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African Journal of Environmental Science and Technology

April 2021
ISSN 1996-0786
DOI: 10.5897/AJEST
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Vol. 15(4), pp. 158-166, April 2021
DOI: 10.5897/AJEST2020.2918
Article Number: 559DB4366827
ISSN: 1996-0786

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African Journal of Environmental Science and Technology

Full Length Research Paper

Ecological status of a tropical river in Niger delta area of Nigeria, using aquatic insects

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Received 8 September, 2020; Accepted 29 March, 2021

Freshwater ecosystems are the major source of water, being used for domestic, agricultural and industrial purposes. Water bodies are subjected to anthropogenic activities leading to degradation of the water quality. The aim of this study is to assess the health status of Isiokpo River. Aquatic insects were sampled from March to August 2017. Physico-chemical parameters were examined using standard laboratory procedures. A total of 21 taxa comprising of 543 individual insects were recovered. Stations 1, 2 and 3 recorded 53.41, 21.36 and 25.23% of the insect population respectively. A total of six Ephemeroptera, Plecoptera and Trichoptera (EPT) species were recorded in the study. The %EPT was 28.57, 33.33 and 30.77% in station 1, 2 and 3 respectively. There were significant differences in the distribution of dissolved oxygen, phosphate, nitrates transparency, flow velocity, and total dissolved solids across the various stations (p<0.05). The reduced level of dissolved oxygen in station 3 as well the dominance of Chironomus sp. are indications of the impact of anthropogenic activities. The study showed that the Isiokpo River is relatively unhealthy.

Key words: Aquatic insects, Biomonitoring, Freshwater, Ephemeroptera, Plecoptera, Trichoptera, Water quality.

INTRODUCTION

Insects, over the years are used as indicators for changes in aquatic ecosystem caused by disturbances such as pollution from domestic, agricultural and industrial wastes, including effluents. The aquatic ecosystem, particularly rivers are regular characteristics of many landscapes which constitute great socio-economic importance to humans; prevision of vast regional freshwater biodiversity (Dalal and Gupta, 2015), and goods and services essential to human communities globally (Adu and Oyeniyi, 2019).

Water pollution threaten aquatic biodiversity (Haggag et al., 2018), degrade water quality (Koff et al., 2016) and impact the ecosystem adversely. The growing use of macroinvertebrates, including insects to access the health status of freshwater ecosystem (Valente-Neto et al., 2018; Miguel et al., 2017). The use of insects become necessary due to their abundance and diversity which dominate freshwater ecosystem (Jooste et al., 2020). Insects are the most directly affected group that vulnerable to any disturbance or pollution in the aquatic

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ecosystem due to their diversity and abundance (Selvanayagam and Abril, 2016).

In the Niger Delta region of Nigeria, tropical rivers such as the Isiokpo river located near an abattoir and used by humans for bathing, laundry and fishing may have been stressed and impacted. Investigation on the impact of such stressors on the ecological status of the river is yet to be determined and this provides the basis for this present study with an aim to assess the health status of Isiokpo River using entomofaunal assemblage and biodiversity.

MATERIALS AND METHODS

Research design

The study was conducted at River Isiokpo which was divided into three stations based on the relative level of human activities; Station 1 is upstream and is characterized by very little or no human activities.; Station 2 is midstream and characterized by relatively moderate human activities which includes bathing and fishing while Station 3 is downstream with relatively high human activities which includes bathing, laundry and fishing with a market nearby, abattoir and waste dump. The study area covered a total area of 3,540 m^2 with the low, moderate and high impacted stations separated from each other by 1.5-2 km. Each station was divided into four substations using biotopes as criteria within a completely randomized design.

The Isiokpo River is located in Isiokpo town. Isiokpo is the headquarters of Ikwerre Local Government Area of Rivers State in the Niger Delta Area of Nigeria and lies within Longitude 4°56'N-5° 0'N and Latitude 6°51'E - 6^o52'E (Figure 1). The vegetation is tropical rainforest plant species dominated by trees and shrubs such as Raphia palm - *Raphiahookeri*, Ferns, Bamboo – *Bambusa* sp., *Alchorneacardifolia*, Oat Grass -*Acroceraszizanioides,* Elephant grass – *Pennisetum purpureum*, Water Lily - *Nymphaealotus,* etc. The area is characterized by high relative humidity (80-92%), with an average annual rainfall of approximately 2800 mm (Njoku et al., 2019). There are two seasons in the study area: rainy and dry seasons. The rainy season is typically from the month of April to October, while the dry season is usually from November to March. The average temperature is about 28°C (Adejuwon, 2018).

Sample collection

Aquatic insect collection

Insect samples were collected monthly for six months using a rectangular frame and triangular frame dipnet and a kick net with mesh size of 500 µm. For insect sampling of the water surface, the rectangular-frame net was swept over the water surface and then turned to prevent captured insects from escaping. For sampling in the vegetation, the dipnet is jabbed under floating vegetation that are undisturbed, the vegetation was then shaken to dislodge organisms from the vegetation and sediments. Collection by kick-net was done by holding the net against water current and the leg is used to kick three times at about an area of 1 m^2 in front of the net for one minute. Collected samples were preserved in 70% alcohol and transported to the Entomology Research Laboratory of the University of Port Harcourt for sorting and identification. In the laboratory, samples were washed in a 250 µm mesh size filter to remove debris while aquatic insects were carefully picked with the aid of forceps and a masticated toothpick and placed in separate labelled vials containing 70% ethanol. Sorted insects were identified to genus level using the keys (Badawy et al., 2013; Mahmoud and Riad, 2020).

Water physico-chemical sampling

Water samples used for the analysis of chemical variables were collected monthly in 250 ml plastic bottles for six months (March 2017 – August 2017). Dissolved oxygen (DO) was measured using JPB-607A DO Analyzer while pH, conductivity, total dissolved solids (TDS) and oxidation reduction potential (ORP) were measured using SPER Scientific 860033 Benchtop; calibrated handheld pH electronic meter (D1-4337), electronic conductivity meter model (H1-4103)Transparency was measured using a secchi disk Water Quality Meter. (Haggag et al., 2018; Mahmoud and Riad, 2020), Flow rate was measured using a timed float as it moved over a distance of 10 m (Adu and Oyeniyi, 2019). Total nitrates and phosphates concentrations were measured spectrophotometrically using standard methods (Calibrated HACH 3900DR spectrometer, TDS by calibrated handheld electronic TDS meter D4-7103).

Data analysis

Results were descriptively analyzed and represented with tables and charts using Microsoft Excel. Physicochemical parameters of sites were compared using one-way ANOVA. Calculated means were compared using the Tukey Honest Significant Difference (HSD) test to assess the significant differences in aquatic insects abundance and distribution in relation to physiochemical parameters measured among the studied sites, with level of significance set at P<0.05.

Species diversity indices

Species diversity index comprising; Simpson dominance (D), Shannon-Weiner index(H) and Evenness index(E) were used to analyze species diversity, distribution and richness among study stations in the river. Percentage composition of species of three orders of insects: Ephemeroptera, Plecoptera and Trichoptera (%EPT) was calculated using number of EPT species collected from the respective sampling stations in the formula (Hamid and Rawi, 2017).

$$\%EPT = \frac{\text{No of EPT species}}{\text{Total No of Species collected}} \text{ x } 100$$

Simpson dominance D = $\text{£}(Pi)^2$ Shannon-Weiner Index H = $\frac{{}^{s}\text{£ }(Piln(Pi))}{X}$

Evenness Index E = $\frac{H}{Ln(S)} = \frac{Ln(N^1)}{Ln(No)}$

RESULTS

Variations in physico-chemical parameters

Physico-chemical parameters vary in concentrations among the various stations, for example, parameters such as temperature, conductivity, pH mean values were

