

Research article

Perceptions and exposure to climate events along agricultural value chains: Evidence from Nigeria

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ARTICLE INFO

Keywords:

Climate change perception
Food system
Value chain
Adaptation
Mitigation
Nigeria

ABSTRACT

Africa's food systems are among the most vulnerable sectors to climate risk. Unfortunately, numerous activities along food supply chains (production, processing, storage, marketing and consumption) are also important contributors to climate change. Despite the differential effect of climate events on activities along food supply chains and vice versa, most climate change perception studies in agriculture focus on producers, particularly crop farmers. This study adopts a value chain perspective to examine climate change perceptions among economic agents all along the maize-poultry value chain in Nigeria. We find that economic agents perceive those climate events that have a direct effect on their economic activity and this is not restricted to crop farmers. We also find that very few actors along the maize-poultry value chain believe that their economic activity negatively affects the environment and contributes to climate change. Though African countries might currently not be major contributors to climate change, this indicates a need for more awareness among economic agents about the effects of various agriculture-related activities on the environment and their contributions to climate change to encourage practices and technologies that can reduce agriculture's negative effect on the environment and contribution to climate change.

1. Introduction

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) has confirmed that many countries worldwide are experiencing increased incidences of climate-related hazards such as heat waves, droughts, floods and cyclones, with disproportional impacts on poor and vulnerable populations in developing countries (IPCC, 2014). Africa's food systems (including production, transport, processing, storage, marketing and consumption) are among the most vulnerable sectors to climate risk because of heavy reliance on rain fed agriculture, high intra- and inter-seasonal climate variability, recurrent droughts and floods that affect both crops and livestock, and low adaptive capacity due to persistent poverty and low technological development (Boko et al., 2007; IPCC, 2014).

Without appropriate adaptation actions, climate change will exacerbate food insecurity in the region and derail global efforts to achieve a

zero-hunger world (Thornton et al., 2011; Wheeler and Von Braun, 2013). Unfortunately, food systems also contribute to climate change. For instance, agricultural activities such as the use of inorganic fertilizer, livestock production, biomass burning, and manure handling are sources of greenhouse gases. Similarly, industrialization, food processing and transportation also contribute to climate change. Thus, adapting food systems to the threats posed by climate change must occur while simultaneously mitigating greenhouse gas emissions emanating from the sector.

In this paper, we assess climate change perceptions among different actors in the maize-poultry value chain in Nigeria, where climate change poses a serious threat to food production (Ajetomobi et al., 2015; Bosello et al., 2018). In particular, we examine (1) the heterogeneity in perception of changes in climate events among maize farmers, maize traders, feed millers, poultry farmers and poultry retailers; (2) whether actors perceive that their activities contribute to climate change; (3) the

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<https://doi.org/10.1016/j.jenvman.2020.110430>

Received 16 November 2019; Received in revised form 11 January 2020; Accepted 12 March 2020

Available online 25 March 2020

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factors determining the perceived changes in climate; and (4) the determinants of the actors believing that their economic activities contribute to climate change.

It is well established that perception is an important precondition for effective climate change adaptation and mitigation (Maddison, 2007; Adger et al., 2009; Arbuckle et al., 2015). Farmers' attitudes towards adjusting farming activities to adapt to changes in climate and to contribute to a decrease in greenhouse gas emissions are shaped by their perceptions about climate change and associated risks (Maddison, 2007). Consequently, there is a growing body of literature investigating farmers and other stakeholders' perceptions of climate change. The vast majority of these studies have reported that most populations have perceived changes in climate, particularly in terms of increasing temperatures and decreasing and irregular rainfall patterns (e.g., Mertz et al., 2009; Deressa et al., 2011; Combest-Friedman et al., 2012; Bryan et al., 2013; Tambo and Abdoulaye, 2013; Boansi et al., 2017). Some of the studies have shown that farmers' perceptions are in line with records from meteorological stations (Meze-Hausken, 2004; West et al., 2008; Gbetibouo, 2009; Hasan and Kumar, 2019). Another strand of the literature has confirmed that farmers' perceptions and awareness of climate change lead to behavioral changes in terms of the uptake of adaptation measures (Nhemachena and Hassan, 2007; Deressa et al., 2011; Tambo and Abdoulaye, 2012; Waldman et al., 2017).

Our paper makes several contributions to the existing literature. First, while there is an increasing number of studies documenting perception of climate change in the food system, most previous studies have focused largely on farm households. In contrast, our paper adopts a value chain approach by looking at how six different actors along the poultry-maize value chain perceive climate change.¹ Climate change may have differential effects on each of these actors; hence, understanding their perceptions and exposure to climate events will be useful in designing appropriate awareness-raising and adaptation strategies tailored to each actor. Second, most studies on farmers' climate change perceptions have focused on crop farmers, and the few studies in the area of animal husbandry tend to be based on the perceptions of large-livestock farmers or agro-pastoralists (e.g., Silvestri et al., 2012; Barnes et al., 2013; Zampaligré et al., 2014; Debela et al., 2015). The poultry subsector, despite its sensitivity to climate change and its important contributions to rural livelihoods (Nyoni et al., 2019), has received limited attention in the climate change literature. We contribute to filling this gap by examining climate change perceptions among poultry farmers and traders. Third, we also expand on previous research by investigating the perceptions of the poultry-maize value chain actors regarding whether their activities contribute to climate change. This is important, as efforts to mitigate greenhouse gas emissions in food systems may hinge on whether the actors in the system perceive that their activities are contributing to climate change in the first place. Finally, in addition to comparing climate perceptions across the various actors, we highlight differences in perceptions across two climatic zones. Our data comes from Kaduna state in north-west Nigeria where drought is a common phenomenon, and Oyo state in south-west Nigeria where flood is the main climate extreme event; with both flooding and drought occurring alongside increased temperatures.

The remainder of the paper is structured as follows. Section 2 presents the conceptualization of how climate change affects various activities along the maize-poultry value chain as well as the ways various activities along the maize-poultry value chain contribute to climate change. Section 3 describes the study methodology while Section 4 presents the study results and Section 5 concludes.

2. Conceptualizing the interaction between climate events and the maize-poultry value chain

Like other agricultural activities, climate change significantly affects the poultry-maize value chain in Nigeria. Simultaneously, poultry production and associated activities contribute to climate change. However, these interactions with climate change and their implications are rarely part of policy debates and need to be better addressed in the development literature. Most discussions about climate change and agriculture focus largely on crop production, with limited consideration for the rapidly growing livestock industries and associated supply chains.²³ This section discusses (1) how climate change is affecting and likely to affect the maize-poultry value chain in Nigeria and (2) how poultry farming and associated activities affect climate change.

2.1. How does climate change affect the poultry-maize value chain in Nigeria?

Climate change effects vary along the poultry-maize value chain. Maize farming in Nigeria is largely rain fed and subject to irregularities in rainfall and temperature patterns (Ayanlade et al., 2017). Thus, maize farmers are directly affected by many climate events such as increased temperature and increased frequencies of droughts and/or floods. Drought is a major challenge to maize production in northern Nigeria (Ogunlade et al., 2010; Tambo and Abdoulaye, 2013). Increased temperatures can be stressful for the maize crop, affecting its growth. Similarly, under rain fed production, variability in rainfall, the onset and length of the rainy season, rainfall amount and the number of rainy days all play a role in maize production and yield (Omotosho et al., 2000). For maize to flourish, it needs dry conditions in the flowering stage and large quantities of rain in the vegetative stage (John and Olanrewaju, 2014). Studies have shown that maize production in Nigeria from 1990 to 2050 will experience high variability and increased sensitivity to weather from 2025 onwards (Olabisi et al., 2016). Thus, these effects are only likely to increase in the future.

Like maize farmers, poultry farmers in Nigeria experience the direct effects of climate change as events such as increased heat stress, frequency of droughts and flooding, all directly impact poultry farming. Higher temperatures (linked to changing weather patterns) affect the growth rate of birds, the quality of meat and eggs produced, and the frequency of disease outbreak (Gregory, 2010; Liverpool-Tasie et al., 2019a). Limited access to water during drought also directly affects poultry farming. Increased frequency of droughts and poor access to water are also challenges for poultry production.

