstract

In Yatta sub-County, a semi-arid land, there is scanty information on the causes and effects of climate change, as well as agricultural adaptation strategies. This scanty information assessment of climate related risks, and decision making about appropriate adaptation measures. A survey was conducted in two wards of Yatta, Kenya, to identify opportunities for building farmer capacity in dealing with climate variability. A semi-structured questionnaire was administered to 60 households randomly distributed in the two wards and data was analyzed using Statistical Package for Social Scientists (SPSS). Results showed that farmers in the region were aware of climate change (98%) with the known indicators reported to be erratic and low rainfall (50%), drought (33%), and rising temperatures (14%). Farmers mentioned deforestation (73%) as the main cause of climate change, and reported major impacts on crop production in the region, such as the introduction of drought tolerant crops (45%) reduced yields (43%) and changes in planting time (38%). As a result, farmers prepared the land early using organic and inorganic fertilizers, planted early-maturing crop varieties and carried out water and soil conservation practices. Even though farmers in Yatta sub–county are aware of climate change its impacts and different coping and adaptation strategies, crop production in the region continues to decline. There is need, therefore, to increase farmer's capacity to better adapt to the effects of climate change to ensure sustainable agricultural production and improved food security.

Key words: Agricultural production; Climate Change; Arid and Semi-Arid Lands; Adaptation to climate change

DOI: 10.18697/ajfand.84.BLFB1017

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Introduction

It has been argued that the world's climate will continue to change at rates unprecedented in human history, and that all societies need to enhance their adaptive capacity to face subsequent present and future challenges (Adger *et al.,* 2003). Climate change has thus become the most important topical development policy and global governance issue in the 21st century (African Development Bank, 2010). Despite agriculture being the most important sector in the Kenyan economy, contributing 24% of the annual Gross Domestic Product directly and another 27% indirectly, agricultural productivity has been on the decline at a rate of 21.41% annually (World Bank, 2016). Over 75% of the Kenyan population earns their living from agriculture, and the population is increasing. According to United Nations' projections, the population will grow by around one million people per year, hitting 95 million by 2050 (United Nations, 2015). Worse still, are the expected adverse effects of climate change in the future as global circulation models are predicting increased temperatures of about 4^{o}C and variability in rainfall of up to 20% by the year 2030, leading to severe droughts and unreliable rainfall to cater for the predominant rain fed agriculture practices in the country. These changes will adversely affect agriculture in both the arid and semi-arid areas and high potential areas (Kabubo- Mariara and Karanja, 2007)

Countries in sub-Saharan Africa are particularly vulnerable to climate change impacts because of their limited capacity to adapt. In Kenya, where the poverty rate is 52% and 73% of the labour force depends on agricultural production for their livelihood, poor farmers especially in the Arid and Semi-Arid lands (ASALs) are likely to experience many adverse impacts from the climate change (FAOSTAT, 2010). Agricultural production remains the main source of income for most rural communities in the region, therefore adaptation of the agricultural sector is imperative to enhance the resilience of the agriculture sector, protect the livelihoods of the poor and ensure food security. According to UNEP (2009), adaptation refers to reducing the negative effects of climate change by modifying systems to take into account new or anticipated climatic conditions.

There is a large deficit of information and knowledge on climate change causes and effects and adapting it in the ASALS, which are the most vulnerable. This in turn impedes decision making and assessment of climate related risks and adaptation (McSweeny *et al*., 2010). Information about this issue may be put into two groups: (1) climate trend analysis and future projections from climate scientists and (2) the perception and adaptation information from people at risk in those regions (mainly farmers). Adaptation and coping strategies are therefore necessary to reduce vulnerability to the changing climate as well as to prepare for possible future extreme climate events.

The Intergovernmental Panel on Climate Change (2001) defines adaptation as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. On the other hand, Blaikie *et al.* (1994) defines coping as the manner in which people act within existing resources and ranges of expectation in a given context to achieve various ends. Therefore, adaptation involves longer-term shifts in livelihood strategies, while coping involves temporary adjustment in response to change or to mitigate shocks and stresses on

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livelihoods (Eriksen et al., 2005; Migosi *et al*., 2012). Adaptation is widely recognized as a vital component of any policy response to climate change. Studies show that without adaptation, climate change is generally detrimental to the agriculture sector; but with adaptation, vulnerability can largely be reduced (Smit and Skinner, 2002). Thus, the adaptive capacity of a system or society describes its ability to modify its characteristics or behavior so as to cope better with changes in external conditions. Adaptation can greatly reduce vulnerability to climate change by making rural communities better able to adjust to climate change and variability, moderating potential damages and helping them cope with adverse consequences (IPCC, 2001). A better understanding of farmers' perceptions of climate change, ongoing coping and adaptation measures, and the decision-making process is important to inform policies aimed at promoting successful adaptation of the agricultural sector which will require the involvement of multiple stakeholders, including policymakers, extension agents, NGOs, researchers, communities and farmers (UNEP, 2009).

The reduced availability of resources (particularly food, energy and water) has positively changed the rural community's outlook towards the need to conserve the environment and resources resulting in an increasing need to achieve food security (FAO 2013). To achieve increased food production in this region, farmers would, therefore, have to cope and adapt to climate change. There is, however, little knowledge on how farmers perceive climate change and if they have formulated adaptation measures (Fosu-Mensah *et al.,* 2012). Hence, this paper seeks to explore farmers' perceptions, coping and adaptation to climate change and investigate the factors and barriers affecting the adaptation process.

Materials and Methods

The study was conducted in Yatta sub-County of Machakos county, Kenya which lies between 1º37' S and 1º45' S latitude and 37º15' E and 37º23' E longitude. It is made up of five wards formerly known as sub-locations before the implementation of the 2010 Constitution of Kenya; Ndalani, Matuu, Kithimani Ikombe and Katangi (Figure 1). The sub-county is mainly in agro-climatic zone IV, which is classified as semi-arid land (Jaetzold *et. al.*, 2006). The mean annual temperature ranges from 17ºC at night to 24ºC during the day and the rainfall pattern is bimodal with long rains (LR) commencing end of March to

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May (about 400 mm) and short rains (SR) from end of October to December (500 mm). The sub-county lies on a plateau at an elevation of 1,700 m, it has an approximate area of 1,059 Km^2. The major soils in Yatta sub-county are a combination of Ferric Luvisols, Lithisols and Rhodic Ferralsols (USDA, 1978; WRB, 2006). The majority of the farmers in the sub - county are small-scale, practicing mixed farming, keeping indigenous livestock and mainly growing crops such as *Zea mays* (maize), *Phaseolus vulgaris* (beans), *Pennisetum glaucum* (millet), *Sorghum vulgare* (sorghum), *Manihot esculenta* (cassava) (Macharia *et al*., 2010).

Data collection

According to the 2009 Kenya national census, Yatta sub-County has a population of 147,579 of which 48% is male and 52% is female. It also consists of 33,162 households (KNBS, 2013). Ikombe and Katangi wards were selected as the main regions of study as they are the two biggest wards in the sub-County making up more than half of Yatta sub-county. Ikombe ward has a population of 34,683 while Katangi ward has a population of 21,781. Data on effect of climate change on crop production and adaptation strategy was collected in 2011 through household surveys. The sampling size was chosen by proportion in line with the farmer population size of the sub-county based on Cochrane formulae (Cochran, 1977).
Cochran's formula:

$$SS = \frac{Z^2 * (p) * (1-p)}{c^2}$$

Z = Z value (e.g. 1.96 for 95% confidence level),
p = percentage picking a choice, expressed as decimal (0.5 used for sample size needed),
c = confidence interval, expressed as decimal (e.g., 0.04 = ±4) and SS = sample size

Figure 1: Map of Yatta sub-county (Machakos County Integrated Development Plan, 2015)

Using a semi structured manually pretested open-ended questionnaire, a total of 60 households equally distributed in the two wards (Katangi and Ikombe) were randomly selected. The questionnaires were pretested on 5 farmers from a farmer group in Machakos and 5 students (also to be used as enumerators) from the University of Nairobi to determine how long the questionnaire will take to administer and how they will be understood and answered. Pretesting was done to check for mistakes in wording of questions, lack of clarity of the questions, potential difficulties in answering the questions, structuring of the questions (whether to have open-ended or close ended-

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questions) and identifying questions already addressed by other questions. A total of 60 adult farmers identified as heads of households were individually interviewed (30 per sub-location). A stratified random sampling procedure was used to select 60 farmers (30 per sub-location) for questionnaire administration, with wards forming the stratum. From the sub-locations, villages were randomly selected and a list of farmers was generated with the assistance of village heads and agriculture officers from which the households were selected. In each case, a computer random number generator was used to generate random numbers and select the households to be interviewed in each village. This technique eliminated sampling bias and ensured that each household had an equal chance of being sampled. This ensured that the sample was normally and the population sufficiently represented (Ndambiri *et al.*, 2013).

Primary data collected included household demographic data, farmers' perception on climate change, causes of climate change, effects of climate change on crop production, crop type change, adaptation to climate change and future predictions of climate change. The questionnaire was designed to capture information on [i] perception: rating of climate change effects, timescale of anticipated changes, occurrence and value attached to understanding these changes, [ii] experiences: awareness of incidences of extreme weather events, source of information on climate change, traditional technical knowledge on weather events, effect of climate change on crop production, crop type change over the years, and [iii] coping and adaptation strategies: changes in farming techniques in response to climate change.