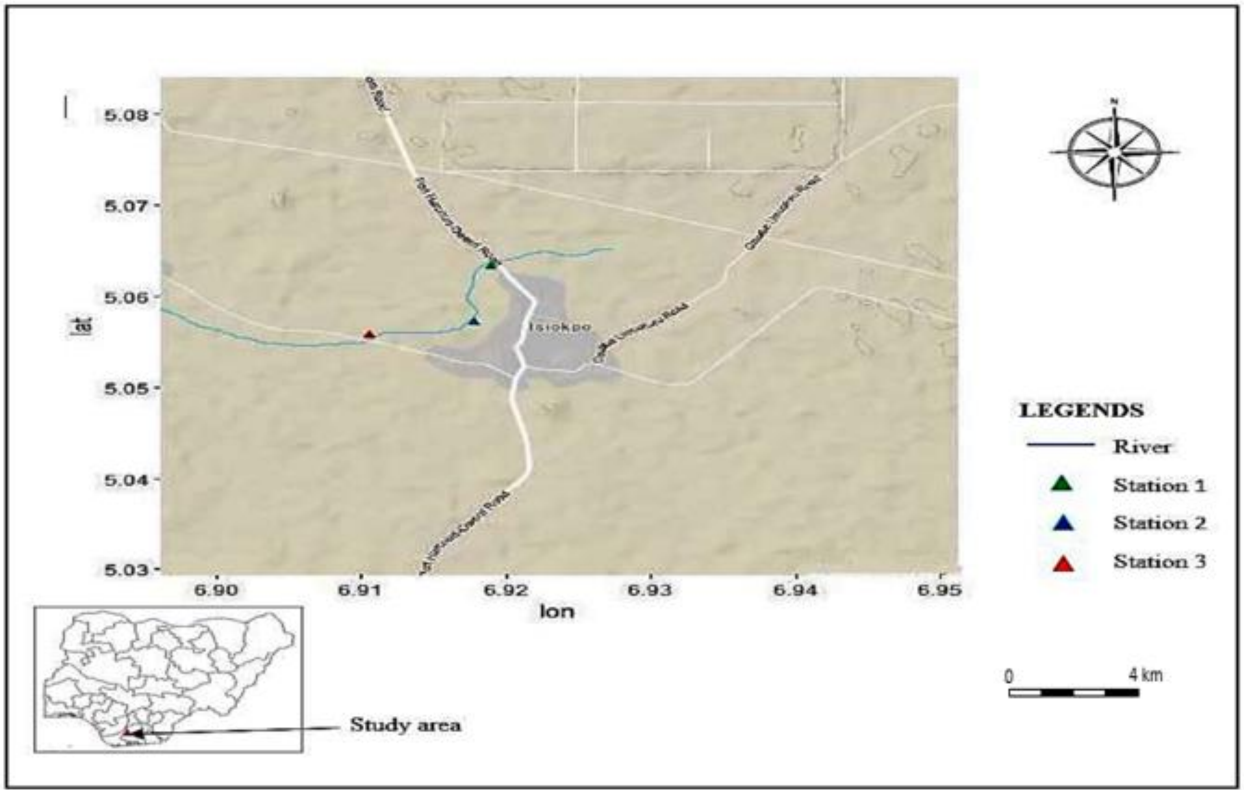

Figure 1. Map of study area with sampling stations.

Table 1. Mean ± Standard error of Physico-chemical parameters measured in Isiokpo River.

Parameter	Station 1 Least human impact	Station 2 Moderate human impact 2	Station 3 High human impact 3
Temperature (°C)	24.5±0.55^{a}	24.67 ± 0.52^{a}	25.67 ± 0.75^{b}
Dissolved Oxygen (mg/l)	5.87 ± 0.12^{a}	5.38 ± 0.15^{b}	4.40 ± 0.22^{c}
pH	7.19 ± 1.03^{a}	7.4 ± 0.93^{a}	7.24 ± 0.7^{a}
Conductivity (µS/cm)	29.54 ± 2.28^{a}	19.90 ± 4.49^{a}	34.52 ± 2.65^{a}
Phosphates (mg/l)	0.14 ± 0.00^{a}	0.13 ± 0.01^{b}	0.14 ± 0.00^{c}
Nitrates (mg/l)	0.14 ± 0.01^{a}	0.12 ± 0.01^{a}	0.18 ± 0.04^{b}
Transparency (cm)	54.00 ± 0.89^{a}	45.67 ± 1.37^{b}	36.00 ± 3.63^{c}
Flow rate(cm/s)	0.31 ± 0.01^{a}	0.15 ± 0.03^{b}	0.22 ± 0.02^{c}
TDS (ppm)	10.54 ± 1.13^{a}	12.55 ± 2.99^{a}	43.86 ± 41.64^{b}
ORP (mv)	145.34 ±65.70^{a}	151.86±6.97^{a}	158.07±11.35^{a}

Means with the same superscripts in a row are not significantly different (P<0.05).

higher in highly human disturbed sites (Station 3) than lowly human disturbed sites (Station 1) (Table 1). Contrarily, transparency and flow rate were higher in lowly disturbed station than highly distributed station. On chemical parameters, dissolved oxygen and phosphates concentration were higher in lowly disturbed station than highly disturbed station (Table 1). The mean concentrations of Nitrates and total dissolved solids (TDS) were all higher in the highly disturbed than lowly disturbed stations. In the moderately disturbed station (Station 2), mean temperatures, dissolved oxygen, pH and TDS were slightly higher than those of lowly disturbed station.

Statistically, no significant difference in concentration in some physic chemical parameters across the three

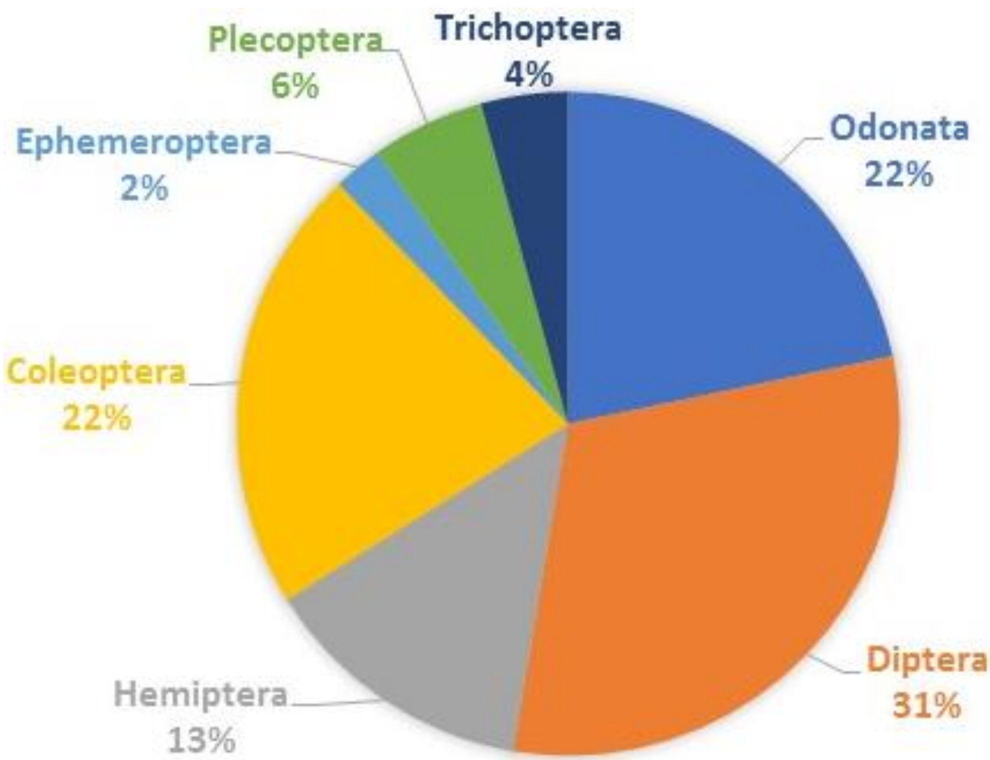

Figure 2. Percentage composition of Insect Orders at Isiokpo River, Rivers State, Nigeria.

stations was recorded. The parameters are pH, conductivity, ORP values. There was significant difference in parameters such as dissolved oxygen, phosphates, transparency and flow rate across the three stations (Table 1). Similarly, significant differences occurred in concentration of TDS, Nitrates, temperatures between lowly- and highly- disturbed stations, but did not occur between lowly and moderately disturbed stations (Table 1).

Community composition

At the end of the study a total of 543 insect individuals were collected and identified into twenty-one species, belonging to seven orders and fifteen families at the Isiokpo River. The major percentage of insects occurred in the order Diptera (30.94%), followed by equal insect abundance 21.73% of Odonata and Coleoptera Hemiptera (13.43%), Plecoptera (5.52%) Trichoptera (4.24%) Ephemeroptera (2.39%) (Figure 2).