Maize traders (who are not also farmers) are likely to have different experiences with climate events. They may not experience the direct effects of climate events on production but may be exposed to the effects of events such as increased temperature and increased flooding on the quality of their maize. High levels of heat and humidity are associated with maize contamination, due to mold and fungi and this has been demonstrated along the maize-poultry value chain in Nigeria (Liverpool-Tasie et al., 2019b). Feed Millers, like maize traders, are less likely to be exposed to direct climate events such as increased temperature, flooding and heat stress since they are largely focused on milling procured maize with other ingredients to produce feed. Their role is to

¹ By value chain we are referring to a set of activities consisting of actors and actions that improve (or add value to) a product while linking commodity producers to processors and markets.

² It should be mentioned that there have been some studies on climate change adaptation and mitigation in mixed crop-livestock farming systems in recent years (e.g., Thamo et al., 2017; Tang et al., 2018; Liverpool-Tasie et al., 2019a; Tang and Hailu, 2019).

³ Livestock production in Africa has been on an upward trend; no other meat production in Africa has skyrocketed at a faster rate than poultry. Using nationally representative data from Nigeria, Liverpool-Tasie et al. (2017) estimate that from 1980 to 2012, egg and chicken output grew by 300% and 220% respectively.

provide a product for poultry farmers (and live poultry retailers) to sustain and/or grow their birds. Feed millers vary in size and scope of operation. Many engage in custom milling for clients and patrons and thus stock their own ingredients. Others who produce branded feed for sale are also likely to procure their ingredients and potentially store them as well. If a disease outbreak occurs on poultry farms, it can affect the feed millers through the reduction in demand for feed, but this may be less apparent if such outbreaks were infrequent (Sanou et al., 2017). If feed millers need to store and/or transport maize, investments and costs may increase (for warehouses and transportation logistics) for storage due to unpredictable weather events that are capable of disrupting both yields and maize transportation logistics (Sanou et al., 2017). These all affect the final price of feed and cost of poultry production.

Other actors along the chain such as poultry retailers selling live birds are likely to have a similar experience as poultry farmers since they must maintain the bird's health until it is sold and passed on to the consumer. However, they might have further exposure to direct climate events such as heat stress and flooding as this may affect their procurement of the live birds. On the other hand, poultry retailers selling frozen/chilled birds are likely to have a different experience with climate events since they do not have to worry about keeping the birds alive. Thus, their limited exposure to the effects of heat stress and inadequate water availability. Their experience is likely to be more related to issues around electricity and logistics where they may be more exposed to climate events such as increased flooding which could damage electrical appliances and or cause increased frequency of blackout. To be able to keep the birds chilled or frozen they need to consider the cost of energy to have operations with freezers, storage, and their consumer base.

2.1.1. How do activities along the maize-poultry value chain contribute to climate change?

Agriculture contributes to global Greenhouse Gas (GHG) emissions due to constant production of methane (CH₄), ammonia (NH₃), and nitrous oxide (N₂O) that are major contributors to climate change (Sanou et al., 2017; Food and Agriculture Organization of the United Nations Statistics Division (FAOSTAT), 2019). Anthropogenic emissions of N₂O are primarily from agriculture sources (USGCRP, 2009). The structure and trajectory of growth in the maize poultry value chain could also have a significant effect on the Nigerian environment and future contribution to GHG emissions (Sanou et al., 2017). In Nigeria, the major contributors to GHG emissions comes from land use change, particularly deforestation and land clearing for agriculture and development (USAID, 2019).

Requirements for growing maize include healthy soil, farming equipment, and consistent water. The practices that farmers are using on their maize crops can affect the climate. Maize production practices can be intensive and depend on the technology available to the farmer. Production of maize can lead to the emissions of N₂O through, for instance, increased use of nitrogen fertilizer and crop residue burning. The global nitrogen fertilizer application has increased approximately 10-fold between 1950 and 2008 (Robertson and Vitousek, 2009).

Transportation is key throughout the maize poultry value chain, to move agriculture supplies, feed, and the poultry. The potential negative impacts of transportation on environment can be listed as degradation of air quality, greenhouse gas emissions, increased threat of global climate change, degradation of water resources, noise and habitat loss and fragmentation (Demirel et al., 2008). As the infrastructure improves and the demand for a product increases the more transportation is needed. In a study on several developed countries, emissions from transport are rising faster than from other energy-using sectors and are predicted to increase by 80% between 2002 and 2030 (Kahn Ribeiro et al., 2007). This raises concern about the potential effect of current and future growth trajectories in transportation in Nigeria.

For poultry farmers, the daily production of waste is a concern for

Table 1

Sample size across states and nodes.

Node	North	South	Full sample
Maize	288	288	576
Poultry	465	437	902
Feed millers	36	111	147
Retailer	243	333	576
Traders	199	128	327
Total	1231	1297	2528

producing GHG. The poultry housing and operation zones simultaneously produce proportional amounts of wastes – poultry manure, sewage water, nonfood products of killing rooms, fallen/dead poultry carcasses and incineration, hair, and feathers, manure being produced in most considerable quantities (Lysenko, 2008). The waste from poultry farming can also lead to the emissions of greenhouse gases (Sanou et al., 2017).

Machinery can be used when cultivating, harvesting, and processing the maize into food and animal feed. Majority of the machinery need fuel to operate and that can lead to an increase in carbon dioxide emissions. Industrialization for processing agriculture products has led to an increase in the need for energy. Energy consumption exerts a positive direct effect on carbon emission in Africa (Raheem and Ogebe, 2017).

Thus, as food systems transform across Africa, it is important to bear this simultaneous relationship between value chains and climate change in mind. These interactions and their implications need to be part of policy debates and addressed more in the development literature to ensure that current and future food systems are more resilient and productive.

3. Materials and methods

3.1. Data

This study relies on a survey conducted along maize-poultry value chains in two Nigerian states (Kaduna and Oyo) that have experienced rapid growth in poultry production over the last decade (see Figure A1 in the supplementary material for a map of the study area). Both states serve as major production zones for consumption centres in the country; Kaduna in the north and Oyo in the south. We used a stratified random sampling approach to capture heterogeneities over space and size at each of the selected nodes of the value chain. That means we purposively chose first nodes along the chain (i.e. maize farmers, feed millers, maize traders, poultry farmers etc.), then major areas of operation within each node and then strata of the actor within each area. Finally, from the list of actors in each stratum we randomly sampled individual actors. The supply chain segments (nodes) studied were central points downstream of the supply chain of chicken and eggs which feed the main consumption zone of Greater Ibadan City in south-west Nigeria and Kaduna City in north-west Nigeria. Ultimately, data was collected from over 2500 respondents including maize farmers, maize traders, poultry farmers, poultry feed millers, and poultry retailers between March and September 2017. Table 1 presents the distribution of sample size across the nodes.

Detailed information was collected (via a formal questionnaire administered by trained enumerators from the study area⁴) from each actor about their enterprise and enterprise manager as well as

⁴ The questionnaires were co-designed at Michigan State University (MSU) and institutions of higher learning in the study states in Nigeria. Then the questionnaires were coded and administered using computer aided personal interviews (CAPI) to minimize errors from data entry associated with paper surveys. The data collection was supervised by an experienced team of researchers at Institutions of Higher learning in the study area and MSU.

information on management and marketing practices. In addition, identical modules with questions on climate change awareness, perception and exposure were collected from all respondents at all nodes. This study focuses on four types of climate events that came out as potentially impacting the value chain from several stakeholder workshops that were held in 2016 and 2017 with representatives from all the nodes of the value chain in the two study regions. These climate events are (1) increased frequency of droughts, (2) increased frequency of floods, (3) increased heat stress and (4) increased average temperature.

3.2. Empirical strategy

We combine a descriptive analysis with several parametric estimations in a multiple regression framework. We use descriptive statistics to highlight the variation in perceptions about climate change and its link to economic activities revealed by actors along the maize-poultry value chain in our study areas. Then we explore our key hypothesis, which is that perceptions about climate events and their link to economic activities varies significantly across actors operating at different nodes along the value chain, likely due to differential exposure to and hence awareness of its impacts.