Data analysis

The data were analyzed using the Statistical Package for Social Scientists (SPSS) (version 16.0 for Windows; SPSS Inc., Chicago, IL). Depending on the type of data, means and frequencies were computed. Descriptive statistics were used to describe and characterize the demographics, socio-economic characteristics and resource access and endowment of the sampled farmers. This was to give more insight into the structure of sample used. Descriptive analysis (means and frequencies) was also used to illustrate the different levels of adaption to climate change and technique used thereof.

Results

Demographic characteristics

The farmers interviewed were aged between 22 and 80 years old with 42% being male and 58% female. Household size ranged from 3 to 16 household members. The highest level of education attained by the father (Head of household) for the majority of the respondents was upper primary school. (Table 1). Majority of the farmers interviewed (87%) indicated farming as their main source of income with 13 % indicating retail business, pension/retirement and employment as other sources of income. Of the 13% who indicated they have alternative sources of income, 49% earned more than Kshs.10,000 (US$ 115) from the alternative sources of income.

DOI: 10.18697/ajfand.84.BLFB1017

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ISSN 1684 5374

Table 1: Demographic characteristics of interviewed farmers in Yatta sub-county (n = 60)

Demographic characteristic	Ikombe (%)	Katangi (%)
Age		
21 - 40	27	27
41 - 60	50	53
61 - 80	23	20
Land size (Hectares)		
< 2	27	27
2 – 6.1	50	50
> 6.1	23	23
Level of education, household head		
None	27	6
Lower primary	5	19
Upper primary	41	30
Secondary school	27	22
College	0	3
Source of income		
Farming	92	82
Other (Retail business, employment)	8	18
Income from farming (Kshs/year) (1 US$= 87Kshs)		
0 – 2,000	32	9
2, 000 – 4, 000	16	12
4, 000 – 10, 000	24	15
>10,000	28	64
Income from other sources (Kshs/year) (1 US$= 87Kshs)		
0 – 2,000	46	5
2, 000 – 4, 000	0	23
4, 000 – 10, 000	14	18
>10,000	40	55

Farmers' perceptions of climate change

The majority of farmers in Yatta sub-county were aware of climate change (Table 2) with 50% of farmers interviewed reporting erratic and low rainfall, 33% droughts, and 14% reported rising temperatures as the main evidence of climate change observed in both wards (Fig. 2).

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Table 2: Farmers awareness of climate change in Ikombe and Katangi (n = 60)

	Knowledge of climate change		
Division	Know (%)	Do not know (%)	Total (%)
Ikombe	96.2	3.8	100
Katangi	100	0	100
Total	98.3	1.7	100

A small number (3%) identified other indicators which included floods and cold spells as evidence of a changing climate, an indication that these were not common occurrences in the region. The farmers also observed that these changes have been evident throughout the past decade with changes in rainfall being more pronounced longer than 10 years ago.

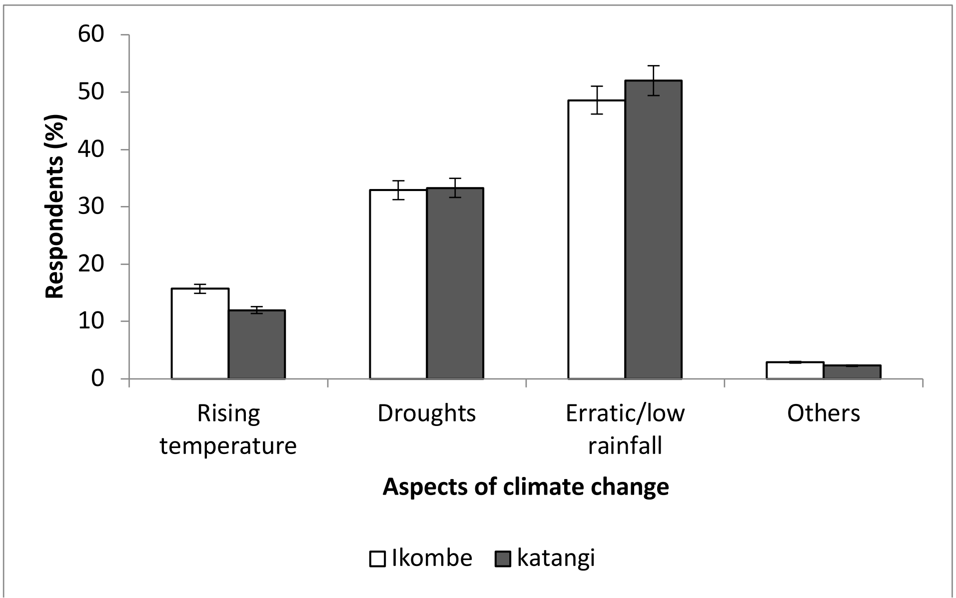

Figure 2: Indicators of climate change in Yatta sub-county

Available historical weather data for the region spread over the past 50 years verifies this trend showing a gradual reduction in rainfall over the years and an increase in temperature (Fig. 3).

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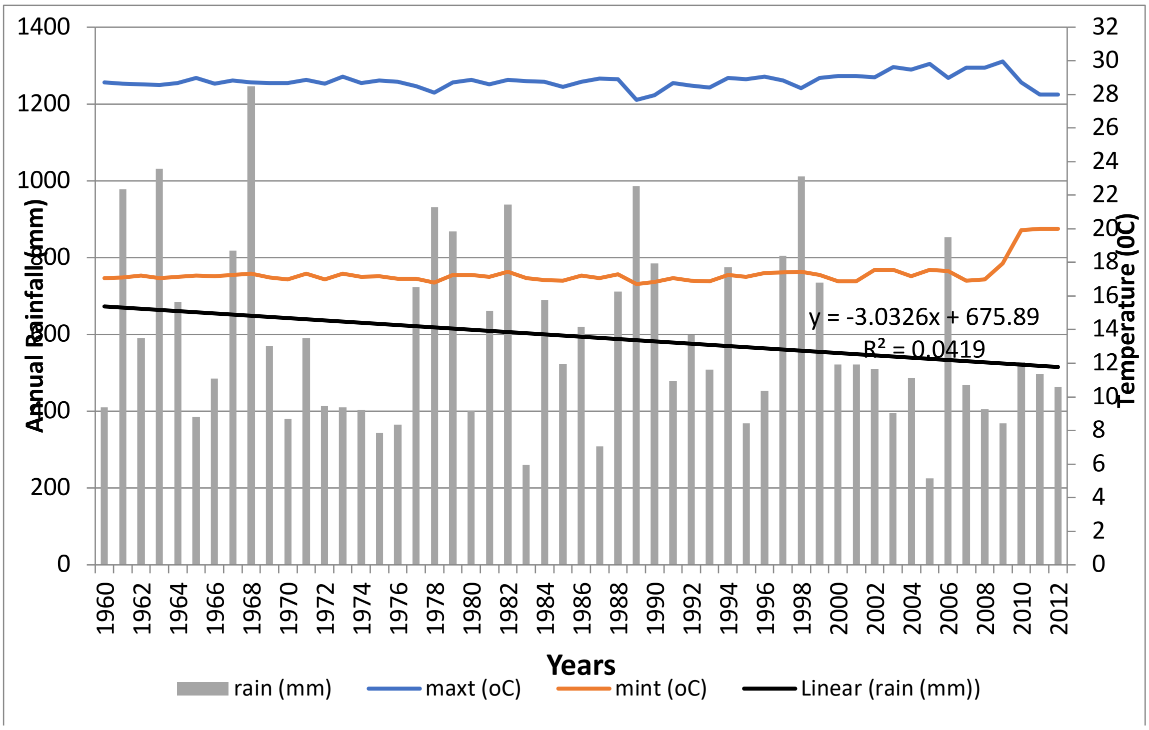

Figure 3: Climate trend in Yatta sub-county (1960 – 2012) (Source: Kenya Meteorological Department)

The main source of information on climate for the farmers in Yatta sub-County was through extension officers (72%) with most of the farmers identifying more than one source of information (Table 3). They also relied on friends, the radio, their own knowledge from years of farming and information passed down through generations, newspapers, seminars and meetings.

Table 3: Farmers' sources of information on climate change in Yatta sub-county (n = 59)

Information sources	Percent of cases (%)
Radio	21
Newspaper	12
Friends	35
Extension officers	72
Own knowledge	14
Others (Seminars and meetings)	2

Respondents identified deforestation as the main cause of climate change (Fig 4). Other causes of climate change identified were, industrial pollution as well as agricultural activities such as use of fertilizers and clearing of vegetation cover for agricultural land. However, some respondents (12%) did not know the causes of climate change despite acknowledging that the climate is changing.