Insect abundance and distribution among the three stations was low human impacted station (Station 1) (290 individuals, 53.41%), moderately impacted station (Station 2) (116 individuals, 21.36%), and highly impacted station (Station 3) (137 individuals, 25.23%) (Figure 3). Figure 4 indicates that Diptera among the seven orders of insects encountered at Isiokpo River recorded more abundance and Ephemeroptera least abundance (Figure 4). It also indicates that stations 1 recorded the highest abundance in all the insect orders encountered in the three stations (Figure 4).

Insect orders at Isiokpo River

Figure 3 shows insect abundance among different orders and distribution between three stations at Isiokpo River, Rivers State, Nigeria.

Spatial variations in species diversity indices across sampling stations at Isiokpo River

Results of species richness among stations, indicated that in lowly impacted or disturbed station (Station 1) twenty-one species, moderately disturbed (Station 2) fifteen, and highly impacted thirteen species were encountered. Abundance among the stations was 290 individuals (Station 1), 116 individuals (Station 2) and 137 individuals (Station 3) (Figure 5). Statistical analysis on species distribution, and evenness across the three stations indicated an increasing dominance index of species; 0.8725 (Station 1) 0.8847 (Station 2) 0.7697 (Station 3) (Table 1). The Shannon-Weiner diversity indices was higher at Station 1 with values of 2.4351 and

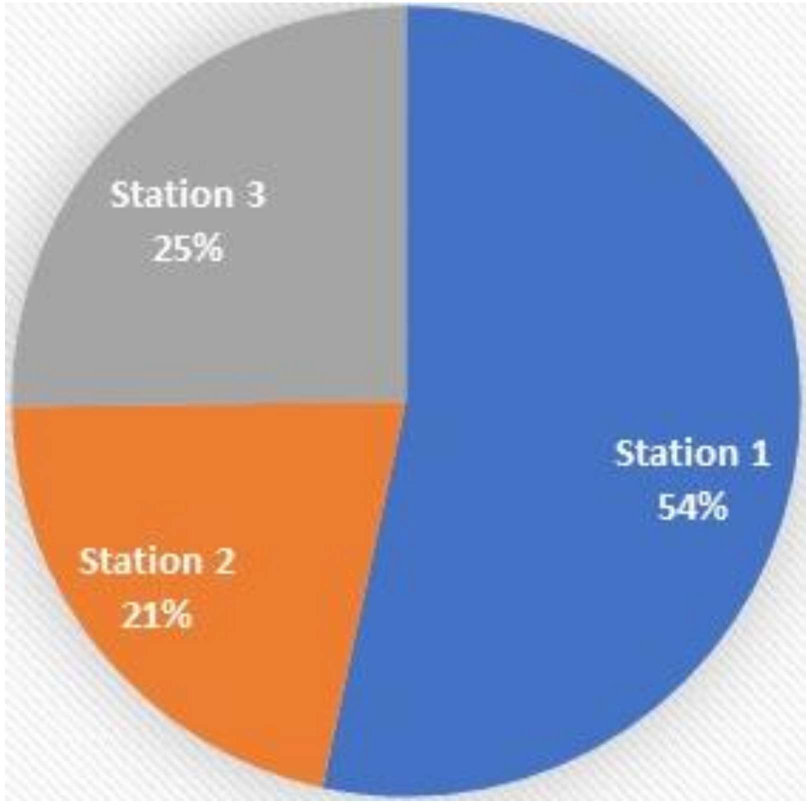

Figure 3. Percentage abundance of insects between three different stations at Isiokpo River, Nigeria.

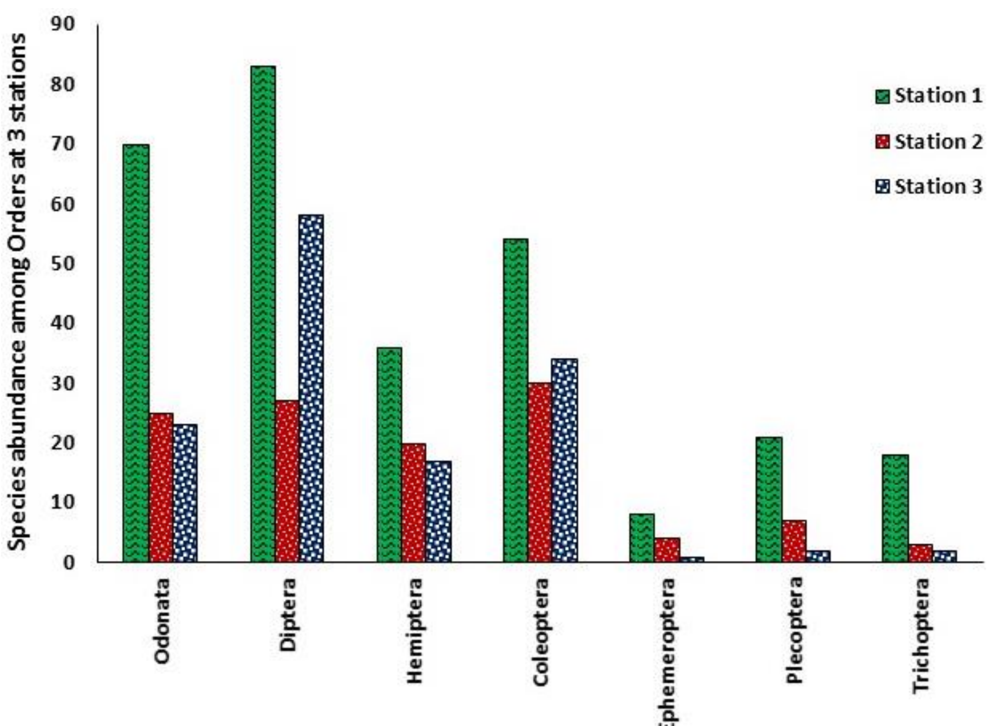

Figure 4. Diptera among the seven orders of insects encountered at Isiokpo River recorded more abundance and Ephemeroptera least abundance.

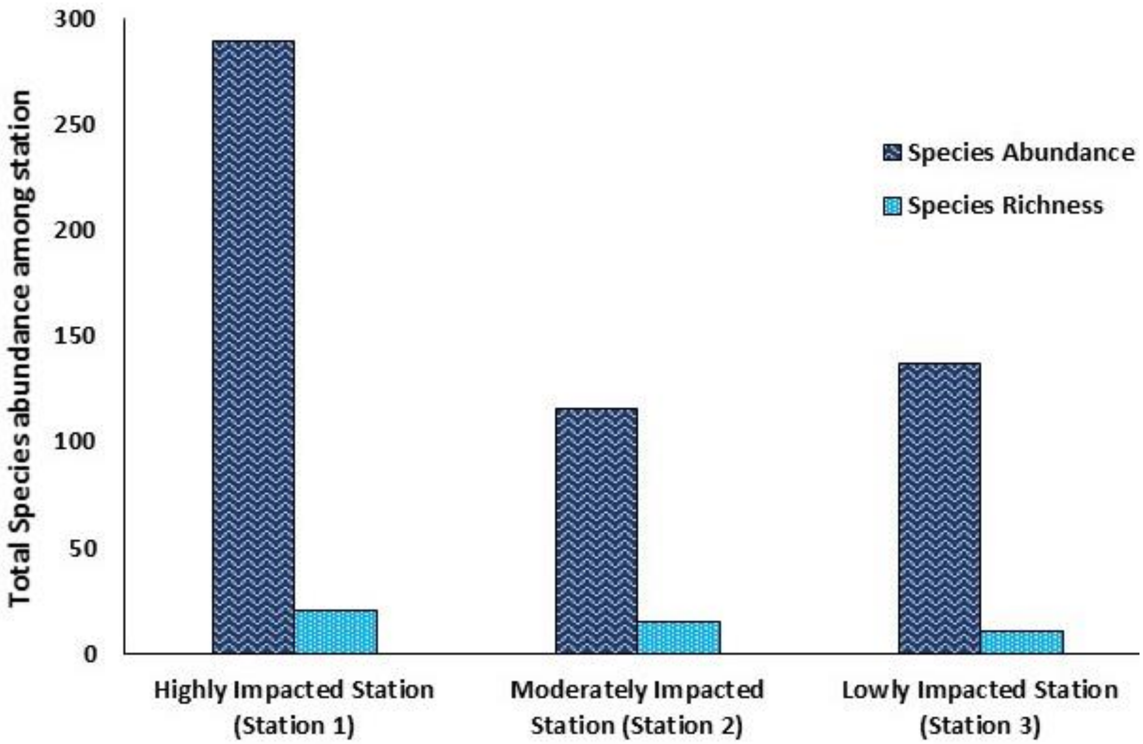

Figure 5. Total species richness and abundance among the three stations at Isiokpo River, Rivers State, Nigeria.