We explore the heterogeneity of climate change perceptions at the extensive and intensive margins. At the extensive margin, we explore the extent to which an economic actor along the maize-poultry value chain perceives that at least one of the four climate events commonly associated with the production and distribution of maize and poultry products has occurred between when they were a teenager and now (i.e., a period of about 30–40 years, given that the mean age of respondents in our sample was 52 years). At the intensive margin, we explore the number of climate events perceived by an economic actor over the same time period. Then we explore the determinants of perception of each of the individual climate events separately to explore the extent to which economic actors (along the value chain) might be more likely to perceive a particular climate event compared to others. Finally, we explore the extent to which respondents believe that their primary economic activity contributes to climate change and how this varies across actors at the different nodes of the maize-poultry value chain.

To assess the perception of climate events at the extensive margin, we explore the probability that respondent i perceives at least one of 4 climate events. This is a binary outcome which can be estimated using a probit model where the response probability depends on a set of explanatory variables. We model this probability with the model below by Wooldridge (2010).

$$P(y = 1|X) = \Phi(x\beta) \quad (1)$$

Where y is the binary outcome variable which takes a value of 1 if the respondent perceived any of the 4 climate events and 0 otherwise. X is the vector of explanatory variables including the age and gender of the respondent, the length of experience they have had in their business, their exposure to formal education and training, their membership in a farmers group, the coefficient of variation of rainfall and temperature in their community during the survey year as well as the node of the value chain that they operate at. These explanatory variables are motivated by literature on the determinants of farmers' perceptions of climate change (e.g., Deressa et al., 2011; Debela et al., 2015; Opiyo et al., 2016). Φ is the standard normal cumulative distribution function and β is a vector of parameters to be estimated.

Consequently, we first estimate the following regression model:

$$y_i = \alpha + \beta X_i + \gamma \text{Node}_i + \varepsilon_i \quad (2)$$

Where y , X and β are as earlier defined and γ refers to the coefficient associated with the node of the value chain that respondent i operates at. ε_i is the error term assumed to be normally distributed with mean zero and variance sigma squared.

To estimate the extent of perception we replace the binary variable (1 if the respondent perceived any of the 4 climate events and 0 otherwise) with the number of climate events the respondent observed. We then estimate equation (2) using the zero inflated Poisson model typically used for a count dependent variable such as ours and which accounts for the pile up of 0's since 38% of our study respondents did not perceive any of the four climate events.

To explore respondent perception about the four individual climate events we use the multivariate probit (MVP) model. The MVP model allows us to control for the interdependence between perception of the different climate events. It accounts for potential relationships between the different climate events that can lead to the correlation of unobserved factors and the error term (Greene, 2012). In this case, we have a variable y_{im} rather than just y_i for each of the $m = 4$ climate events. Thus we model the respondents perception of either of these 4 events using the following 4 equation MVP model in line with Cappellari and Jenkins (2003):

$$Y_{im}^* = [\beta_m' X_{im} + \varepsilon_{im}]; m = 1, 2, 3, 4 \quad (3)$$

$Y_{im} = 1$ if respondent i perceived a particular climate event and 0 otherwise, ε_{im} , $m = 1, \dots, 4$, are error terms distributed as multivariate normal, each with a mean of zero, and variance-covariance matrix V , where V has values of 1 on the leading diagonal and correlations $\rho_{jk} = \rho_{kj}$ as off-diagonal elements. X_{im} is the vector of explanatory variables included in the model. β_m is a vector of parameters to be estimated. We evaluate the MVP model using Geweke-Hajivassiliou-Keane (GHK) smooth recursive conditioning simulator. For each observation, a likelihood contribution is calculated for each replication, and the simulated likelihood contribution is the average of the values derived from all the replications. The simulated likelihood function for the sample as a whole is then maximized using maximum likelihood.

4. Results and discussion

Fig. 1 presents the share of respondents at particular nodes along the maize-poultry value chain in Nigeria who have perceived at least one of the 4 study climate events [i.e., (1) increased frequency of droughts, (2) increased frequency of floods, (3) increased heat stress, and (4) increased average temperature] between when they were a teenager and now. The mean age of respondents in our sample was 52 years so this is a period of about 30–40 years.

A majority of the actors (64% of our sample) along the maize-poultry value chain are aware of at least one climate event. However, the share of feed millers perceiving climate events (consistent across states) is significantly lower than actors at other nodes. Only about 30% (5%) of these actors reported to have perceived at least one climate event in Oyo (Kaduna). This compares to between about 50% and 85% for other nodes. Across states, there is a higher share of actors who perceive at least one climate event in Oyo compared to Kaduna in all nodes except poultry farmers and live bird sellers. Given that poultry farmers and live bird sellers both need to maintain and, in some cases, grow birds, this perception is likely driven by common experiences shared that expose these actors in Kaduna to particular climate events.

Fig. 2 breaks down the perceptions of actors along the value chain for individual climate events. There is a strong perception across all nodes in Oyo state that there has been an increase in the average temperature. The largest share of actors in all nodes perceived increased temperature. Another climate event that tends to be perceived by actors along the maize-poultry value chain is increased heat stress. The one exception is poultry retailers specialized in chilled/frozen birds where less than 15% of actors perceived this climate event. Across nodes, maize traders tend to have a strong perception of climate events. Maize traders have the largest share of actors perceiving each of the climate events; consistently between about 40% and 75%.

At the other extreme but in line with Fig. 1, the feed mill node has the

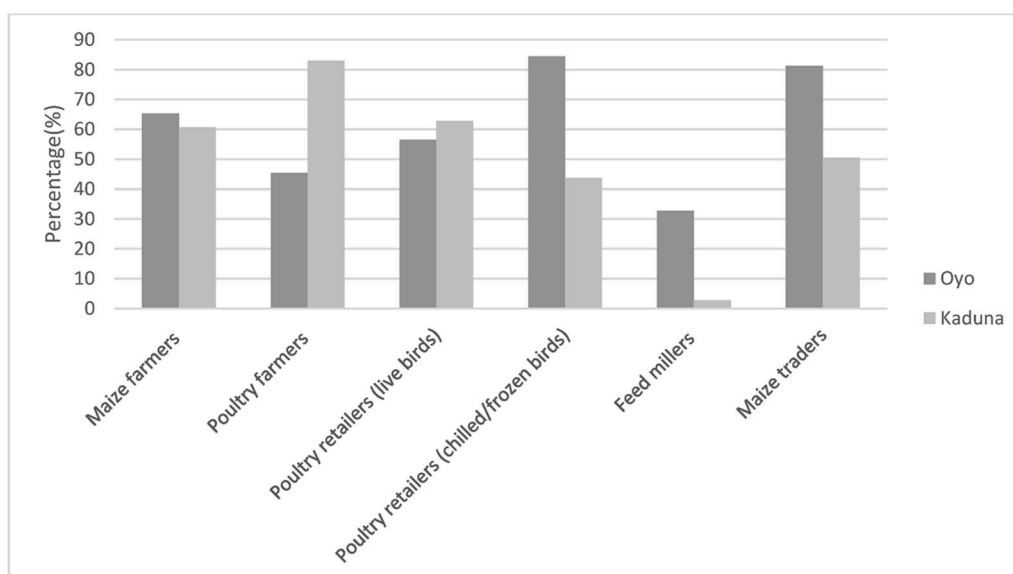


Fig. 1. Percentage of actors along the maize-poultry value chain perceiving at least one climate change event.