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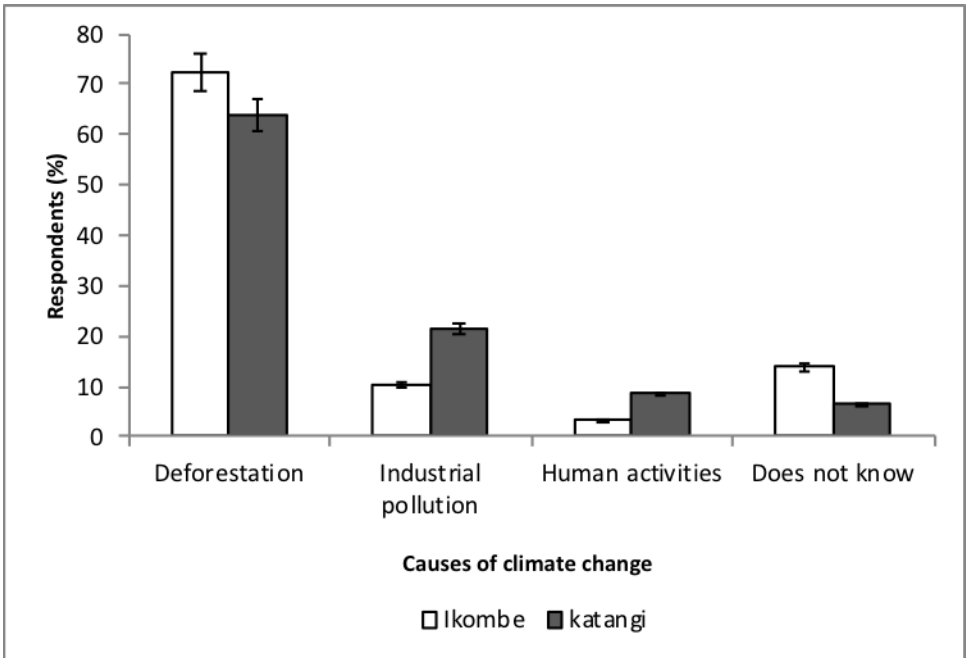

Figure 4: Causes of climate change in Yatta sub-county

Impacts of climate change on crop production

Majority of the farmers (75%) interviewed had been practicing farming for over 30 years. All of the farmers interviewed used oxen plough for land preparation with 8% using both oxen plough and hand hoes, <5% using tractors and oxen plough and <5% using oxen plough, hand hoes and tractors. This is in contrast to Oluoch-Kosura (1983), who found that 84% of land cultivation in Kenya was cultivated by hand, 12% by oxen and the rest by tractor. The farmers preferred oxen plough because it was cheaper and faster (90%), easily available (37%) and its effectiveness in breaking the hard pan (20%). Other reasons included its effectiveness in preparing large sizes of land (12%) and making planting easier (12%). These reasons are derived from the fact that due to the unpredictability of the rainfall, farmers in the area have a short window to prepare land and earlier than expected hence the need to have a cheap and faster means of preparing the land.

Crop production was one of the main agricultural activities highly affected by climate change, with 70% of the farmers interviewed pointing out that their farms productivity had declined over the years due to climate change. According to 95% of the farmers, unreliable rainfall was the main reason for the deteriorating performance. Drought, low soil fertility and low soil moisture, were also identified as well as pests and diseases (28%), lack of inputs (17%), planting of the wrong type of crop for the region (12%), and lack of funds (7%) (Fig.5). Most of these reasons identified are as a result of climate change suggesting that climate variability has a big impact on crop production in the region.

DOI: 10.18697/ajfand.84.BLFB1017

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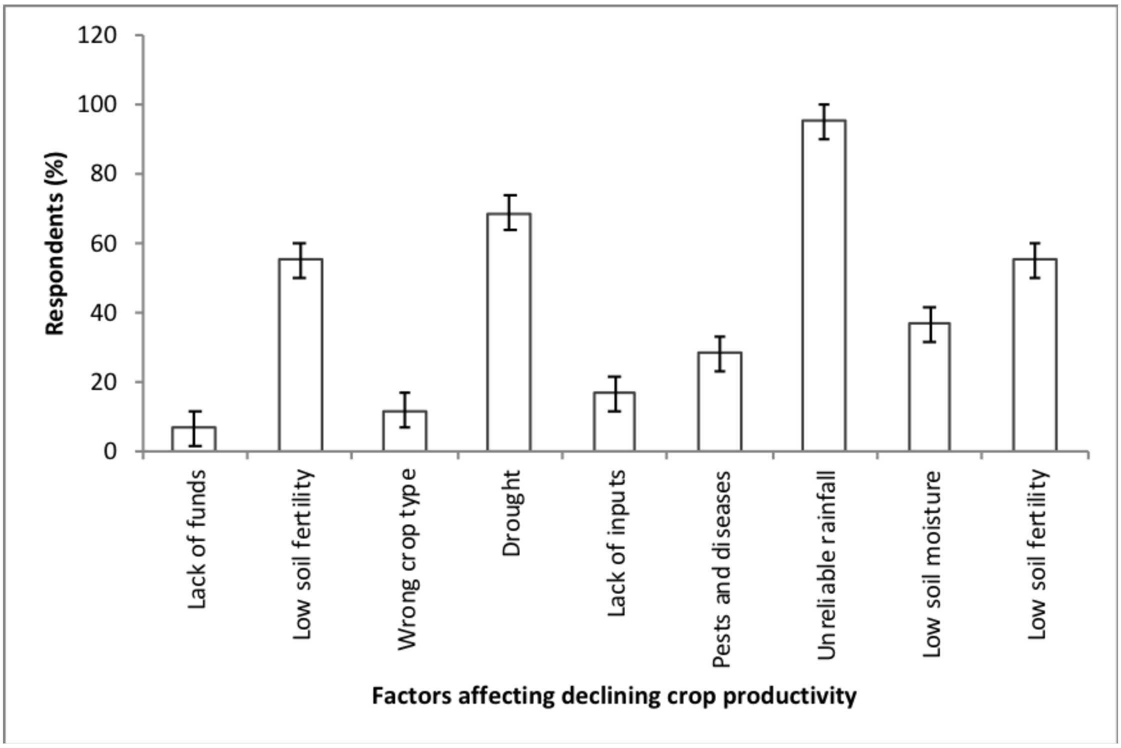

Figure 5: Factors influencing declining crop productivity in Yatta sub-county

Reduced crop yield, change in planting time, crop failure and reduced soil moisture were some of the impacts of climate change identified by farmers in the sub-county. Farmers in both Ikombe and Katangi observed that crop yield and crop failure were significantly felt as a result of climate change. Change in planting time, pest and disease infestation and reduced soil moisture were moderately felt while flooding of crop fields due to heavy downpours was only slightly felt as a result of climate change (Table 4).

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Table 4: The extent of climate change impacts on crop production in Yatta sub-county (n = 59)

Effect	Location	Slightly (%)	Moderately (%)	Significantly (%)
Reduced crop yield	Ikombe	0	50	50
	Katangi	2.9	44.1	52.9
	Total	1.7	46.7	51.7
Change in planting time	Ikombe	24	68	8
	Katangi	24.2	45.5	30.3
	Total	24.1	55.2	20.7
Crop failure	Ikombe	4.2	58.3	37.5
	Katangi	20.6	38.2	41.2
	Total	13.8	46.6	38.7
Pests and disease infestation	Ikombe	16.7	62.5	20.8
	Katangi	45.5	51.5	3
	Total	33.3	56.1	10.1
Flooding of crop fields	Ikombe	100	0	0
	Katangi	90.9	9.1	0
	Total	92.9	7.1	0
Reduced soil moisture	Ikombe	4.2	83.3	12.5
	Katangi	45.5	48.5	6.1
	Total	28.1	63.2	8.8

About 30% of the farmers in Katangi observed that change in planting time was affected significantly as compared to 8% in Ikombe. However, 21% of farmers in Ikombe observed that pests and diseases was a significant effect as compared to 3% in Katangi. Most of the farmers in Katangi (52%) and Ikombe (48%) had identified erratic rainfall as a major climate change aspect therefore explaining the change in planting time in both sub-locations.

The onset of rainfall was identified as the major determinant of when to prepare land for planting while planting was mainly determined by weather forecasting. Weeding was mainly determined by schedule for weeding as per crop management practices, while harvesting was mainly determined by physiological maturity. Most farmers in Yatta sub–County intimated that while in the past they would begin planting in March, they now begin planting either in April or, most frequently, as late as May. According to the farmers interviewed, climate change has resulted in the introduction of drought tolerant crops (45%), reduced yields (43%) and change in planting time (38%) in Yatta sub–county (Fig. 6).