Table 2. Species diversity indices across sampling stations in Isiokpo River, Rivers State, Nigeria.

Indices	Station 1	Station 2	Station 3
Taxa	21	15	13
Individual	290 (53.41%)	116 (21.36%)	137 (25.23%)
Simpson index (D)	0.8725	0.8847	0.7697
Evenness (E)	0.5438	0.7097	0.5002
Shannon-Weiner (H)	2.435	2.365	1.872

least at station 3 with values of 1.872 (Table 2).

Indicator species

Results of bioindicator species (or taxa) that belong to three orders of insects; Ephemeroptera, plecoptera and Trichoptera in Isiokpo River showed that out of a total of six species encountered, three belong to Ephemeroptera, one to Plecoptera and two species to Trichoptera (Table 3). The percentage EPT distribution of Isiokpo River at the period of study was 40% (Station 1), 33.3% (Station 2) and 26.7% (Station 3) (Table 3).

A total of sixty-six EPT individuals were encountered with the highest recorded at Station 1 and least at Station 3 (Table 3). Out of the three Ephemeroptera species encountered, only one; Ephemera sp occurred at Station 3. Eight out of twenty-one species encountered during the study were absent at Station 3 and six did not occur at Station 2 (Table 4). Eleven species comprising all the four species of Coeloptera and seven other species were encountered across the three stations (Table 4).

DISCUSSION

Community composition of insect species recorded at the Isiokpo River in this study gives an indication of the ecosystem health of the river because it is in accordance with the fact that the quality of water is examined by comparing the number of tolerant and intolerant insect species (Gogoi and Guha, 2000). At the Isiokpo River, Station 1 which is less impacted by human activities contained more species than the highly impacted station

Table 3. EPT richness across sampling stations in Isiokpo River.

Species	Station 1	Station 2	Station 3
Ephemeroptera			
Baetis sp	3	3	0
Caenis sp	3	1	0
Ephemera sp	2	0	1
Sub-total	**8**	**4**	**1**
Plecoptera			
Neoperla sp	21	7	2
Sub-total	**21**	**7**	**2**
Trichoptera			
Hydropsyche sp.	15	2	1
Leptonema sp.	3	1	1
Sub-total	**18**	**3**	**2**
Total EPT species	6	5	4
No. of EPT individuals	47	14	5
%EPT	40	33.33	26.46

3, thus it is ecologically healthier. The abundance of species recorded in the three stations also add credence to the ecological status of the river as Station 1 is more abundant than others. The high abundance of species recorded at Station 3 over the moderately impacted Station 2 is due to the high abundance of tolerant species recorded at Station 3. The Isiokpo River harbor eleven tolerant species which occurred through the three stations, and *Chironomus* sp (Diptera), *Baetis vagans*, *Cybister* sp, *Gyrinus* sp., and *Agabus* sp (Coleoptera). Out of them occurred in large number of individuals, particularly in the higher impacted station 3. The increase in the number of individuals at Station 3 indicates that they have the ability to tolerate the pollution caused by high human activities. It has been stated that higher concentrations of organic and/or inorganic pollutants decreased chironomid larvae, but increased the abundance of tolerant species, which are mainly Chironomus spp (Salman et al., 2010). Our study agrees with this, however, the high abundance of Chironomids at low impacted station 1, indicates that some species occur in clean and moderately polluted water. These two categories of chironomids were encountered in our study, though the category that tolerated low polluted or impacted station was higher at Isiokpo River. This agrees with Salman et al. (2010) that those chironomids which have the "ability to survive in extreme environmental conditions with low dissolved oxygen and high concentrations of pollutants are considered tolerant species", while some species occur in clean water. The two categories encountered tolerated low and high dissolved oxygen of station 3 and 1, respectively, indicating that station 3 has higher level of anthropogenic activities, particularly as DO value was below WHO Standard minimum limit for optimum aquatic productivity (5.0 mg/L) (Esenowo et al., 2015).

The low flow rate recorded at Station 3 indicates that mixing of water was slow as compared to Station 1 due to accumulation of pollutants caused by high impact of human activities. This caused reduced pH and transparency at Station 3, leading to low distribution of species. Human activities leading to discharges through run-offs from refuse dumpsites and nearly abattoir into rivers caused organic pollution and reduced dissolved oxygen (Elemile et al., 2019; Folami et al., 2019). The situation at Station 3 in our study is in conformity with this report.

Hamid and Rawi (2017); Savic et al. (2017) reported that freshwater insect species belonging to three orders; Ephemeroptera, plecoptera and Trichoptera (EPT) are used as indicators of health status of freshwater bodies due to their response (presence, absence, abundance and distribution) to environmental changes. In our study, the %EPT species recorded showed that Station 3 (26.7%) is relatively low, indicating that the station is polluted.

Edeghene (2020) stated that water bodies with Margalef's water quality index values of greater than 3 is an indication of clean water conditions. In our study, Station 1 had an index value of 3.527 while Station 3 showed 2,439 indicating that our study agrees with the report.

CONCLUSION AND RECOMMENDATION

The high human activities of the Isiokpo River has impacted much on Station 3, with a reduced diversity of

Table 4. Insect species distribution in the three stations.

Orders	Species	Station 1	Station 2	Station 3
Odonata	*Aeshna* sp.	9	8	5
	Hemistigma sp.	1	0	0
	Libellula sp	57	17	17
	Enallagma sp.	3	0	1
	Sub-total	**70**	**25**	**23**
Diptera	*Chironomus* sp.	72	24	58
	Culex sp.	3	3	0
	Aedes sp.	8	0	0
	Sub-total	**83**	**27**	**58**
Hemiptera	*Gerris* sp.	14	15	17
	Belostoma sp.	20	5	0
	Nepa sp.	1	0	0
	Lethocerus americanus.	1	0	0
	Sub-total	**36**	**20**	**17**
Coleoptera	*Hyphydrus sp*	11	14	14
	Cybister sp.	22	8	10
	Gyrinus sp.	12	6	6
	Agabus sp	9	2	4
	Sub-total	**54**	**30**	**34**
Ephemeroptera	*Baetis vagans*	3	3	0
	Caenis simulars	3	1	0
	Ephemera sp.	2	0	1
	Sub-total	**8**	**4**	**1**
Plecoptera	*Neoperla* sp.	21	7	2
	Sub-total	**21**	**7**	**2**
Trichoptera	Hydropsyche sp.	15	2	1
	Leptonema sp.	3	1	1
	Sub-total	**18**	**3**	**2**
	TOTAL	**290 (53.41%)**	**116(21.36%)**	**137(25.23%)**

insect species, including EPT species and changes the ecological health status of the River. The Station 1 of the River still have a relatively diverse aquatic insect fauna and low human impacts compared to Stations 2 and 3. The diverse aquatic insect fauna pointed out that Station 1 is relatively healthy. We wish to recommend that adequate water management program be introduced into the river to control the continuous and uncontrolled activities around the river in order to conserve its insect fauna inhabitants and its dependable organisms.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Vol. 15(4), pp. 167-178, April 2021
DOI: 10.5897/AJEST2020.2943
Article Number: E3D974766855
ISSN: 1996-0786

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Determinants of climate change adaptation and perceptions among small-scale farmers of Embu County, Eastern Kenya

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Received 9 November, 2020; Accepted 29 March, 2021

Climate change threatens the livelihoods of millions of small-scale farmers in East Africa. How farmers perceive climate change and its impacts has a strong bearing on how they adapt to the adverse impacts. This paper focused on factors that determine climate change adaptation and perceptions among small-scale farmers of Embu County. A survey was carried out across five sub-counties of Embu County where a multi-stage sampling procedure was used to select 411 households. A questionnaire was administered to each household. A total of five FGDs were generated by the use of quota sampling. The data obtained from the FGDs were thematically analyzed while that from each household was subjected to both descriptive statistics and Heckman's probit model. The results showed 96% of the respondents observed unreliable seasonal rainfall amount, distribution, and increased temperatures. For instance, 23% interviewed were aware of the long-term change in temperature while 55% were aware of a change in the amount of rainfall per season. These respondents identified crop failure and the decline in crop yields as indicators of climate change. The farmers' perceptions were corroborated by the long-term rainfall and temperature of Mann-Kendall trends analysis, which showed a negative rainfall correlation and temperatures increased by 0.02°C for Kiambere and 0.03°C for Embu stations. Gender was significant at p<0.1 in influencing farmers' perception of climate change while education level and social networks were statistically significant at p<0.05. Furthermore, Heckman's selectivity probit model showed that the education level of the household head and access to a credit facility influenced small-scale farmers' adaptation choices. There is a need to strengthen the capacities of farmers through training, provision of extension services, and formulation of a climate advisory committee within the county government to breakdown climate change information into user-friendly.