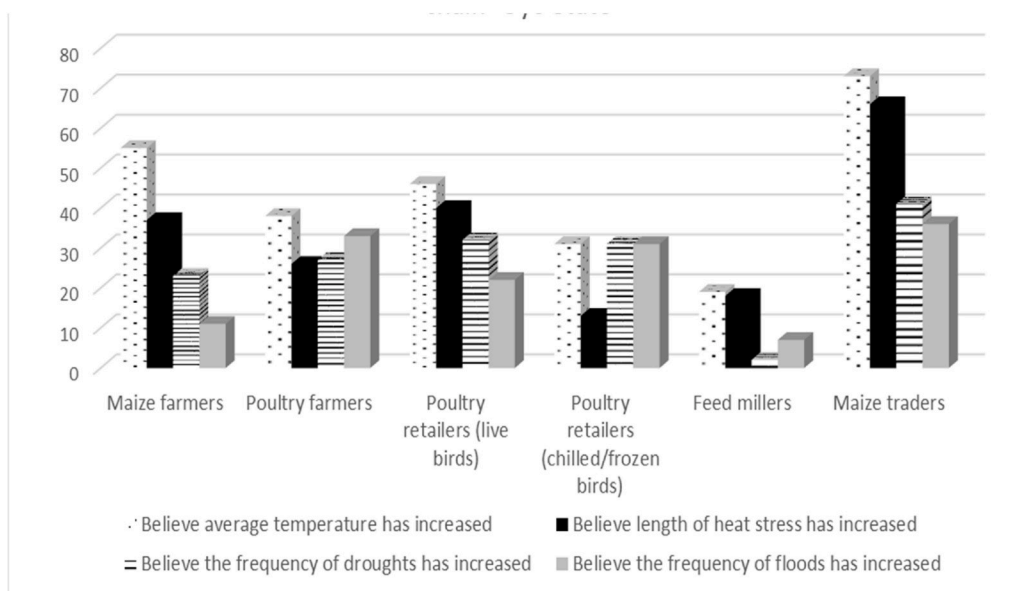


Fig. 2. Perception of climate change events along the maize-poultry value chain in Oyo State, Nigeria.

lowest share of actors perceiving all climate events apart from the increase in heat stress. Less than 20% of feed millers perceived any particular climate event. Maize farmers in Oyo state tend to be most aware about increases in average temperature and heat stress but less aware about increased frequency of droughts and floods. On the other hand, poultry farmers in Oyo are more likely to have perceived increases in the frequency of floods compared to other events as seen from Fig. 2.

In contrast to Oyo, there is more significant variation in the climate event that is most perceived across the nodes of the maize-poultry value chain in Kaduna (see Fig. 3). For example, while the largest share of actors that perceive increased floods are poultry retailers (particularly those involved in selling frozen birds), poultry farmers and maize traders are the largest share of actors that perceived increased temperature compared to other events. Maize farmers tend to be aware of temperature related climate events as compared to other events, the largest share of maize farmers perceived increased heat stress (50%) followed closely by increased temperature, which was perceived by 45% of these

farmers. Maize farmers also tend to perceive increased occurrence of droughts. While this was not the climate event perceived by the largest share of maize farmers, the share perceived by maize farmers is still higher than the share perceived of all other nodes. Poultry farmers particularly tend to have strong perceptions of increased temperatures with over 70% of respondents at that node perceiving this climate event; higher than all others.

Fig. 4 presents the share of actors along the value chain who believe that climate change negatively affects their economic activities while Fig. 5 presents the perceptions of these same actors about the extent to which their economic activities affect climate change. Several points stand out. First, across all nodes of the maize-poultry value chain, the share of respondents who believe their economic activities contribute to climate change is consistently lower than the share who believe that climate change affects their businesses. Second, apart from poultry farmers in Kaduna where 59% believed their activities contributed to climate change, the share of actors at all other nodes is very low;

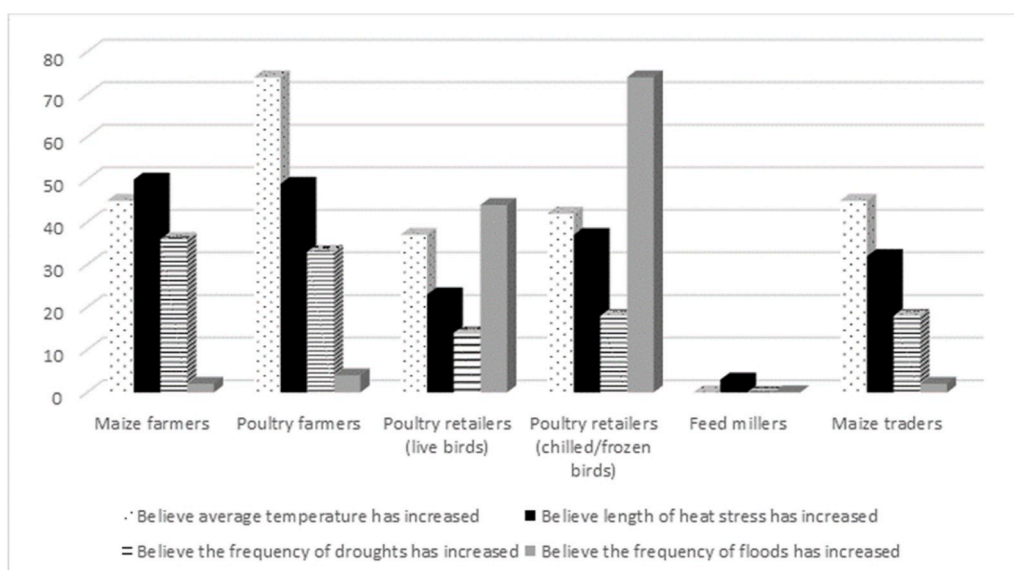


Fig. 3. Perception of climate change events along the maize-poultry value chain in Kaduna State, Nigeria.

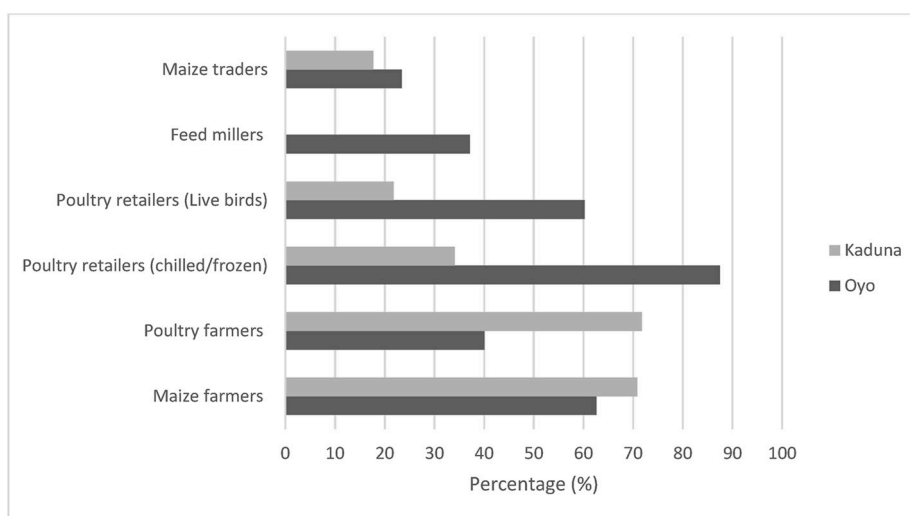


Fig. 4. Percentage of actors along the maize-poultry value chain that believe climate change affects their business.

between 0% and about 30%.

Despite the numerous efforts to promote climate-smart agriculture as a way to make maize farmers more resilient and also to reduce agriculture's contribution to greenhouse gas emissions, maize farmers are the least likely to believe that their activity (maize farming) contributes to climate change; 3% and 14% in Oyo and Kaduna respectively. This contrasts with the share of maize farmers who believed climate change was hurting their economic activity; 63% and 71% in Oyo and Kaduna respectively. Compared to other nodes, the share of maize traders and feed millers in Oyo (Kaduna) that felt that climate change affected their economic activity was low; 23% and 37% (18% and 0%) respectively, with the share who feel their activity affects the environment even lower at 5% and 30% (4% and 0%).

The descriptive analysis above was complemented with an empirical analysis. Table 2 presents the descriptive statistics of the study variables while Table 3 reveals the results of the probit model on the determinants of respondent perception about climate events along the maize value chain in Nigeria. Table 2 reveals perception variation between Kaduna and Oyo that is consistent with climate events associated with their agro-ecological conditions. Respondents in the north are on average, more

likely to have perceived climate events related to temperature and frequency of droughts compared to Oyo. On the other hand, respondents in Oyo are more likely to have identified increased flooding (33%) compared to only 4% in Kaduna. While climate change is expected to lead to increase aridity and desertification in northern Nigeria, it will lead to increase in flooding in the southern part especially in the coastal regions (Uyigue and Agho, 2009).