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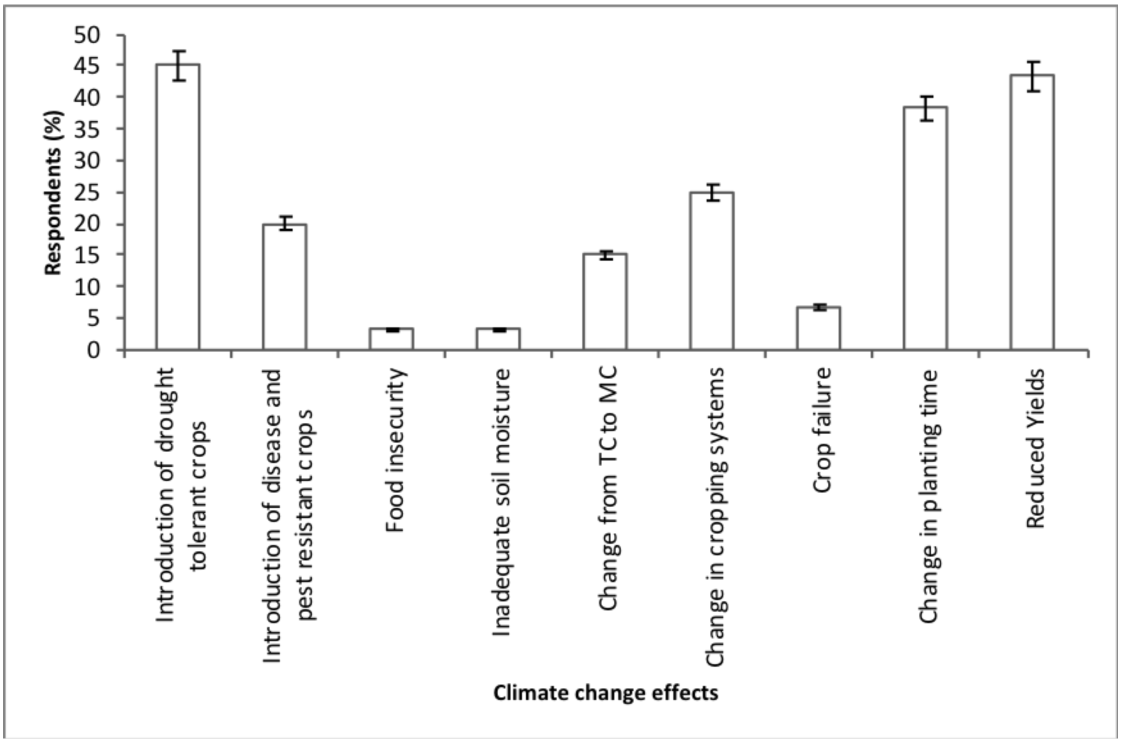

Figure 6: Effects of climate change on farmers' crop production in Yatta sub-county

Other impacts include change in cropping systems from mono cropping to mixed and intercropping (25%), introduction of pest and disease resistant crops (20%), change from traditional crops (TC) to modern crops (MC) (15%), increased pests and diseases (8%), crop failure (7%), food insecurity (3%) and low water availability (3%). However, it is important to note that some of these impacts may not necessarily be as a result of climate change which is an important factor in helping identifying knowledge gaps.

Despite all the negative effects of climate variability, there is a need to increase crop production with 98% of the farmers in agreement that the application of inorganic fertilizers as well as changing crop varieties (37%) would increase crop production. Other reasons identified by study participants included use of pesticides (10%) and use of new technologies in water conservation such as earth dams (7%). A small number (<5%) identified change in cropping systems from mono-cropping to intercropping and crop rotation and planting of appropriate certified seeds. These responses showed that the interviewed farmers were aware of the different approaches to increase their crop productivity. However, some of the practices that may prove very helpful are not widely practiced such as water conservation techniques and changing of cropping systems.

Even though it was evident that crop productivity in the region was declining, 33% of the respondents were not willing to change their farming practices to improve their crop yields. They were aware of the effect of climate change on their crop yields, but were constrained by finances and resources to implement the changes on their farms. Most of these farmers are small scale farmers who lack the resources to improve their

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farming. On the other hand, 67% of the respondents were willing to change their farming practices to include improved cropping systems (17%), changes in crop varieties (17%), practicing irrigation (8%) and abandoning crops not suitable for the area (3%). Addition of organic and inorganic fertilizers (8%), water harvesting (8%), use of appropriate and certified seeds (7%), carrying out alternative farming activities (3%0 such as dairy and poultry farming, timely planting (3%) and adopting modern farming techniques (3%) such as precision farming and conservation tillage were also some of the techniques identified to improve farming practices.

Most of the farmers interviewed (77%) had changed the crop types cultivated over the years. Most crops grown in the region had been grown for over 20 years. The trends in the types of crops produced clearly show a shift from traditional crops to modern or exotic crops with *Zea mays* (maize), *Phaseolus vulgaris* (beans), *Solanum lycopersicum* (tomatoes) and *Brassica oleracea* (kales) increasing in area under production over the years while *Vigna unguiculata* (cowpea), *Lablab purpureus* (dolichos), *Dioscorea* (yams), *Eleusine coracana* (finger millet), *Manihot esculenta* (cassava), *Ipomoea batatas* (sweetpotatoes), *Maranta arundinacea* (arrowroots), *Helianthus* (sunflower) and *Gossypium* (cotton) were diminishing over the past two decades. *Sorghum bicolor* (Sorghum) shows a steady increase over the years while *Cajanus cajan* (pigeon pea) shows no distinguishable differences. Area under cultivation of modern crops such as maize, beans, tomatoes and kales is increasing over the years as compared to traditional crops that may be potentially abandoned such as yams, cowpea, fingermillet, cassava, arrowroots, sweet potatoes and dolichos. This can be attributed to their economic importance in terms of market as compared to the traditional crops even though they are not they are not best suited for the climate of the study area hence their poor production. This could also explain the increase in area under sorghum production in the area as sorghum demand in the country for the beer industry has soared following a recent government decision to roll back taxes on sorghum beer (IFDC, 2015).

The farmers attributed stopping/abandoning the production of crops such as sunflower and cotton as seen in fig. 7 to pests and diseases (51%), lack of labour and inputs (31%), low rainfall (24%) and unreliable rainfall (18%). The other reasons were lack of market (13%), low economic returns (7%) and tediousness (7%) and low yields (<5%).

However, crops such as yams, cowpea, fingermillet, cassava, arrowroots, sweet potatoes and dolichos are on the decline and this trend whereby area cultivated under modern crops is increasing as compared to abandoned or traditional crops according to the respondents was due to low unreliable rainfall (91%), population increase (42%), low inputs (42%) and finally poverty (37%)(Fig. 7).

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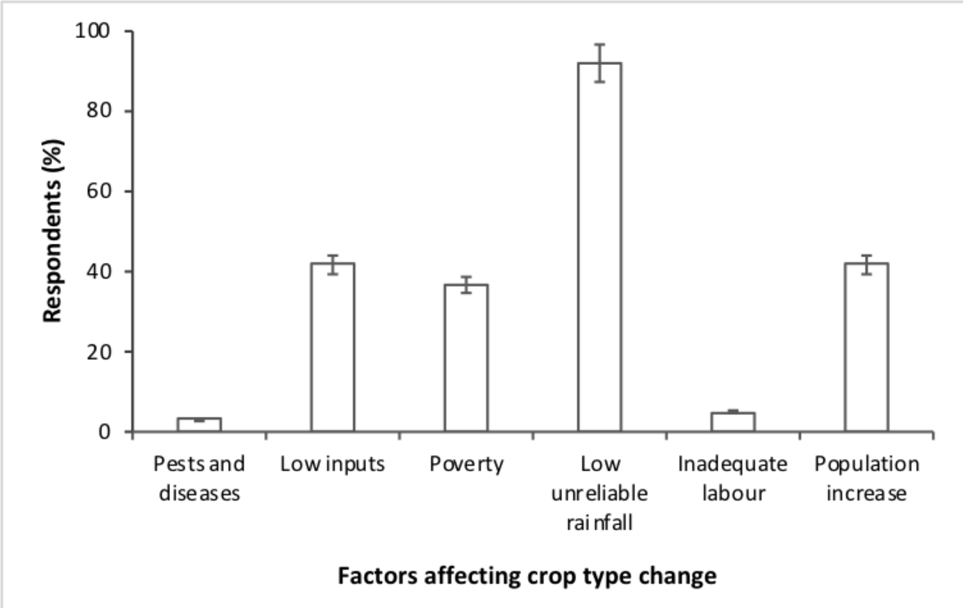

Figure 7: Factors influencing crop type change in Yatta sub - county

Coping strategies to climate change

Farmers in the sub-county identified more than one coping strategy which included agroforestry, application of organic and inorganic fertilizers, rain water harvesting and planting of appropriate crop varieties suitable for the region as the major coping strategies to climate change (Fig. 8). Soil and water conservation measures and use of different cropping systems (intercropping and crop rotations) were also identified. These are immediate short-term strategies which farmers would employ depending on availability of resources and the climatic conditions. Although majority of the farmers were aware of the different strategies of coping with climate change, it was not clear if they practiced these measures.