Key words: Heckman model, climate variability.

INTRODUCTION

Climate variability directly affects the agricultural system that has a predictable influence on the socio-economic system in all the regions of the world (Porter et al., 2014). For instance, extreme drought hinders the ability of farmers to rear livestock and grow food (Connolly-Boutin and Smit, 2016). This is because climate change alters the patterns of both precipitation and temperature which are the major elements in agricultural production.

According to Arimi (2014), a rise in temperature amid crop growing season leads to a water deficit that affects seedlings on the farm. Besides, superfluous rainfall threatens soil functions by causing erosion, loss of organic carbon, waterlogging, salinization, and nutrient imbalances (Montanarella et al., 2016). Furthermore, climate change causes uncertainty and risks in the decisions on the onset of farming season and losses in agricultural production as a result of fluctuating temperatures and rainfall patterns (Thornton and Herrero, 2015). For instance, a study carried out in Pannonian, Central Europe indicates an increase in water deficit affects planting time and limits vegetation physiological ability hence reducing yields (Trnka et al., 2010). Furthermore, unfavorable weather conditions render sowing impossible during spring. Climate change leads to productivity decline with a range of 3.8-5.5% (Lobell et al., 2011). This decline is a result of modifications in rainfall, temperature, soil quality, pest, and disease infestations on both crops and livestock (Connolly-Boutin and Smit, 2016).

Small-scale farmers in Africa are vulnerable to increasing temperature and constant droughts (Codjoe et al., 2011). Furthermore, in Sub-Saharan Africa (SSA), 97% of agricultural land is rain-fed and people depend on agriculture for subsistence and surplus produce for income (Blanc, 2012). It is estimated that African countries are more likely to experience losses in agriculture in ranges of 8-22% depending on the crop and the region (Schlenker and Lobell, 2010). According to Arimi (2014), African regions that face soil erosion and rely on rain-fed agriculture are likely to experience 50% losses as a result of the increasing impacts of climate change. One-third of the African population resides in drought-prone areas (Rojas et al., 2011). These populations face devastating epidemics, famine, malnutrition, and displacement of the human population Malnutrition is a result of an increase in infectious disease transmission, scarcity of clean and safe water, and inadequate food. Also, these droughts have had an impact on water levels (Mboera et al., 2011). These in turn escalate poverty and reduce the standards of living of the African population.

Based on threats of climate change on agricultural productivity in Africa, farmers need to should implement adaptation mechanisms to the effects of climate change to ensure continuous productivity (Fahad and Wang, 2018). Climate variability varies from region to region and so individual farmers may adapt to climate change in various ways based on their capability (Batisani and Yarnal, 2010). According to Kawasaki and Herath (2011) individual farmers have a unique adaptation scheme that differs from large-scale government policy. The adaptation scheme can either prevent the occurrence or minimize damages. Adaptation refers to “decision-making processes and actions that ensure adjustment or coping with potential damage” (Eisenack and Stecker, 2010). Therefore, climate change adaptation is planned or unplanned actions that individuals make to shield themselves from the effects of climate change. This may involve making adjustments to the land, natural resources, and social and economic establishments (Sanga et al., 2013).

In Kenya, small-scale farmers are facing climate change which is associated with extreme weather events such as droughts, soil infertility, floods, and unreliable rainfall patterns up (Nzau, 2013). According to IPCC (2007) temperatures are expected to increase gradually to nearly 3°C by 2050 whereas Nzau (2013) reports an increase of 1.3°C for maximum temperature and 2.0°C for minimum temperature. High temperatures in South West Kenya reduce the length of crop growing periods while in highlands the interplay of high temperature and rainfall variability leads to the extension of the crops growing season (Herrero et al., 2010). In terms of rainfall, Kenya displays considerable topographic and climatic variability associated with temporal and spatial bimodal rainfall (Bryan et al., 2013). According to Nzau (2013), drought brings about water deficiency which affects crop productivity and livestock rearing. Moreover, floods of different magnitude and frequency occur in different parts of the country as a result of the change in rainfall patterns (Opere, 2013). Small-scale farmers develop many adaptation mechanisms to cope with the scathing effects of climate change. For example, shifting to mixed cropping, crop diversification and agroforestry, early maturing crops, and destocking (Hoang et al., 2014; Mwang’ombe et al., 2011). Despite the availability of these measures, food insecurity is still recorded in the eastern region of the country (Bryan et al., 2013), the reason being that adaptation to climate change is site-specific and effective mechanisms depend on many other factors such as vulnerability, socioeconomic status, and the degree of climate change (IPCC, 2014). Furthermore, adaptation may be influenced by individuals’ perceptions of the uncertainty and risks to vulnerability (Fahad and Wang, 2018). Singh et al. (2017) observe that households' ability to determine adaptation is a factor of perception of risks and change. Perception is a process in which stimulus or information is received and transformed to

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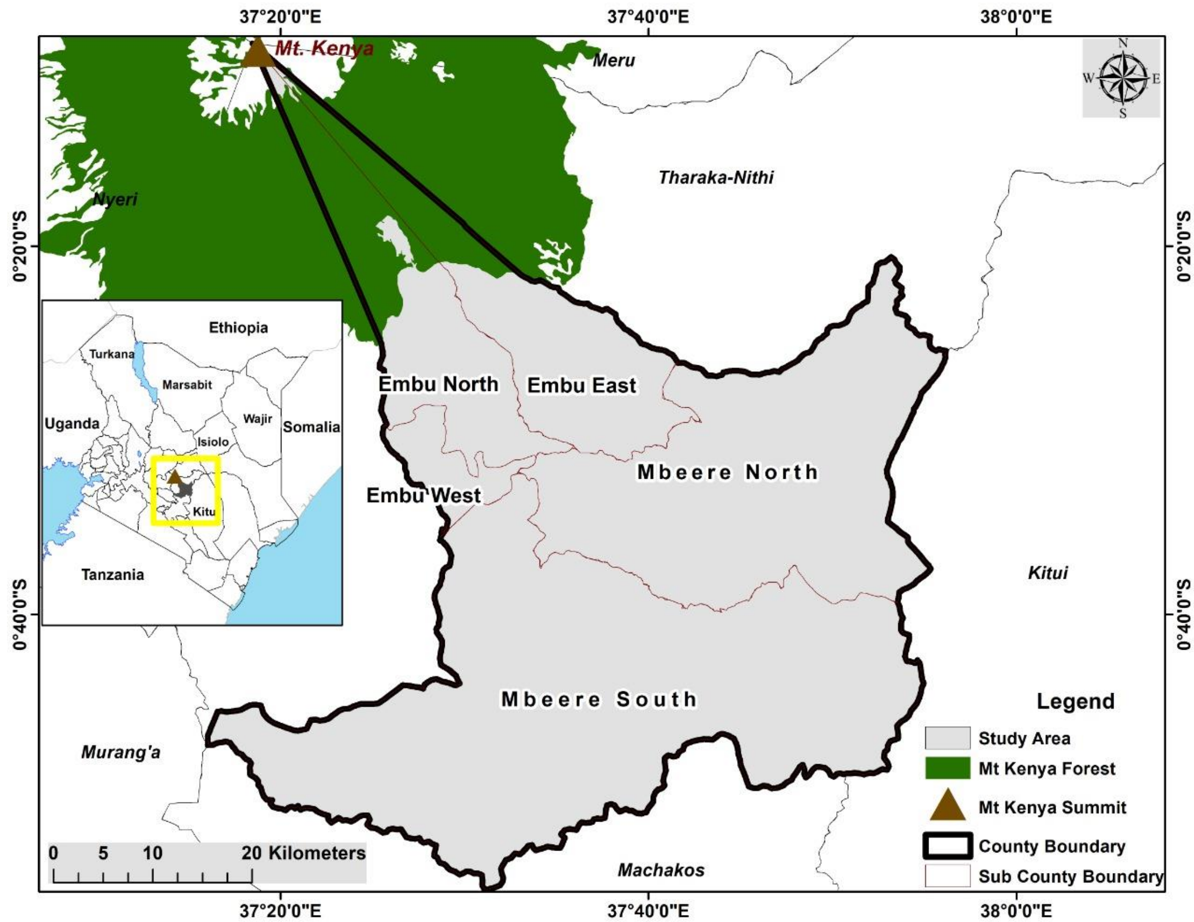

Figure 1. Location of Embu County in Kenya.

generate a psychological awareness (Ayal and Filho, 2017). This stimulus is formulated based on cultural background, prior experience, and socioeconomic factors. Farming is a risky adventure where farmers have to decide on what to plant, when to plant, how to plant, what input to use, and what crop, water, and soil management strategies to use to avoid massive losses (Rao et al., 2011). Determinant factors being site-specific, it is imperative to carry out this study to enhance adaptability among the small-scale farmers. It is hypothesized that demographic, socio-economic, and perception levels of small-scale farmers increase the probability of climate change adaptation.