Large size for poultry farm means the farm has more than 100 birds, while for feed millers it means that milling capacity is greater than 4 tons/day (0/1), for chicken retailers it means that the number of chickens sold daily >50 (0/1) and for traders it means that the trader sells more than 32 tons per month (1/0), for maize farmers, the area allocated to maize was divided into three terciles and the mean land size in each of the three terciles is as follows: T1 = 0.48Ha, T2 = 2.01Ha, T3 = 9.24Ha. Maize farmers are the base for the nodes. The dependent variables capture those reported perceiving an increase in average temperature, increase in heat stress, the frequency of drought and floods.

Though there is variation by node, consistently fewer people in both states believe that their activity contributes to climate change compared

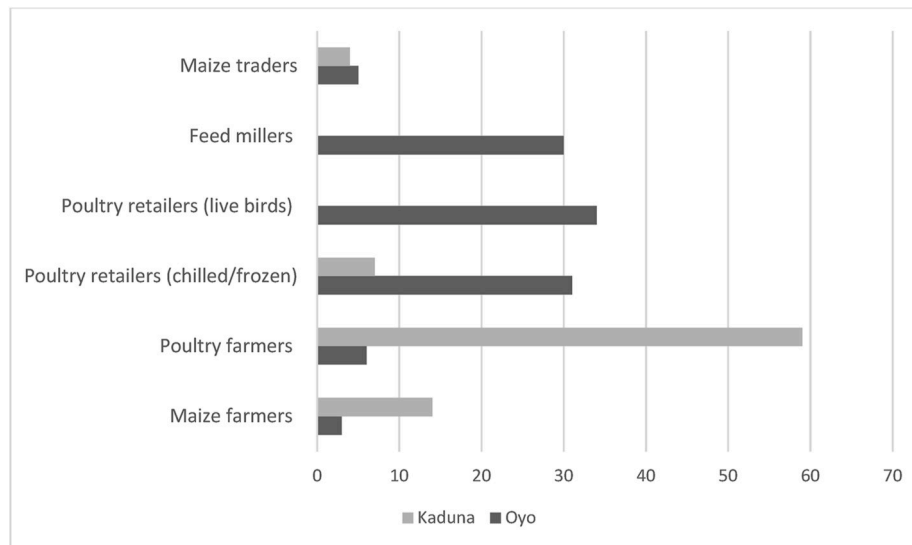


Fig. 5. Share of actors along the maize-poultry value chain who believe their activities contribute to climate change.

Table 2
Descriptive statistics.

	North		South	
	mean	standard deviation	mean	standard deviation
Age	52.13	20.21	51.41	13.39
Male (0/1)	0.46	0.50	0.21	0.41
Education (0/1)	0.65	0.48	0.92	0.27
Number of years in activity	6.22	8.37	8.27	8.65
Received training in activity (0/1)	0.06	0.24	0.07	0.26
Size (0/1)	0.08	0.27	0.09	0.28
Distance to highway in Km	5.56	10.26	4.10	12.73
Membership in association (0/1)	0.05	0.22	0.05	0.22
CV of rain	132.14	0.80	92.87	1.39
CV of temperature	7.66	0.78	6.20	0.63
Have perceived and increase in temperature (1/0)	0.48	0.50	0.39	0.49
Have perceived and increase in heat stress (1/0)	0.48	0.50	0.27	0.45
Have perceived an increased frequency of droughts (1/0)	0.32	0.47	0.27	0.45
Have perceived an increased frequency of floods (1/0)	0.04	0.19	0.33	0.47
Believe climate change affects their business	0.68	0.47	0.40	0.49
perceived that their activities contribute to climate change	0.55	0.50	0.06	0.24
Number of observations	1231		1297	

to those who believe climate change affects their business. This is particularly the case in Oyo where 40% of respondents feel that climate change affects their economic activities but only 6% of them feel their activities contribute to climate change. Women are active participants in the maize-poultry value chain in both Kaduna and Oyo though their presence is significantly more in Oyo (79% of economic actors) compared to Kaduna where they are 54%. A majority of farmers in our study sample are formally educated and have been engaged in their economic activity along the value chain for 6 (8) years in Kaduna (Oyo). Their activities tend to be located in or around cities with majority of actors being micro and small enterprises.

Columns 1 and 3 of Table 3 are the average marginal effects of the explanatory variables. They tell us the average change in probability of perceiving at least one climate event when our independent variable

increases by one unit. Columns 5 and 7 reveal the marginal effects of the explanatory variables on the intensity of awareness measured as the number of climate events perceived. Table 3 reveals that the probability of perceiving at least one climate event varies significantly across actors along the maize-poultry value chain in Nigeria, particularly in Kaduna. Compared to maize farmers in Kaduna, maize traders, poultry retailers and feed millers are all less likely to perceive at least one climate event and this is significant at 1%. The magnitude of these differences is significant ranging between 41.9 percentage points for traders to 52.7 percentage points for live bird sellers. However, the probability of perceiving climate events is not significantly different between maize farmers and poultry farmers. This is consistent with the hypothesis that economic actors more likely to be directly engaged in production (such as maize farmers and poultry farmers) are more likely to be exposed to these climate events and thus perceive them compared to others whose exposure might be less direct such as traders. In Oyo state, feed millers are less likely to have perceived any of the study climate events and perceive a fewer number of the 4 climate events compared to maize farmers and this is significant at 1%. Compared to maize farmers, feed millers are 28.3 percentage points less likely to perceive at least one event. They also tend to perceive 1.05 fewer climate events. However, the difference between maize farmers and other actors along the chain is not significantly different. This difference between Oyo and Kaduna might be because Kaduna is located in a slightly hotter climate so actors close to climate events in this region are likely to experience climate change effects, which will subsequently inform their perception.

Apart from an economic actor's location along the value chain, we find that a male actor along the maize-poultry value chain in northern Nigeria is 9.4 percentage points less likely to perceive a climate event compared to a female respondent and this is significant at 5%. This is consistent with Bryan et al. (2013) and Opiyo et al. (2016) who obtained similar results and is likely due to the fact that women tend to be more directly exposed to such climate events in their economic activities outside of the home as well as in their home production and maintenance activities compared to men whose exposure is likely limited to their economic activities outside the home. In the south, while we do not see any significant difference between males and females at the extensive margins, women are more likely to perceive more climate events than men are, and this is likely due to a similar reason of more exposure. Table 3 also reveals that those who have been formally educated in Kaduna are less likely to perceive at least one climate effect. This is contrary to the results for the south and a number of studies that have found that level of education does not significantly affect climate change

Table 3
Determinants of perception of climate change.

LABELS	Probability of perceiving at least one climate change event (1/0) (Probit)				Number of climate events perceived (ZIP)			
	North		South		North		South	
	Marginal effects	p > 0	Marginal effects	p > 0	Marginal effects	p > 0	Marginal effects	p > 0
Age in years	-0.000	0.898	-0.001	0.345	-0.108	0.803	0.002	0.380
Male (0/1)	-0.094**	0.014	0.033	0.380	-15.450	0.773	-0.188*	0.086
Education (0/1)	-0.223***	0.000	-0.058	0.137	-67.163	0.769	0.030	0.776
Number of years in activity	0.005***	0.007	0.005***	0.001	1.038	0.763	0.010***	0.008
Received training in activity (0/1)	0.085***	0.007	0.151***	0.000	39.296	0.768	0.290***	0.001
Size (0/1)	-0.128***	0.000	-0.097***	0.001	-14.328	0.773	-0.315***	0.001
Distance to highway in Km	-0.000	0.544	-0.001	0.163	1.574	0.786	0.006**	0.014
Membership in association (0/1)	0.013	0.709	0.037	0.246	26.047	0.770	0.092	0.337
CV of rain in 2017	-0.035***	0.004	-0.001	0.907	-3.077	0.786	-0.023	0.394
CV of temperature in 2017	0.198**	0.026	0.006	0.928	43.743	0.752	0.233	0.196
Poultry farmers	0.029	0.537	0.093	0.371	14.367	0.764	0.431	0.207
Feed millers	-0.465***	0.000	-0.283***	0.005	-128.570	0.768	-1.053***	0.000
Retailers - frozen/chilled birds	-0.440***	0.000	-0.058	0.850	-37.815	0.823	0.969	0.537
Retailers - live birds	-0.527***	0.000	0.033	0.900	-61.383	0.789	1.070	0.406
Traders	-0.419***	0.001	0.075	0.698	-192.349	0.747	-0.524	0.275
Maize farmers (base)								
	1231		1297		1231		1297	