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ISSN 1684 5374

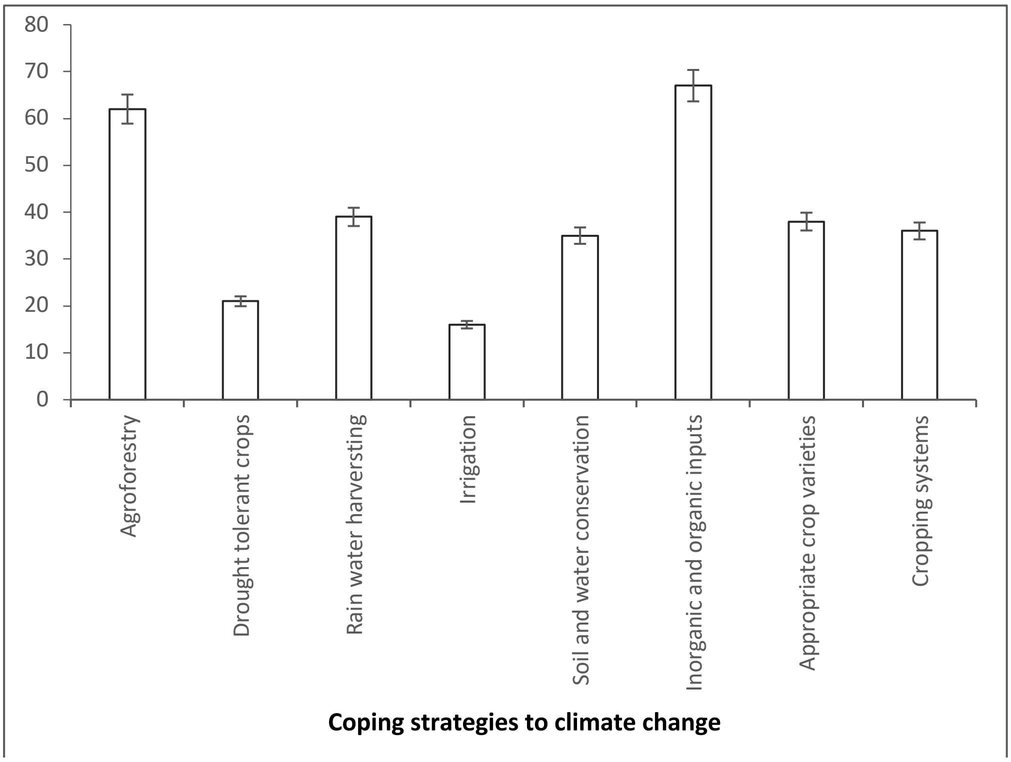

Figure 8: Farmers' coping strategies to climate change in Yatta sub-county

Most (87%) of the farmers practised agroforestry in the sub-county with 73% planting indigenous trees. All the farmers were aware of the benefits of trees which included provision of fuel wood (52%), fixing of nutrients through provision of organic inputs to the soil (43%), provision of shade (38%), source of food such as fruits (35%) and provision of timber (33%) (Fig.9). Providing livestock feed, attracting rainfall, conservation of soil and water, provision of medicine, source of income, windbreakers and purification of the air were identified as other benefits. This, therefore, showed that despite the farmers being aware that deforestation is a major cause of climate change, they did not attach climate change mitigation as a major benefit of trees but rather only a small percentage of farmers identified rainfall attraction as a benefit. This might suggest that even though the farmers are aware that deforestation is a major cause of climate change, they may not be aware of how trees mitigate against climate change.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 1
January 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

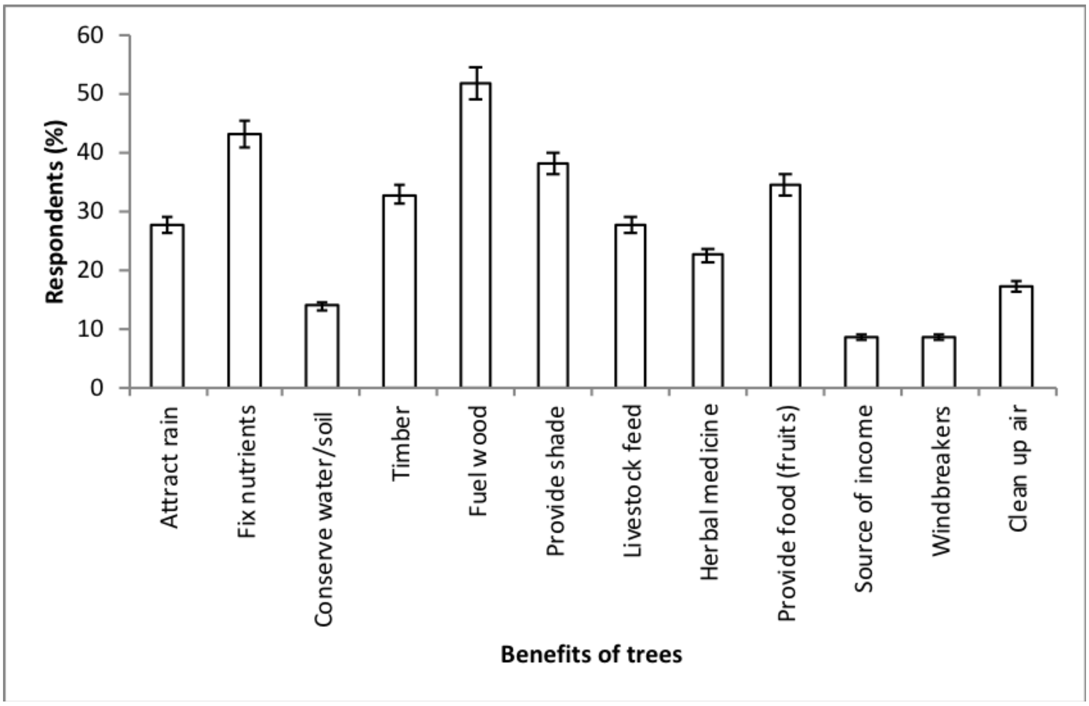

Figure 9: Benefits of trees to farmers in Yatta sub-county

Despite the realization of how important trees are, 95% of the respondents were in agreement that the forest cover was decreasing over the years. This they attributed to different reasons with respondents identifying more than one reason including: deforestation (72%), expansion of land for cultivation and settlement (39%), poverty (22%) and lack of knowledge on the importance of trees (12%) (Fig. 10). A small number (6%) felt that forest cover had increased attributed it to increased knowledge on the importance of trees.

DOI: 10.18697/ajfand.84.BLFB1017

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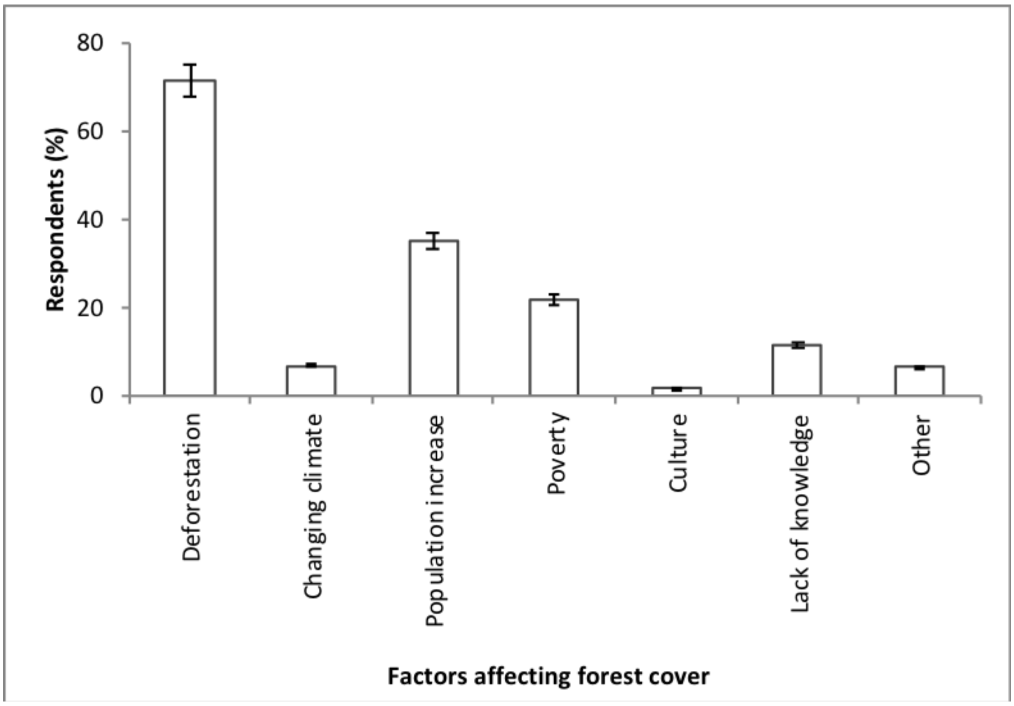

Figure 10: Factors affecting forest cover according to farmers in Yatta sub-county

Adaptation to climate change

Various adaptive measures were identified as being used by the farmers to reduce the adverse effects of climate change, with farmers pointing out more than one adaptation strategy. Early land preparation and planting on time (at the onset of rains) (52%), addition of organic and inorganic fertilizers (37%), planting early maturing crop varieties (28%) and water and soil conservation (18%) were the top four adaptation responses to climate change within the sub - County (Fig. 11). Tree planting (13%), changing cropping systems (12%), introduction of new and modern farming technologies such as zai pits, irrigation (8%), and storing of crops after harvest (<5%) were also cited as responses to climate change. Less than 5% of the farmers did not know how to adapt to climate change. It is important to note that some of the adaptation strategies are also coping strategies as the two are intrinsically linked and more often than not coping strategies usually end up as adaptation strategies. The main adaptation strategies identified were as a result of low and unreliable rainfall, a major aspect of climate change. None of the interviewed farmers was aware of any Decision Support Tools (DSTs) and how these tools could be used to assist them better adapt to the changing climate. Decision Support Tools are tools that will assist farmers better predict the impact of the anticipated climate changes so that they can be able to make decisions based on the predictions to minimize losses on their farms, for example the Agricultural Production Systems sIMulator (APSIM) tool and the NUTrient MONitoring (NUTMON) tool.