METHODOLOGY

Study area

The study was carried out in Embu County within the Kenyan highlands on the eastern foot slopes of Mount Kenya (Figure 1). The County is located on the latitude of 0° 8' and 0° 50' South and longitude 37° 3' and 37° 9' East, with an altitude ranging from 1,080 m to over 4,700 m above the sea level (Embu County Government Integrated Development Plan, 2013). Embu County with an area of about 2,818 km^2 is divided into five sub-counties namely Embu North, Embu West, Embu East, Mbeere North, and Mbeere South. Embu County has soils of volcanic origin in the upper midland and higher zones near Mt Kenya which include andosols, ando-humic nitisols, and humic nitisols. In most of the lower midland zones, soils are based on metamorphic basement rocks with volcanic influence with moderate to low fertility (Jaetzold et al., 2010). The County borders Kitui County to the East, Kirinyaga County to the West, Tharaka Nthi County to the North, and Machakos County to the South. The County receives a total annual rainfall of between 1,200 and 1,500 mm in two rainy seasons, March to June which is considered as the long rainy season, and October to December as the short rainy season, although the rainfall quantity received varies with altitude. Temperatures range from a minimum of 12°C in July to a maximum of 30°C in March and September with a mean of 21°C (Kisaka et al., 2015). The difference between the minimum and maximum temperatures is due to the extensive altitudinal range of the county. However, there is localized climate in areas along the

Table 1. Distribution of respondents in five sub-counties in Embu County.

Sub-county	Divisions	No. of small-scale farmers	No. of questionnaires	Percentage
Embu West	Central	10 866	41	10.2
	Nembure	6 360	24	5.8
Embu North	Manyatta	17 218	64	15.5
Embu East	Runyenjes	16 552	64	15.5
	Kyeni	13 448	52	12.6
Mbeere South	Gachoka	6 818	27	6.7
	Mwea	6 060	24	5.8
	Makima	5808	23	5.6
	Kiritiri	6565	26	6.3
Mbeere North	Evurore	7 830	30	7.3
	Siakago	9 395	36	8.7
	Total	**106,920**	**411**	100

Tana River due to the presence of five dams, Masinga, Kamburu, Gĩtaru, Kĩndaruma, and Kĩambere with a total population of 513,363 comprising of 254,303 males and 261,909 females as of 2009 census who occupy 2,615.2 km^2 excluding 202.8 km^2 which is a part of Mount Kenya forest.

Out of the total population in this County, 83% live in rural areas where agriculture is prominent (Embu County Government Integrated Development Plan, 2013). The presence of favorable temperature and rainfall allows the small-scale farmers of the study area to practice rain-fed agriculture. In the study area agriculture supports 70.1% of the population and 87.9% of the households are directly involved in farming activities. These agricultural activities take about 80% of the total area of Embu County (Embu County Government Integrated Development Plan, 2013). Arable land is used for both crop and livestock production. In crop production, the county has three categories; food, industrial, and horticulture crops. The food crops include maize, sorghum, pearl millet, beans, cowpeas, green grams, sweet potatoes, cassava, and Irish potatoes while the industrial crops are cotton, coffee, tea, and macadamia (Embu County Government Integrated Development Plan, 2013). Besides, horticultural crops are mangoes, bananas, passion fruits, avocadoes, kales, tomatoes, carrots, butternuts, and watermelons. Furthermore, livestock types are cattle, sheep, goats, chickens, rabbits, donkeys, beehives, and pigs.

Data collection

This survey was conducted in March and April 2018. An exploratory study was done in the County to help enhance an understanding of perception and adaptation of climate change. A total of 411 respondents were arrived at by the use of a multi-stage sampling procedure. Purposive sampling was the first stage where five sub-counties were selected within Embu County. This was to ensure equitable distribution of the questionnaires and unbiased responses from the households. The second stage involves the stratified sampling of administrative divisions within the sub-counties to form the sub strata. This was to arrive at sampling units with proportional sample sizes for each division. A simple random sampling technique was the third stage that involved selecting respondents from each division (Table 1).

The questionnaires were coded and entered into a digital survey tool and tablets for data collection. This enabled standardization of responses, quality control, quick retrieval, and analysis. These questionnaires captured data on demographics, socioeconomic characteristics, agricultural practices, perception of climate change, and adaptation options. Local field enumerators assisted in collecting the required data after a vigorous four days of training and piloting before the start of the interviews. The objective was to reduce biases and errors in data collection. The enumerators were selected from each sub-county to ensure they are familiar with the local environment and the native language. This survey was conducted in March and April 2018.

Quota sampling was used to generate Focus Group Discussion (FGDs) participants which comprised of 8-12 smallholder farmers. Every sub-county age cohort was used to generate the sample size. The age cohorts were divided into 6 groups with an interval of 10years. In every group, 2 smallholder farmers were randomly chosen to participate in the focus group discussion. Long-term rainfall and temperature data (1976-2016) relevant to this study were obtained from the Kenya Meteorological Department (KMD). The data collected was for Embu station with 40 years' data (1976-2016) which was a representative of three sub-counties namely Embu East, Embu West, and Embu North. Kiambere station had records for 13years (2003-2016) that represented Mbeere North and Mbeere South Sub-counties.

Data analysis

Heckman's model is a two-stage process that is used to analyze the determinants of climate change adaptation and perceptions as proposed by Maddison (2006). The first stage involves small-scale farmers' ability to perceive or not to perceive changes in temperature or rainfall amount, intensity, or duration of a season, while the second stage is whether the households adapted to climatic change immediately they experienced climate change or otherwise.

According to Heckman (1976) probit model for sample, selection accepts that there are underlying relationship that exists with a latent equation as shown below;

$$y^{x}_{j} = xj\beta + u_{1j,} \quad (1)$$

Only the binary outcome is observed given by probit model as

$$y_j^{probit} = (y^{x}_{j}>0), \quad (2)$$

If $_j$ is observed in the selection equation, then the dependent variable is detected

$$y_j^{select} = (z_j\delta + u_{2j} >0), \quad (3)$$

u_1~N (0, 1)
u_2 ~ N (0, 1)
corr (u_1, u2) =p,

Where x represents a k-victor of regressors which includes explanatory variables with different factors assumed to sway adaptation mechanisms, z is an m vector of repressors that include explanatory variables with different factors assumed to affect perception, u_1 and u_2 are error terms. The first stage in Heckman's model is therefore represented in Equation 3 which denotes the perception of the household towards climate change. Equation 1 gives the outcome model in the second stage which shows whether the small-scale farmers adapted to climate change and is restricted on stage one which represents the perception of climate change. Rainfall and temperature data from KMD (1976-2016) were subjected to the Mann-Kendall trend test by the use of XLSTAT version 2020 to give a graphical representation of the variation of time and standard precipitation Index.

RESULTS AND DISCUSSION

Perception of temperature and rainfall

The small-scale farmers of Embu county drew most of their livelihoods from subsistence farming. The farming experience of these farmers ranged from 1 to >60 years. Agriculture is the major source of livelihood which is under threat due to the effects of climate change and variability. The farmers identified climate change indicators as crop failure, the decline in crop yields, the disappearance of crop variety, outbreak of crop pest and diseases, the outbreak of livestock pest and diseases, insufficient and poor quality pasture, low milk and meat production, and death of livestock as the major constraints to farm incomes. The majority (96%) of these farmers indicated that they had observed unreliable seasonal rainfall amount, distribution, and increased temperatures. For instance, 23% interviewed were aware of the long-term change in temperature while 55% were aware of a change in the amount of rainfall per season. There were frequencies of prolonged dry spells and a general delay in on-set of rains and abrupt end of the seasons (Table 2).