Note: ***p < 0.01, **p < 0.05, *p < 0.1. For the ZIP results, age is the predictor of the excess zeros. Large size for poultry farm means the farm has more than 100 birds, while for feed millers it means that milling capacity is greater than 4 tons/day (0/1), for chicken retailers it means that the number of chickens sold daily >50 (0/1) and for traders it means that the trader sells more than 32 tons per month (1/0), for maize farmers, the area allocated to maize was divided into three terciles and the mean land size in each of the three terciles is as follows: T1 = 0.48Ha, T2 = 2.01Ha, T3 = 9.24Ha. Maize farmers are the base for the nodes. The dependent variables capture those reported perceiving an increase in average temperature, increase in heat stress, the frequency of drought and floods.

perception (Gbetibouo, 2009; Deressa et al., 2011; Silvestri et al., 2012; Bryan et al., 2013; Opiyo et al., 2016). As expected, individuals who have been engaged in their economic activity along the maize-poultry value chain for longer or trained in the activity are more likely to perceive at least one event as well as more climate events. This is consistent with Bryan et al. (2013). They found that farmers with more farming experience were more likely to perceive long-term changes in rainfall variability, an increase in average temperature, and a decrease in average rainfall. In general, larger operations are less likely to perceive climate events compared to smaller operations.

Table 4 presents the results of the MVP estimation on the determinants of the perception of particular climate events. It reveals that the perception of climate events by actors along the maize-poultry value chain varies significantly across the different climate events and across study states. Compared to maize farmers in Kaduna, poultry farmers are more likely to perceive increases in average temperature and heat stress. This is consistent with other studies that have demonstrated that poultry farmers tend to be exposed to heat stress, which affects the growth and productivity of their birds (Liverpool-Tasie et al., 2019a). However, they are not significantly more likely to perceive increases in the frequency of

Table 4
Determinants of perception of climate change events.

	Increased temperature (1/0)	Increased Heat stress (1/0)	Frequency of Drought (1/0)	Frequency of flood (1/0)	Increased temperature (1/0)	Increased Heat stress (1/0)	Frequency of Drought (1/0)	Frequency of flood (1/0)
	North				South			
Age	-0.003**	-0.005***	-0.002	0.002**	-0.001	-0.001	-0.003**	-0.005***
Male (0/1)	-0.04	-0.084**	-0.048	0.01	-0.03	0.02	0.96	-0.084**
Education (0/1)	-0.123**	-0.258***	-0.143***	-0.077**	0.062	-0.045	-0.123**	-0.258***
Number of years in activity	0.006***	0.004**	0.005***	0.00	0.004**	0.005***	0.006***	0.004**
Received training in activity (0/1)	0.131***	0.145***	0.054**	0.021	0.065**	0.161***	0.131***	0.145***
Size (0/1) = 1	-0.111***	-0.103***	0.014	0.03	-0.134***	-0.125***	-0.111***	-0.103***
Distance to highway in Km	-0.001	-0.001	0.00	0.00	0.00	0.001	0.001	0.001
Poultry farmers	0.118**	0.124**	-0.057	0.081**	-0.07	0.232**	0.118**	0.124**
Feed millers	0.00	-0.289**	0.00	0.00	-0.441***	-0.144	0.00	-0.289**
Retailers - frozen/chilled birds	-0.149	-0.163	-0.133	-0.327	0.049	-0.237	-0.160	-0.159
Retailers - live birds	-0.239	-0.344	-0.244	-0.417	0.143	0.043	0.093	0.171
Traders	-0.650**	-0.789**	-0.03	-0.147	-0.284	0.013	-0.650**	-0.789**
Maize farmers (base)								
Membership in association (0/1)	0.089**	0.148***	0.046*	-0.079**	0.062*	0.037	0.089**	0.148***
CV of rain	-0.008	-0.007	-0.002	-0.020**	-0.009	0.001	0.0003	0.003
CV of temperature	0.264**	0.282***	-0.013	0.062	0.087	0.069	0.264**	0.282***
Number of observations	1231				1297			

Note: ***p < 0.01, **p < 0.05, *p < 0.1.

drought, which is understandable, as drought tends to be a climate event commonly affecting crop farmers, particularly cereal farmers in the north (Tambo and Abdoulaye, 2013). Poultry farmers are 8.1 percentage points more likely to perceive increases in the frequency of flooding, another factor that has a strong and negative effect on poultry production (drowning chickens and introducing disease) particularly for farmers using the deep litter system. In Oyo, poultry farmers are significantly more likely than maize farmers to perceive all of the climate events, except increased temperature, indicating that poultry farmers are also significantly exposed to the effects of climate change and thus very aware of these events. As expected, where significant, feed millers are less likely to perceive climate events than maize farmers. This effect is quite significant in magnitude ranging between 28.9 percentage points for heat stress in Kaduna and 44.1 percentage points less for heat stress in Oyo.

Compared to maize farmers, maize traders in Kaduna are significantly less likely to perceive temperature related climate events. The probability of perceiving increased temperature and heat stress are 65 and 78.9 percentage points respectively. In Oyo, maize traders are 65 percentage points less likely to perceive increased droughts and 78.9 percentage points less likely to perceive floods. The large effect on flooding is consistent with the reality that flooding is often a climate event faced in the south of Nigeria where Oyo state is located (Sanou et al., 2017) and a climate event that maize farmers are more likely to be directly exposed to compared to maize traders.

Factors such as the number of years an economic actor has been engaged with the subsector, exposure to training and being a member of an association tend to be positively associated with perceptions about almost all the climate events in both Oyo and Kaduna. This contrasts with factors such as farm size, education and age, which tend to be consistently negatively associated with perceiving all of the climate events in both Oyo and Kaduna. Though surprising, it might be because larger farms are engaged in practices that prevent them from facing the effect of extreme conditions such as air ventilation, water ventilation, engagement in fish farming, litter spreading and de-caking in chicken houses, the use of energy efficient bulbs, the use of vitamins and medicines for the birds (Liverpool-Tasie et al., 2019a).⁵ Older and more educated farmers might be more conservative and less willing to accept the phenomenon of climate change as explained earlier. As expected, farmers in locations which have higher coefficients of variation in their annual temperature in Kaduna tend to be significantly more likely to perceive increased temperature and heat stress while those in Oyo with higher coefficient of variation in temperature tend to be more likely to perceive increased drought and flooding. Southern Nigeria is more likely to experience flooding events and the north is expected to see more drought and desertification (Uyigwe and Agho, 2009; Tambo and Abdoulaye, 2013).

However, the effect of coefficient of variation in rainfall tends not to impact perception of most climate events, except for flooding in Kaduna where the effect is negative. This is not surprising given that flooding deals with precipitation and farmers in northern Nigeria are usually associated with drought-like conditions and thus generally less likely to be exposed to flooding. Higher variation in temperature is more likely due to late onset of rains, changing mid-season rains or early cessation of rain.

Table 5 presents the correlation matrix for the different climate events. As expected, perceptions of climate events are complementary. Respondents who perceive one event are more likely to perceive others. Consistent with the nature of the climate events, (i.e. whether based on temperature or precipitation) we find higher levels of complementarity among temperature related climate events compared to those related to

precipitation. These results indicate that perceptions are correlated and justify the use of the MVP estimation over individual probit estimations for the different events.