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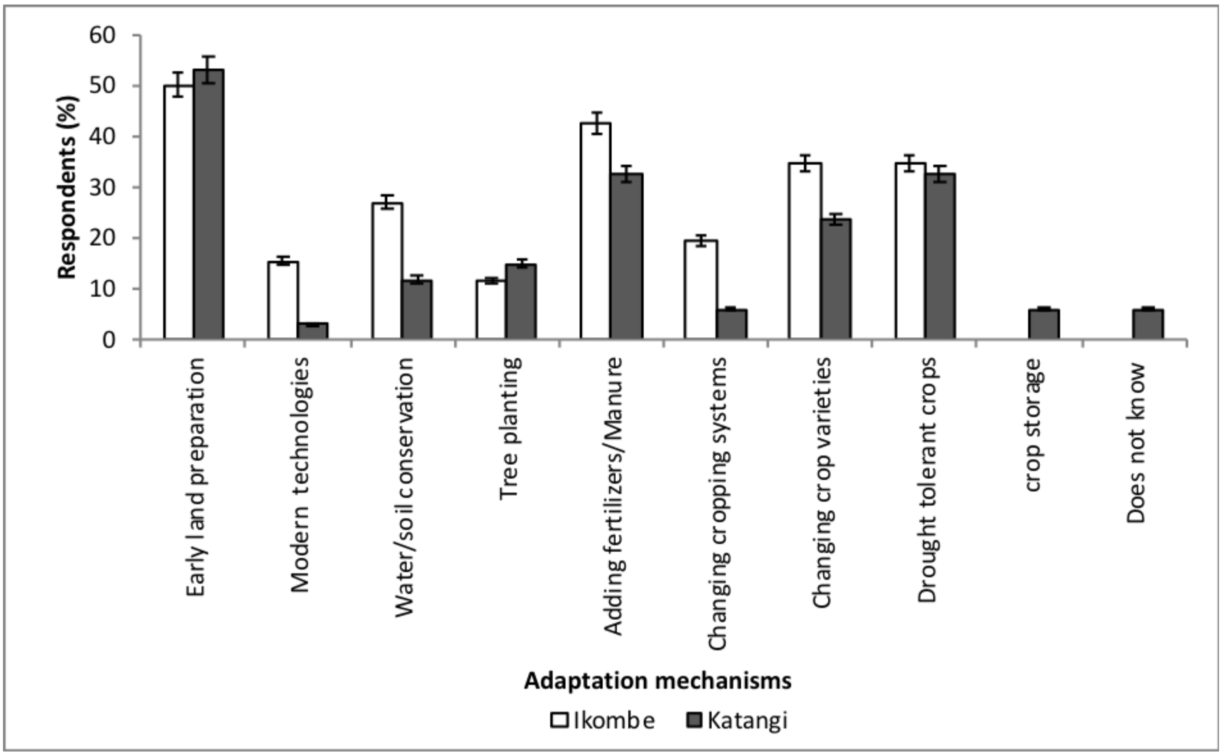

Figure 11: Farmers' adaptation mechanisms to climate change in Yatta sub-county

Farmers in Yatta sub–county would also like to introduce new and abandoned crops in their farms as an adaptation strategy in view of the changing climate. Crops were mainly abandoned due to their lack of economic importance and longer maturing period as compared to the modern or introduced crops. Some of these crops such as cassava took a long time to mature, causing farmers to prefer growing modern crops that take a shorter time to mature and have economic benefit. The crops that were ranked highest in preference for introduction were cassava and green grams, followed by millet, hybrid maize, sorghum and fruit trees such as mangoes and oranges. The farmers mentioned a number of reasons for the preference of these crops, the main one being that the crops are drought tolerant and will ensure continuous production (58%). Other reasons were the nutritional significance (19%), increased economic returns (13%) and improved food security (10%) (Fig.12). This, therefore, indicated that the farmers were gradually appreciating the impact of growing crops that are more adaptable to the semi arid region, in light of the ever changing climate.

DOI: 10.18697/ajfand.84.BLFB1017

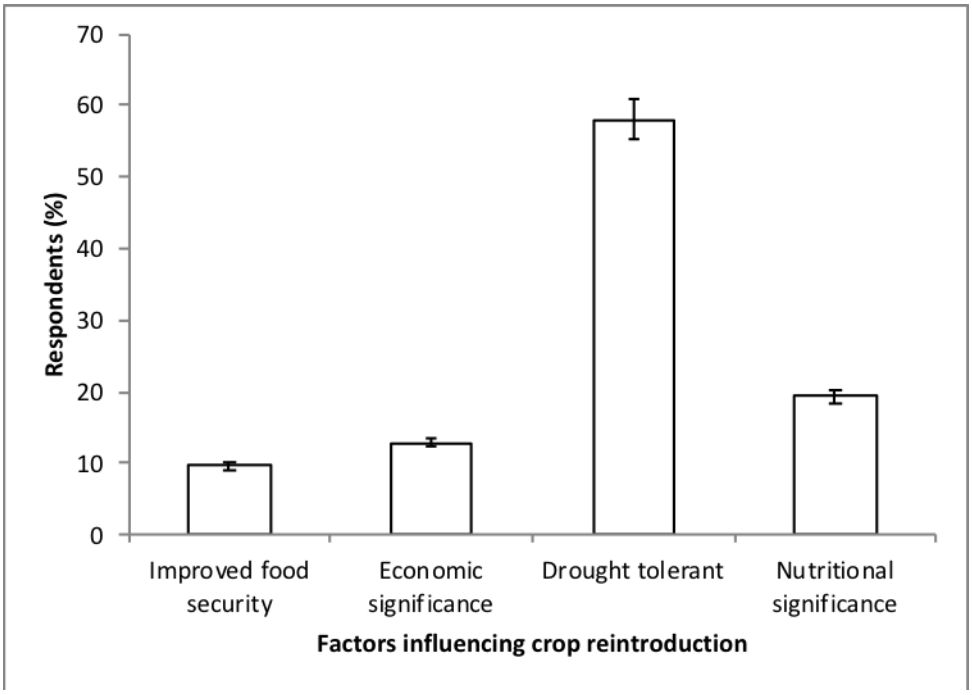

Figure 12: Factors motivating reintroduction of traditional crops by farmers in Yatta sub-county

Future climate predictions

Farmers have observed a slow but steady increase in climate variability and decreases in forest cover and anticipated that these trends would continue. Most of the farmers (90%) anticipated change in the climate in the near future. Ninety percent of the farmers interviewed anticipated changes in the climate in the near future with 83% and 78% anticipating low rainfall and high temperatures respectively (Fig. 13). This is because over the years there has been a slow but steady increase in climate variability, thus, farmers are anticipating that this trend will continue for many years to come. With the anticipated decrease in forest cover, farmers are expecting continued climate variability in the area. However, a small number, 18% and 17% of the interviewed farmers, anticipated increased rainfall and colder temperatures, respectively. This can be attributed partly to those farmers who believed that forest cover had increased over the years and partly due to farmers that believed that more farmers were now more informed on how to reduce climate change going forward.

ajfand SCHOLARLY, PEER REVIEWED
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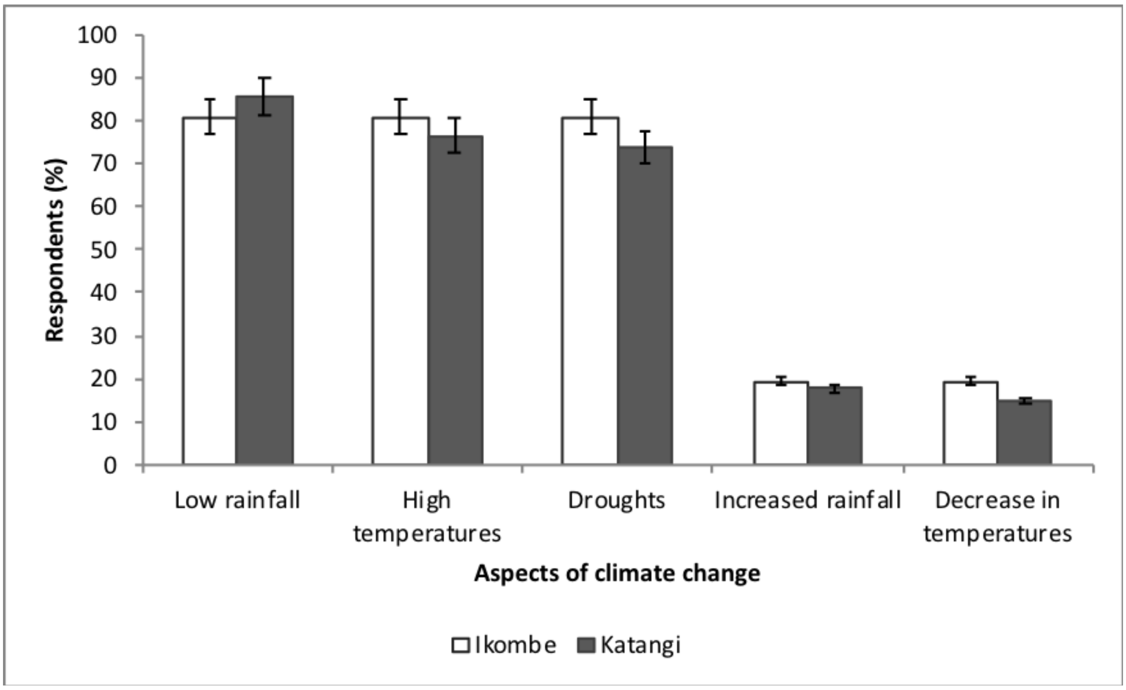

Figure 13: Future climatic changes anticipated by farmers in Yatta sub-county

These changes in rain, temperature and droughts are mostly anticipated within the next five years with 70% of the farmers indicating changes in rain, 71% indicating changes in drought and 66% indicating changes in temperatures within the next five years (Table 5).