Analysis of temperature and rainfall data

The small-scale farmers' perception was compared to the meteorological data from the two stations in Embu County. The results indicated a statistically significant trend ($P< 0.05$) in both minimum and maximum temperatures during the 40years period (Table 3). In the Embu station, the minimum temperature has risen by 0.014°C, (y=0.0135x -24.936) whereas the maximum temperature has increased by 0.032°C, (y=0.0318x – 38.806). On the Kiambere station, an increase in trend was also recorded in both minimum and maximum temperature (0.02°C) fluctuating between the lowest being 16°C and highest of 30°C. This scenario is repeatedly seen in various parts of the country with an increase in temperature ranging from 0.2 to 1.3°C depending on the regions in Kenya (Kotir, 2011; Nzau, 2013).

Figure 2 shows a significant increase in temperature in 1978, 1988, 1990, 1997, 2002, 2006, and 2013 for the Embu station. Increased drought incidences were a common view in the study area for both the individual farmers and focus groups. Furthermore, focus group discussions identified 1979-1980, 1983-1984, 1999-2001, 2004-2005, and 2013-2014 recording worst memories of extreme temperatures. The respondents were concerned about the high variability and seasonal changes that stalled their ability to predict and plan farming activities on time. Analysis of rainfall data showed a mean rainfall amount of 3553 mm with an SD 81.57 and a var6653.96 (y = -10.0171x +376.65) in the Embu station while Kiambere station recorded 1257 mm with y=13.541x + 435.67.

These results show that there was a slight decline in the amount of rainfall with 10.02 mm per year for 40 years in Embu station while 13.54 mm in Kiambere station for 13 years (2003-2016). SPI representation in Figure 2 showed a rainfall variability pattern with drought events being witnessed between 1983 and 1987, 1991 and 1993, 1999 and 2001, 2004 and 2005, 2007 and 2011, 2013 and 2014, and 2016 in Embu station. These timescales reflect the possible impact of unreliable rainfall that affected both crops and livestock production. Small-scale farmers can relate to this dryness because of precipitation anomalies which directly influence the soil moisture conditions on the farm. According to Kisaka et al. (2015) rainfall patterns have become unreliable with a short rainy season shifting from mid-October to late October and early November. This shift becomes worrisome to the small-scale farmers who find it problematic to time their farming activities for instance planting crops.

Table 2. Small-scale farmers' perceptions and specific indicators of climate variability and change in Embu County.

Perceived change in weather patterns	Specific indicator	% of respondents
Temperature extremes	Crop failure Declined in crop yields Hot temperatures than before Intense cold in June and July	23
Increased drought incidences	Poor soil conditions The disappearance of crop variety, The outbreak of crop pest and diseases The outbreak of livestock pest and diseases Death of livestock	18
Poor rainfall distribution	Delay in the onsets of the rainy season The abrupt ends of the rainy seasons low milk and meat production Longer dry spells within the seasons Insufficient and poor quality pasture Flash floods during heavy rains seasons	55
Other	Drying of water beds and wetland Water scarcity Presence of severe cold months	4
Total		100

Table 3. Annual temperature time-series trends and variability.

Station	Temp	N	Min	Max	Mean	SD	Trend℃/year	Kendall's tau	P-value
Embu	Tmax	40	13	15	14	0.433	0.032	0.341	0.002*
	Tmin	40	23	27	25	0.784	0.014	0.365	0.001*
Kiambere	T min	13	16	18	17	0.922	0.020	0.702	0.004*
	Tmax	13	26	30	28	0.398	0.018	0.708	0.002*

*****significant trend at P<0.05 level, SD =Standard Deviation.

Factors influencing the perception of climate change by households

Explanatory variables in the Heckman model

Heckman model makes use of independent and dependent variables (Table 4). The independent variables are assumed to affect small-scale farmers' perception of climate change and show the extent they are adapted based on their perception. The findings of the selection model analysis show the factors that influence small-scale farmers' perception of climate change in the study area in Table 5.

In the analysis gender of the household head, social networks, and education level of the tertiary, secondary, and upper primary were found to be significantly influencing household's perception towards climate change. Male-headed households ($P<0.05$) were more likely to perceive climatic change than female-headed households (Table 5). This is because male-headed households had a better chance to attain information and new technology as compared to their counterparts (Ndambiri et al., 2013). According to Bryan et al. (2013), training and capacity building is associated with a better perception of climate change. This would benefit the female-headed households within the county towards

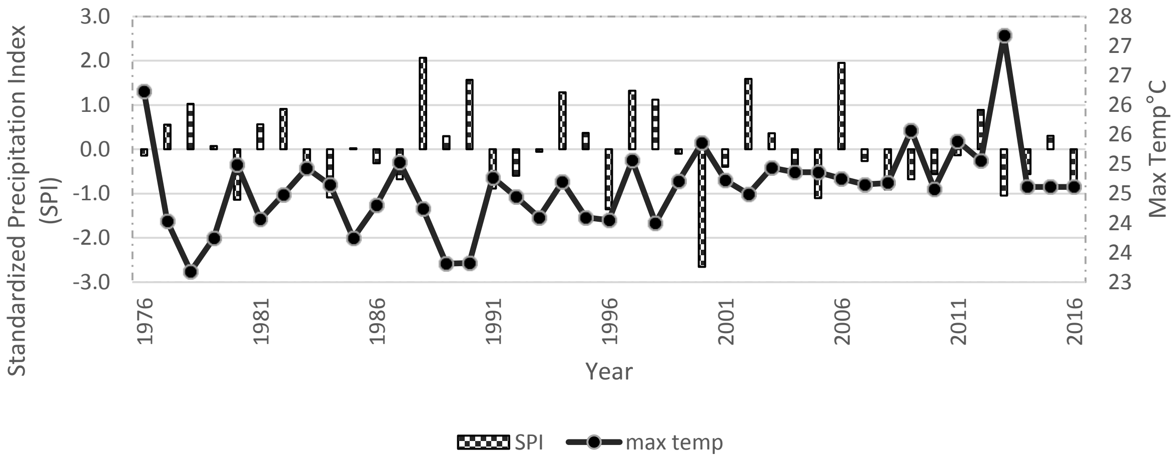

Figure 2. Standardized precipitation index and temperature variability for Embu station.

Table 4. Dependent and independent variables in the Heckman model.

Dependent variable	Units	Respondents who experienced climate change (%)	Respondents who did not experience climate change (%)
Perception of climate change	1 = yes, 0 = no	97.8	2.2
Independent variable	**Units**	**Mean**	**Std. deviation**
Gender of the household head	1 = female, 0=male	0.591	0.492
Age of the household head (years)	18 - 30	0.153	0.002
	31 - 40	0.281	0.004
	41 - 50	0.258	0.006
	51 - 60	0.189	0.009
	61 - 70	0.073	0.012
	≥ 71	0.077	0.014
Households size	Continuous	4.175	1.664
Education levels	Tertiary =1, secondary =2, upper pry =3, lower pry = 4, no formal Edu. = 5	0.067	0.002
		0.31	0.004
		0.481	0.006
		0.142	0.009
		0.014	0.012
Marital status of the respondents	1 = Married, 0 = not married	0.851	0.358
Type of occupation	1 = On-farm, 0 = non-farm	0.092	0.293
Land ownership	Government land =1	0.064	0.01
	Leasehold = 2	0.037	0.04
	Private land =3	0.914	0.1
Years in farming	Continuous	18.602	13.501
Land under cultivation	Continuous	1.383	0.984
Off-farm income	Below 10,000	0.018	0.028

Table 4. Contd.