Finally, we explore the determinant of economic agent's perception about their activities on climate change. Table 6 reveals that compared to maize farmers, poultry farmers, maize traders and feed millers are all more likely to believe that their economic activities contribute to climate change. Poultry farmers and feed millers are 10 and 7.9 percentage points more likely to have believed that their economic activity contributes to climate change while this is much higher for maize traders at 17.7 percentage points. This indicates that though their activities have direct effects on climate change through high greenhouse gas emissions, maize farmers are significantly less likely to believe that their farming activities contribute to climate change and this has important implications for their likely willingness to adapt technologies being promoted to reduce these negative effects.

Compared to respondents in Oyo, those in Kaduna are less likely to believe that their economic activities affect climate change. Other factors that are associated with the probability of believing that one's economic activities contribute to climate change are firm/farm size, education and experience which are all positive. This is consistent with the idea that larger operations, actors with more experience and exposure to formal education are more likely to be aware of climate events and their drivers, while simultaneously being aware of the effects of their activities.

5. Conclusion

The study results reveal that there is significant variation in perceptions about climate change across actors along the maize-poultry value chain in Nigeria and also across regions within the country. Economic actors with more direct exposure to climate events (such as women, poultry farmers and maize farmers) are more likely to perceive these events than those whose exposure is more indirect such as men, feed millers and maize traders. We find that other economic actors along the maize-poultry value chain, typically ignored in the literature on climate change are also experiencing the effects of climate change on their economic activities, which in turn affects their perception about these climate events. Across climate events, we find that economic actors tend to perceive those particular climate events that have a direct effect on their economic activity. For example, increased temperature and heat stress significantly affect crop and animal production and thus tend to be significantly perceived by these farmers. Similarly, increased flooding, which can devastate a farmer's poultry flock, or be associated with increase in the frequency of power outage is also highly perceived by poultry farmers, and poultry retailers selling frozen/chilled birds. This is important given the prevalence of studies that only focus on crop

Table 5

The complementarity or substitutability of climate event perceptions.

	NORTH	Temperature	Heat	Drought	Flood
Temperature	1				
Heat	0.883*** (0.0558)	1			
Drought	0.658*** (0.0576)	0.692*** (0.0609)	1		
Flood	0.196*** (0.0594)	0.190*** (0.0591)	0.187*** (0.0638)	1	
SOUTH					
Temperature	1				
Heat	0.664*** (0.0493)	1			
Drought	0.580*** (0.0515)	0.108*** (0.0629)	1		
Flood	0.227*** (0.0466)	0.484*** (0.0491)	0.772*** (0.0537)	1	

Note: Standard errors in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1.

⁵ We are not claiming causality here and recognize that It is also possible that larger farmers have adopted these practices in response to perceiving climate impacts.

Table 6

The determinants of believing that economic activities contributes to climate change.

	Marginal effects	p value
Age	0.000	0.726
Male (0/1)	0.004	0.856
Education (0/1)	0.043*	0.080
Number of years in activity	0.002*	0.083
Received training in activity (0/1)	−0.020	0.263
Large operation (1/0)	0.093***	0.000
Distance to highway in Km	−0.002*	0.067
North (1/0)	−0.073**	0.026
Poultry farmers	0.100***	0.002
Feed millers	0.079**	0.049
Retailers - frozen/chilled birds	0.043	0.357
Retailers - live birds	−0.020	0.597
Traders	0.177**	0.032
Maize farmers (base)		
Membership in association (0/1)	0.024	0.210
CV of rain	0.005***	0.000
CV of temperature	−0.111***	0.000
Number of observations	2528	

Note: ***p < 0.01, **p < 0.05, *p < 0.1.

farmers and indicates the need for further studies on other actors along the maize-poultry value chain to encourage their adoption of technologies and practices that will make them more resilient to climate events.

Another important finding is that few actors along the maize-poultry value chain believe that their economic activity negatively affects the environment and contributes to climate change. This is so particularly with maize farmers. Though African countries might currently not be major contributors to climate change, the importance of this finding is that the adoption of climate-smart technologies or practices recommended for reducing agriculture's contribution to climate change are less likely to be adopted if economic agents do not believe that their activities contribute to climate change. This indicates that there is need for more awareness among economic agents about the effects of various agriculture related activities on the environment and their contributions to climate change if these economic agents are expected to adopt practices and technologies that can reduce agriculture's negative effect on the environment and its contribution to climate change.

Declaration of competing interest

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

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Lenis S.O. Liverpool-Tasie: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Supervision, Project administration, Funding acquisition. **Holly Pummel:** Writing - original draft. **Justice A. Tambo:** Conceptualization, Writing - original draft, Writing - review & editing, Visualization. **Laura Schmitt Olabisi:** Investigation, Writing - review & editing. **Olubukola Osuntade:** Investigation, Writing - review & editing.

Acknowledgements

The authors acknowledge and appreciate financial support for this work from the United States Agency for International Development (USAID) Nigeria's Feed the Future Nigeria Agricultural Policy Project and MSU AgBio Research. Justice A. Tambo was supported by CABI with core financial support from its member countries and lead agencies (see: cabi.org/about-cabi/who-we-work-with/key-donors/). We also appreciate inputs and comments from key stakeholders in the Nigerian value chain who participated in the project's rapid reconnaissance and

stakeholder workshops in Kaduna and Abeokuta, as well as from four anonymous reviewers. Any views expressed or remaining errors are solely the responsibility of the authors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jenvman.2020.110430>.

References

- Adger, W.N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D.R., Wreford, A., 2009. Are there social limits to adaptation to climate change? *Climatic Change* 93 (3–4), 335–354.
- Ajetomobi, J., Ajakaiye, O., Gbadegesin, A., 2015. The Potential Impact of Climate Change on Nigerian Agriculture (P. 44). AGRODEP Working Paper 0016. International Food Policy Research Institute (IFPRI).
- Arbuckle Jr., J.G., Morton, L.W., Hobbs, J., 2015. Understanding farmer perspectives on climate change adaptation and mitigation: the roles of trust in sources of climate information, climate change beliefs, and perceived risk. *Environ. Behav.* 47 (2), 205–234.
- Ayanlade, A., Radeny, M., Morton, J.F., 2017. Comparing smallholder farmers' perception of climate change with meteorological data: a case study from southwestern Nigeria. *Weather Clim. Extre.* 15, 24–33.
- Barnes, A.P., Islam, M.M., Toma, L., 2013. Heterogeneity in climate change risk perception amongst dairy farmers: a latent class clustering analysis. *Appl. Geogr.* 41, 105–115.
- Boansi, D., Tambo, J.A., Müller, M., 2017. Analysis of farmers' adaptation to weather extremes in West African Sudan Savanna. *Weather Clim. Extre.* 16, 1–13.
- Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R., et al., 2007. Africa. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E. (Eds.), *Climate Change: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC*. Cambridge University Press, Cambridge.
- Bosello, F., Campagnolo, L., Cervigni, R., Eboli, F., 2018. Climate change and adaptation: the case of Nigerian agriculture. *Environ. Resour. Econ.* 69 (4), 787–810.
- Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., Herrero, M., 2013. Adapting agriculture to climate change in Kenya: household strategies and determinants. *J. Environ. Manag.* 114, 26–35.
- Cappellari, L., Jenkins, S.P., 2003. Multivariate probit regression using simulated maximum likelihood. *Stata J.* 3 (3), 278–294.
- Combest-Friedman, C., Christie, P., Miles, E., 2012. Household perceptions of coastal hazards and climate change in the Central Philippines. *J. Environ. Manag.* 112, 137–148.
- Debelu, N., Mohammed, C., Bridle, K., Corkrey, R., McNeil, D., 2015. Perception of climate change and its impact by smallholders in pastoral/agropastoral systems of Borana, South Ethiopia. *SpringerPlus* 4 (1), 236.
- Demirel, H., Sertel, E., Kaya, S., Seker, D.Z., 2008. Exploring impacts of road transportation on environment: a spatial approach. *Desalination* 226 (1–3), 279–288.
- Deressa, T.T., Hassan, R.M., Ringler, C., 2011. Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *J. Agric. Sci.* 149 (1), 23–31.
- Food and Agriculture Organization of the United Nations Statistics Division (FAOSTAT), 2019. Nigeria, emissions – land use total and emissions – agriculture total. View. June 10, 2019.
- Gbetibouo, G.A., 2009. Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability: the Case of the Limpopo Basin, South Africa, vol 849. IFPRI Discussion Paper 000849.
- Greene, W.H., 2012. *Econometric Analysis*, 7th Edition. Prentice Hall, New York.
- Gregory, N.G., 2010. How climatic changes could affect meat quality. *Food Res. Int.* 43 (7), 1866–1873.
- Hasan, M.K., Kumar, L., 2019. Comparison between meteorological data and farmer perceptions of climate change and vulnerability in relation to adaptation. *J. Environ. Manag.* 237, 54–62.
- IPCC, 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of Intergovernmental Panel on Climate Change* [Core Writing Team. IPCC, Geneva.
- John, K., Olanrewaju, A.V., 2014. Effect of some weather parameters on maize yield in Ibadan, southwest, Nigeria. *Int. J. Environ. Eng. Nat. Resour.* 1 (1), 53–60.
- Kahn Ribeiro, S., Kobayashi, S., Beuthe, M., Gasca, J., Greene, D., Lee, D.S., Muromachi, Y., Newton, P.J., Plotkin, S., Sperling, D., Wit, R., Zhou, P.J., 2007. Transport and its infrastructure. In: Davidson, O.R., Bosch, P.R., Dave, R., Meyer, L. A. (Eds.), *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- Liverpool-Tasie, L.S.O., Omonona, B., Sanou, A., Ogunleye, W., Padilla, S., Reardon, T., 2017. Growth and transformation of chicken and eggs value chains in Nigeria. *Nigerian J. Agri. Econ.* 7 (1), 1–15.
- Liverpool-Tasie, L.S.O., Sanou, A., Tambo, J.A., 2019a. Climate change adaptation among poultry farmers: evidence from Nigeria. *Climatic Change* 157 (3–4), 527–544.