Table 5: Timescale of anticipated climate changes by farmers in Yatta sub-county (n = 59)

Climate aspect	0 – 5 years (%)	5 – 10 years (%)	10 – 20 11 years (%)	>30 years (%)
Rainfall	70	22	6	2
Temperatures	66	24	6	4
Droughts	71	25	2	2

Survey question: "What aspects of climate change do you anticipate profound changes and the expected timescale?"

In order for farmers to be able to better adapt and cope with the effects of climate change, it is necessary to have access and knowledge of weather forecasting techniques. Farmers in Yatta sub-county used both traditional and scientific methods of weather forecasting although traditional methods of weather forecasting were most preferred. Sixty five percent of the farmers used traditional techniques in predicting weather, while 20% used scientific methods and 15% used both traditional and scientific methods. The farmers identified the reasons for relying on their given method of weather prediction with 84% stating reliability and accuracy, while 9% stated ready availability. Scientific weather prediction methods were rated as moderate by 58% of the farmers in terms of accuracy with 17% rated it as high and 13% rated it as low in terms of reliability.

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Traditional techniques of weather prediction used included, tree shading (75%), cloud movement (55%), birds and insect movement (20%) and the local knowledge on the timing of the season (15%). The other techniques identified were emergence of specific plants (9%), appearance of the sun or moon (7%) and temperature fluctuations (2%). Weather forecasts are important and have enabled the Yatta community to make appropriate decisions in terms of timely planting (47%), planting of appropriate crops (35%), and choosing the appropriate crop types and seed varieties to plant (12%).

Discussion

Farmers in Yatta sub-County are aware of climate change and the causes of climate change despite their low level of education. This is corroborated by a study carried out in the ASALs of Kenya by Ndambiri *et al*. (2012), showing that 94% of farmers in the region had noted changes in climate; this implied that majority of the farmers in the region which includes Yatta sub-County were aware of climate change. The area being heavily reliant on rain-fed agriculture with most farmers relying on agriculture as their main source of income, any changes in the climate would be easily noticed by resident farmers.

Previous studies in the ASALs of Kenya and Nigeria have shown that key indicators of climate change as increases in air temperatures, unusual early rains followed by weeks of dryness, low rainfall, erratic rainfall pattern, drying of rivers and long periods of dry season (Kuria, 2009; Farauta *et al.,* 2011). Long-term rainfall and temperature trends are strong indicators of climate variability in the drylands, influencing rainfall effectiveness and water availability for crop and animal sustenance. This study shows that farmers perceive changes in rainfall and prolonged droughts as the major indicators of climate change, which is corroborated by the historical climate data of the area. One key observation of changes in climate is that rainfall has become more unpredictable (Nzau, 2003). A chronology of drought occurrences from 1981 to 2011 by Fitzgibbon (2012) has also shown an increased drought frequency in Kenya. Bryan *et al*. (2011) similarly reported that an overwhelming majority of farmers in Kenya were aware of climate change manifested in the form of increased temperatures and a decrease in rainfall amount with the rainfall being erratic, and increased drought frequencies. Floods and increase in rainfall were less reported.

This study showed that the farmers started experiencing changes in climate over 10 years ago with majority of them having been practicing farming for over 30 years. In Kenya generally, farmers have experienced changes in climate in the past 30 years than in the past 10 years with more changes having been experienced in the semi–arid regions (Kalungu, Filho and Harris, 2013). Long rains in central Kenya have declined more than 100 millimeters since the mid-1970s (Kassile, 2013). This decline is probably linked to warming in the Indian Ocean, and seems likely to continue. Recent years include the most dreadful and severe droughts in 2009 and 2011 in Kenya (FAO, 2013). Parry *et al*. (2012) further noted that at the sub national level, relatively greater rainfall has occurred during the short rainy season of October to December, particularly in northern Kenya's ASALs. However, local observations suggested that the long rainy season of March to April has become increasingly unreliable such as in the Eastern part of Kenya where Yatta sub-County lies. Maitima *et al*. (2009) observed that Kenya has in the last 100 years recorded 28 major droughts with three of them having occurred

DOI: 10.18697/ajfand.84.BLFB1017

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during the last decade. These droughts have led to widespread economic losses, energy crisis, water shortages and food insecurity, particularly among the people in the ASALs where annual rainfall is sporadic and periodical droughts are part of the climate system

The household interviews showed that the farmers' main source of information was extension officers and friends. This would explain why most of the farmers interviewed were aware of climate change as studies have shown that farmers' perceptions were hinged on farmers' experience and availability of free extension advice specifically related to climate change (Maddison 2006). Gbetibouo (2008) also argued that farmers with access to extension services were likely to perceive changes in climate because extension services provided information about climate and weather. Therefore, the high percentage of farmers aware of climate change can be attributed to the fact that more focus is being put on climate change and its impact on agriculture by the Ministry of Agriculture by making information available to the smallholder farmers through radio and extension officers.

Deforestation was identified as the main cause of climate change by respondents as a result of increased population and poverty. However, when farmers in Yatta sub-county were questioned on the importance and benefits they attached to trees, majority of respondents did not attach climatic importance to trees despite identifying deforestation as a major cause of climate change. Only 28% of the farmers actually mentioned the role of trees to attract rainfall with majority of them identifying provision of fuel wood as the main benefit of trees. This is in agreement with a study carried out in Kenya by Macharia *et al*. (2010) who reported that fuel wood was the major reason for planting trees, followed by provision of timber and environmental rehabilitation and a source of food for both humans and animals. This may imply that despite farmers being informed of the causes of climate change, they did not fully understand why aspects such as trees are important in mitigating climate change with past studies carried out in Kenya showing that deforestation and other human activities such as industrial and agricultural activities were altering the composition of the atmosphere and contributing significantly to climate change (Kuria, 2009).

The major impact of climate change identified in this study was declining crop productivity. The major causes of declining crop production identifed were unreliable rainfall, drought, low soil fertility and low soil moisture which are as a result of climate variability. Similar to this study, Thornton *et al*. (2009) demonstrated that in East Africa, crop production decline was due to climate change namely increase in temperatures, low and unreliable rainfall and land degradation. Because temperature has increased and precipitation in the Yatta sub-county decreased in some areas, many farmers are already being affected. For example, from 1996 to 2003, there has been a long term decline in rainfall of 50-150 mm per rainy season which could lead to a corresponding decline in long-cycle crops (slowly maturing varieties of sorghum and maize) across the region (Funk et al*.*, 2005).

The household interviews showed differences in opinions on the extent of the impact of climate change on such aspects as change in planting time, pests and diseases and soil moisture within the two study wards, Katangi and Ikombe. This showed that there are differing opinions within farmers on exactly how much impact climate change has on different aspects of crop production in the region despite being in agreement that

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climate change has a major impact on crop production resulting in declining crop productivity. Crop yields are affected by many factors associated with climate change, which include: temperature, rainfall, extreme weather events, climate variability and carbon dioxide concentration in the atmosphere which is predicted to cause global warming that will have a significant impact on crop production (USDA, 2007). The present findings of this study are supported by Akponikpe *et al*. (2010) and Macharia et al. (2010), who reported that there was a change in planting time, a decrease in crop yield, crop failure, increased pests and disease incidence and reduced soil fertility was a result of climate change in sub-Saharan West Africa and Kenya, respectively.

Even though respondents identified introduction of drought tolerant crops as one of the major impacts of climate variability apart from reduced crop yields, the study found that a majority of drought resistant crops suitable for the region such as yams, cowpea, fingermillet, cassava and arrowroots were either being abandoned or reducing in production in the region with more preference given to modern crops such as maize, beans, tomatoes and kales due to their economic significance despite them not being suitable for the regions' climate. Despite this worrisome trend, it has been proven that crops such as sorghum, yam, cassava, pigeon pea and dolichos which are commonly referred to as abandoned or traditional crops are the most suited for the arid and semi-arid lands as they are more drought resistant (Smartt and Haq, 2008). These varieties are hardy and, therefore, tend to survive in dry climates as compared to modern crops such as maize, beans, kales and tomatoes which, even though are more economically attractive, do not yield well in semi - arid environments. However, there are crops that have been abandoned over the years such as sunflower and cotton and some whose popularity is decreasing as recently as within the past decade. This was around the time that most farmers in the region noted that they started experiencing climate change. This could be attributed to the fact that with the increase in temperature, pests and diseases have become more rampant due to the warmer climatic conditions. This tends to increase production costs of some of the crops which then get abandoned. It further shows, once again that, economic and livelihood importance superseded climate change aspects as was earlier noted in farmers' responses on the importance of trees. Due to unreliable and low rainfall, new crop varieties, suitable for specific climatic regions, have been developed by seed companies. However, optimum yields of these varieties require optimum supply of nutrients and water, without which yields will be low. Due to the low and unreliable rainfall, farmers are forced to wait until the onset of rains before planting as opposed to planting at a specific time. In resonance with the present study, Bryan *et al*. (2011) recognizes change in crop variety, change in planting dates and change in crop types as the major impacts of climate change in crop production. Some of the impacts of climate change and variability are the reduction of agricultural productivity, which causes production instability and poor incomes in the developing areas of the world, especially Africa (FAO, 2012).