	11,00-20,000	0.023	0.014
	21,000-30,000	0.319	0.039
	31,000-40,000	0.13	0.153
	41,000 - 50,000	0.192	0.124
	51,000 and above		
Farm income	Below 10,000	0.129	0.113
	11,00-20,000	0.012	0.106
	21,000-30,000	0.036	0.138
	31,000-40,000	0.018	0.011
	41,000 - 50,000	0.101	0.123
	51,000 and above	0.21	0.115
Access to certified seeds	Yes = 1, no = 0	0.106	0.309
Access to hired labor	Yes = 1, no = 0	0.037	0.166
Access to the credit facility	Yes = 1, no = 0	0.842	0.367
Social network	Yes = 1, no = 0	0.714	0.456
Extension services	Yes = 1, no = 0	0.676	0.467
Distance to the market	Continuous	2.453	1.269
Access to media	Yes = 1, no = 0	0.701	0.453

Source: Authors' analysis from respondents.

Table 5. Parameter estimates from the Heckman's selection model.

Explanatory variable	Adaptation model			Selection model		
	Par. estimate	S.E	Marginal effects	Par. estimate	S.E	Marginal effects
Gender	0.035	0.061	0.582	-4.684*	162.381	0.001
Age (years)						
18-30						
31-40	-0.118**	0.052	-2.240			
41-50	-0.148**	0.055	-2.651			
51-60	-0.102*	0.060	-1.682			
61-70	-0.138*	0.083	-1.654			
>71	-0.109	0.086	-1.264			
Education level						
No formal education						
Tertiary	0.056	0.171	0.331	-4.503**	0.720	-6.25
Secondary	0.033*	0.153	0.224	-3.964**	0.569	-6.96
Upper primary	0.099	0.153	0.651	-4.284**	0.520	-8.23
Lower primary	0.077	0.148	0.526	-4.167		
Social network	-0.026	0.041	-0.626	-0.357**	0.430	-0.83
Access to media	0.013	0.040	0.335	-0.401	0.419	-0.98
Household size	0.015	0.010	1.542			
Access to credit	0.064*	0.045	1.412			

Table 5. Contd.

Off-farm income						
10,000 and below						
11,00-20,000	-0.009	0.043	-0.216			
21,000-30,000	-0.033	0.068	-0.492			
31,000-40,000	0.080	0.117	0.691			
41,000 – 50,000	-0.062	0.164	-0.384			
51,000 and above	0.335	0.291	1.152			
On-farm income						
10,000 and below						
11,000 - 20,000	0.006	0.037	0.178			
21,000 - 30,000	-0.007	0.056	-0.130			
31,000 - 40,000	0.104	0.105	0.983			
41,000 - 50,000	-0.186	0.165	-1.132			
51,000 and above	0.265	0.278	0.953			
Distance to the market	-0.040**	0.017	-2.310			
Extension services	-0.057**	0.049	-1.172	-0.497	0.422	-1.18
Land under cultivation	-0.057**	0.017	-4.470			
Constant	0.207	0.193	1.070	11.629	1562.38	0.01
lambda	0.326	0.591	0.55			
Wald chi2(27)	64.2					
Prob > chi2	0.0001					

S.E: Standard error.*Significant at 10% (P < 0.1), **Significant at 5% (P < 0.05).
Source: Analysis from household interviews.

perception and adaptation to climate change. About the education level of the respondents, the study established a likelihood of farmers with tertiary, secondary, and upper primary education levels as more likely to perceive climate change than the less educated farmers (Table 5). This is because more educated farmers are more likely to be exposed to more information and have a better appreciation of climate change. Ofuoku (2011) observed a likelihood increase in appreciation of climate change with an increased number of years in school among the farmers. Further, Ndambiri et al. (2013) noted that higher education exposed farmers to more information on climate change.

Furthermore, social networks which are informal mechanisms in the study area to acquire and pass climate-related information among farmers was significant (Table 5). This implies that small-scale farmers are more likely to be influenced to perceive climate change by the existence of social interaction. According to Katungi (2006), early adopters slowly circulate information of new technology through sparse social networks that enable perception. Besides, Kristiansen (2004) argues that social networks strengthen individuals' attitudes and bring a commitment to work hard to reduce the risks.

Determinants of households' adaptation to climate change

The results of the outcome model presented in Table 5 show the factors influencing adaptation. The explanatory variables such as age, secondary school education levels credit availability, extension services, size of land under cultivation, and distance to the market centers were found to be significant (P<0.05). Concerning age, the findings showed household heads between the age of 31 and 70 years were influencers of adaptation to changing climate. This indicates that almost all age groups were active in minimizing the climate change effects on the agricultural fields. According to Ajuang et al. (2016), middle-aged farmers are likely to adapt to changes. The education level was categorized into five groups which included no formal education, lower primary, upper primary, secondary and tertiary education (Table 5). The head of households with the secondary educational level was found to be a statistically significant variable in adaptation to climate change. This implies that household heads with more than 10 years of schooling are in a better position to comprehend any information on adaptation to climate change. Meaning that for a better resilience of the small-scale farmers in the study area there is a need to strengthen the education sector (Opiyo et al. 2016). The findings showed that access to credit was statically significant in influencing adaptation to climate change (Table 5). This implies that ease of access to credit facilities by the small-scale farmers in the study area is likely to influence investment in strategies to mitigate impacts of climate change such as the use of drought-tolerant seeds and the adoption of climate-smart technologies. Opiyo et al. (2016) observe that access to credit facilities enables farmers to capitalize on the creation of inputs for adaptation. Besides, access to cash enables households to diversify their livelihood which is a form of adaptation. According to Hassan and Nhemachena (2012), households with more financial resources can use all available information to adapt to climate change. Distance to the market center was found to be significantly influencing households' adaptation to climate change (Table 5). This implies that an increase in distance to the market center negatively influences the adaptation. This is because access to the market centers provides an avenue for the farmers to purchase inputs and sell their produce thus earning income for farm diversification. Farmers with easy access to the market are motivated to purchase certified seeds, fertilizers, and irrigation equipment (Belay et al., 2017). Access to extension services was another explanatory variable that was significant to adaptation (Table 5). This implies that access to extension services leads to improved and better adaption to climate change. This is because extension services are important as a source of information for small-scale farmers in the study area on farming activities and climate-related information. Extension education motivates and increases the likelihood of farmers implementing an adaptation mechanism (Belay et al., 2017). The size of land under cultivation was also considered and the results showed that it is statistically significant to adaptation (Table 5). This implies that as the size of land increases there is a probability of farmers adapting to climate change. This is because land size increases the probability of mixed farming which translates to diversification (Mugi-Ngenga et al., 2016).

Conclusion

This study was implemented to assess the determinants of climate change adaptation and perceptions among small-scale farmers in Embu County, Eastern Kenya. The climatic data records from the weather station within the County obtained from the Kenya Meteorological Department (KMD) were in line with the farmers' perception of temperature and rainfall data. The views of the majority of the respondents and FGDs were closely similar to those obtained from those of increasing temperatures and rainfall variability data obtained from KMD. This showed that the small-scale farmers in the study area can be used as reliable key informants concerning climate change. The findings indicated that male-headed households were more likely to perceive climate change because they had a better chance to obtain information and new technology. Given that female-headed households were the majority in the study area, there was a need to empower the females through training and capacity building to increase the perception of climate change. Besides, there was a need to invest in the education sector to improve the empowerment of males and females to ameliorate their perception of climatic changes and adapt to them. Social networks were paramount in the circulation of information on adaptation mechanisms which gradually improves the farmers' perception levels towards climate change. Furthermore, households with access to extension services were likely to adapt to climatic changes. There was a need therefore to invest in extension agents to provide information and knowledge related to climate change. Also, policies on the minimum land size under cultivation, access to credits, and markets for both livestock and crop production were likely to enhance climate adaptation strategies among the small-scale farmers in the study area. Furthermore, the County government needed to incorporate a climate advisory committee to assist the farmers in the abridgment of the climate change information into user-friendly. Besides, there is a need to assimilate extension services among the small-scale farmers and a continuous follow-up carried out to improve the perceptions that lead to adaptation of climate change. However, a wider scope study is needed to look at both small and large-scale farmers' perceptions and adaptation to climate change to ensure large-scale policy formulation within the country.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENT

The authors appreciate the farmers, the experts in Embu County who responded to this study. Appreciation goes to the Embu County Agricultural and Extension teams for the support to access county-specific information and to access the study sites. Appreciation also goes to Dismas Ongoro, the lead field technicians, and the enumerators who supported with fieldwork. Special thanks go to Mercy Mutua for the support in coding the questionnaires and setting up the digital data collection framework using

ODK. Further appreciation goes to Kevin Onyango for support with data analysis. This study was independently financed by the first author as part of her Ph.D. study. There has been no financial assistance from any organization.

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