- Liverpool-Tasie, L.S.O., Turna, N.S., Ademola, O., Obadina, A., Wu, F., 2019b. The occurrence and co-occurrence of aflatoxin and fumonisin along the maize value chain in southwest Nigeria. *Food Chem. Toxicol.* 129, 458–465.
- Lysenko, V.P., 2008. Ecological problems of Russian poultry plants and the role of biotechnology in recycling organic wastes. *J. All-Russia Rese. Inst. Poultry Breed.* 4–6.
- Maddison, D., 2007. The Perception of and Adaptation to Climate Change in Africa. World Bank Policy Research Working Paper No. 4308. World Bank, Washington DC.
- Mertz, O., Mbaw, C., Reenberg, A., Diouf, A., 2009. Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environ. Manag.* 43 (5), 804–816.
- Meze-Hausken, E., 2004. Contrasting climate variability and meteorological drought with perceived drought and climate change in northern Ethiopia. *Clim. Res.* 27 (1), 19–31.
- Nhemachena, C., Hassan, R., 2007. Micro-level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. IFPRI Discussion Paper No. 00714. IFPRI, Washington, DC.
- Nyoni, N.M.B., Grab, S., Archer, E.R., 2019. Heat stress and chickens: climate risk effects on rural poultry farming in low-income countries. *Clim. Dev.* 11 (1), 83–90.
- Ogunlade, I., Olaoye, G., Tologbonse, D., Ayinde, O.E., 2010. On-farm evaluation of drought tolerant maize varieties and hybrids in the southern Guinea savana zones of Nigeria. In: Paper presented at the South African Society for Agricultural Extension Conference, Langebaan, South Africa. May 4–7, 2010.
- Olabisi, L.S., Liverpool-Tasie, S., Olajide, A., 2016. Towards a Systemic Analysis of the Impacts of Climate Change on Agricultural Production in Nigeria. Feed the Future Innovation Lab for Food Security Policy Research Paper 21. East Lansing. Michigan State University.
- Omotosho, J.B., Balogun, A.A., Ogunjobi, K., 2000. Predicting monthly and seasonal rainfall, onset and cessation of the rainy season in West Africa using only surface data. *Int. J. Climatol.: J. R. Meteorol. Soc.* 20 (8), 865–880.
- Opiyo, F., Wasonga, O.V., Nyangito, M.M., Mureithi, S.M., Obando, J., Munang, R., 2016. Determinants of perceptions of climate change and adaptation among Turkana pastoralists in northwestern Kenya. *Clim. Dev.* 8 (2), 179–189.
- Raheem, I.D., Ogebe, J.O., 2017. CO2 emissions, urbanization and industrialization: evidence from a direct and indirect heterogeneous panel analysis. *Manag. Environ. Qual. Int. J.* 28 (6), 851–867.
- Robertson, G.P., Vitousek, P.M., 2009. Nitrogen in agriculture: balancing the cost of an essential resource. *Annu. Rev. Environ. Resour.* 34, 97–125.
- Sanou, A., Osuntade, B., Liverpool-Tasie, L.S.O., Reardon, T., 2017. Climate change and the poultry value chain in Nigeria: issues, emerging evidence, and hypotheses. *Nigerian J. Agri. Econ.* 7 (1), 45–53.
- Silvestri, S., Bryan, E., Ringler, C., Herrero, M., Okoba, B., 2012. Climate change perception and adaptation of agro-pastoral communities in Kenya. *Reg. Environ. Change* 12 (4), 791–802.
- Tambo, J.A., Abdoulaye, T., 2012. Climate change and agricultural technology adoption: the case of drought tolerant maize in rural Nigeria. *Mitig. Adapt. Strategies Glob. Change* 17 (3), 277–292.
- Tambo, J.A., Abdoulaye, T., 2013. Smallholder farmers' perceptions of and adaptations to climate change in the Nigerian savanna. *Reg. Environ. Change* 13 (2), 375–388.
- Tang, K., Hailu, A., 2019. Smallholder Farms' Adaptation to the Impacts of Climate Change: Evidence from China's Loess Plateau. *Land Use Policy*, p. 104353.
- Tang, K., Hailu, A., Kragt, M.E., Ma, C., 2018. The response of broadacre mixed crop-livestock farmers to agricultural greenhouse gas abatement incentives. *Agric. Syst.* 160, 11–20.
- Thamo, T., Addai, D., Pannell, D.J., Robertson, M.J., Thomas, D.T., Young, J.M., 2017. Climate change impacts and farm-level adaptation: economic analysis of a mixed cropping–livestock system. *Agric. Syst.* 150, 99–108.
- Thornton, P.K., Jones, P.G., Ericksen, P.J., Challinor, A.J., 2011. Agriculture and food systems in sub-Saharan Africa in a 4 C+ world. *Phil. Trans. Math. Phys. Eng. Sci.* 369, 117–136.
- USGCRP, 2009. Global climate change impacts in the US. Retrieved from. <http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts>.
- USAID, 2019. Greenhouse gas emissions in Nigeria. USAID, Abuja, Nigeria.
- Uyigüe, E., Agho, M., 2009. Community adaptation to climate change and other environmental changes in the Niger Delta region of Southern Nigeria. *IOP Conf. Ser. Earth Environ. Sci.* 6 (35), 352041. <https://doi.org/10.1088/1755-1307/6/35/352041>.
- Waldman, K.B., Blekking, J.P., Attari, S.Z., Evans, T.P., 2017. Maize seed choice and perceptions of climate variability among smallholder farmers. *Global Environ. Change* 47, 51–63.
- West, C.T., Roncoli, C., Ouattara, F., 2008. Local perceptions and regional climate trends on the Central Plateau of Burkina Faso. *Land Degrad. Dev.* 19 (3), 289–304.
- Wheeler, T., Von Braun, J., 2013. Climate change impacts on global food security. *Science* 341 (6145), 508–513.
- Wooldridge, J.M., 2010. *Econometric analysis of cross section and panel data*. MIT press, Cambridge, MA.
- Zampaligré, N., Dossa, L.H., Schlecht, E., 2014. Climate change and variability: perception and adaptation strategies of pastoralists and agro-pastoralists across different zones of Burkina Faso. *Reg. Environ. Change* 14 (2), 769–783.