According to Boko *et al*. (2007), the emergence of new traits and varieties of crops offers farmers greater flexibility in adapting to climate change. In Kenya, several pigeon pea varieties such as Mbaazi 3, Katumani 60/8, among others have been developed which are resistant to disease and insect attacks as well as tolerant to moisture stress (GoK, 2012). The Government of Kenya has also set up many interventions to improve the agriculture sector among them interventions that support coping and adaptation to climate change and include: promoting irrigated agriculture, conservation agriculture, support for community-based adaptation including provision of climate information to farmers and enhanced financial and technical support to drought tolerant crops (NCCAP, 2013). Studies further show that the perception or awareness of climate change (Sampei and Aoyagi-Usui 2009; Akter and Bennett, 2009, Semenza *et al*., 2008) and taking adaptive measures (Maddison, 2006; Hassan and Nhemachena, 2008) were influenced by different socio-economic and environmental factors which include lack of information, lack of money, shortage of labor, shortage of land, poor potential for irrigation, climate variability, extreme weather conditions such as droughts and floods, and volatile short-term changes in local and large-scale markets. This, therefore, indicates that even though climate change is a major factor to consider in crop production by farmers, socio economic aspects were a strong determinant of whether adaptation measures were adopted. Without adaptation, climate change is generally detrimental to the agriculture sector but with adaptation, vulnerability can be largely reduced (Smit and Skinner, 2002).

Farmers in Yatta sub-county are also aware of different ways to improve their crop production with most of them agreeing that the application of inorganic fertilizers would increase crop production. While application of inorganic fertilizers is important to increase yields, the farmers of Yatta sub-county also need to be made aware of the tremendous advantages of using organic fertilizers in mitigating and adapting to climate change. Organic fertilizers help fix nitrogen, increased greenhouse gas efficiency, carbon sequestration and promotion of agroforestry, which in turn contribute to reduced climate variability (UNEP-UNCTAD, 2008).

Even though a majority (two thirds) of the farmers were willing to change their farming practices to improve their productivity, a good number (a third) were unwilling mainly due to capital constraints. They were aware of the effect of climate change on their crop yields, but were constrained by finances and resources to implement the changes on their farms. This was in contrast to a study by Gbetibouo (2008) in Limpopo Basin, South Africa which showed that even though a large number of farmers noticed changes in climate, almost two-thirds chose not to undertake any remedial action. This can be an indication that more farmers are becoming aware of the importance of changing their practices in line with the everchanging climate in order to improve their crop production. According to Hellmuth *et al.* (2007), there is a link between farmers practicing improved farming practices and coping with climate variability.

Improved climate forecasting is a central part of improving early warning systems for farmers. Farmers in the study area relied on traditional forms of weather forecasting which may not be as reliable in predicting the ever increasing climatic variability. Despite this, studies by Tasara and Maposa (2012) engaging the Shona of Zimbabwe have shown that the scientific methods of weather forecasting such as use of weather stations are flawed, to some extent and therefore communities are more reliant on own close observations on environmental phenomena with regard to major traditional weather forecasting methods such as use of trees, birds and animals, insects, wind and terrestrial objects like the sun, the moon and clouds considered as the major methods

DOI: 10.18697/ajfand.84.BLFB1017

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used by the communities to determine weather forecasting. Hassan and Nhemachena (2008) found that access to information about climate change forecasting is important in determining the use of various adaptation strategies and important farming decisions. It is, therefore, important to consider the use of Decision Support Tools (DSTs) to assist in predicting the effects of climate change and devising ways of mitigating against them.

Even though the farmers were aware of different coping and adaptation strategies to climate change, none of them was aware of the use of Decision Support Tools (DSTs) as a way of assisting them to better cope and adapt to climate change. Tools and approaches are now available that allow for a better understanding, characterization and mapping of the agricultural implications of climate variability. Currently in Kenya, extension officers have been trained on the basics of operating Decision Support Tools (DSTs) such as the Nutrient Expert tool developed by the International Plant Nutrition Institute (IPNI) which is a nutrient decision support software that uses the principles of Site-Specific Nutrient Management (SSNM) and enables farm advisors to develop fertilizer recommendations tailored to a specific field or growing environment (Pampolino *et al*., 2012). Extension officers have access to these tools which they can use to give free advice to farmers regarding their agricultural production even though no studies have been published yet on the impact of the Decision Support Tools (DSTs). The application of crop simulation models to study the potential impact of climate change and climate variability provides a direct link between models, agro-meteorology and the concerns of the society (Deressa *et al*., 2005). As climate change deals with future issues, the use of General Circulation Models (GCMs) and crop simulation models provides a more scientific approach to study its impact on agricultural production and world food security. This approach should agree well with farmers who in the past have expressed dissatisfaction with research and development aimed at providing the "quick fix", and is rather interested in the development of research methodologies that address the long term economic and ecological issues (Dimes, 2005). This is an area that needs further exploring given the inadequacy of agronomic experiments to provide the much needed solutions to boosting agricultural productivity in the midst of climate change variability.

This study shows that farmers predicted future changes in rainfall (decrease) and temperatures (increase) as well as prolonged droughts given the trend in climate change in the region over the past years. Rainfall and temperature are major determinants of agricultural production in sub-Saharan Africa (Barrios *et al*., 2008). General Circulation Models (GCM) used to develop future climate change scenarios have indicated increased temperatures in the ASALs, reduced rainfall and doubled atmospheric carbon dioxide in the near future (40 years) in Kenya. It is expected that increase in intensity and frequency of droughts will occur and with the projected climatic changes, will enhance the adverse impacts of climate change (UNDP, 2012). Increased temperatures, droughts and floods will reduce productivity leading to increased vulnerability of agriculture which is heavily reliant on rain (UNEP, 2009). Farmers' concerns about changes in rainfall variability are valid given that rain fed agriculture is the dominant source of staple food and cash crop production and livelihood for the majority of the rural poor. Climate variability, in particular the

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occurrence of drought, is a strong determinant of agricultural performance as well as general economic performance of the country (Herrero *et al*., 2010).

Conclusions

Farmers of Yatta sub-county were aware of climate change, the aspects of climate change, the causes of climate change and the impacts of climate change on crop production. The farmers were also aware of different coping and adaptation mechanisms to climate change. It is, therefore, evident that the farmers in the region have sufficient knowledge regarding climate change. However, despite this, the farmers farming decisions were not driven by climate change but by the economic and livelihood importance. This was evident from the importance attached to trees and the willingness of the farmers to adapt better farming practices to cope and mitigate against climate change. Even though farmers were aware of their importance, most of them did not practice the techniques that they identified due to financial constraints and lack of capacity to implement the techniques. This indicates that there is a disconnect between farmers gaining the knowledge and actually practicing what they know as their ability to cope and adapt to climate change is directly linked to the capital intensiveness of the techniques involved. This also shows that the ability of farmers to cope and adapt to climate change sustainably is directly linked to the economic importance of the techniques. This is possibly the reason why crop yields continue to decline resulting in food insecurity in the region every year.

Recommendations

Crop management techniques that will increase the capacity of the Yatta sub-county's farming community to better cope and adapt to the changing climate are needed. This includes, providing assistance to farmers through the provision of more accurate weather predictions and knowledge of the effect of weather on their crops. The use of Decision Support Tools (DSTs) such as the Agricultural Productivity SIMulator (APSIM) model which utilizes over 30 years of weather data allows the prediction of the effects of climate change on crop production under different cropping systems and inputs. It is necessary to find out if different sources of information on climate change are correlated to how farmers perceive climate change. It is also important to devise techniques that farmers could more easily adapt to. Researchers and farming communities need to work together through the 'bottom- up' approach whereby farmers will participate in community-based projects on climate change to ensure their economic and financial concerns are taken into consideration. Involving farmers in the decision-making process would help them better cope and adapt to climate change. By collaborating, researchers could better assist farmers in identifying coping and adaptation strategies of economic significance that they could easily adopt.

Acknowledgement

This paper would not have been possible without the kind support and help from many individuals and organizations. I would specifically like to acknowledge Dr. Jeffrey Vitale of Oklahoma State University and Dr. KPC Rao of ICRISAT for their continued guidance and unwavering support. I would also like to acknowledge the Borlaug LEAP foundation as well as the McKnight Foundation for the financial support.

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Volume 19 No. 1
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DOI: 10.18697/ajfand.84.BLFB1017