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## **Maize Innovation for Climate Change Adaptation: Insights from Rural Nigeria**

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## **58- Maize Innovation for Climate Change Adaptation: Insights from Rural Nigeria**

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### **Abstract**

Maize is an important staple crop in Africa but is severely affected by frequent droughts leading to crop failure. Drought tolerant maize (DTM) has been recognised as one of the most important innovations necessary for maize farmers to be able to adapt to climate change and is, therefore, promoted in the region. This paper examines the determinants of adoption of DTM innovation by smallholder farmers in rural Nigeria. The paper is mainly based on a survey of 200 farm households selected from two agro-ecological zones in north-east Nigeria. Data were analysed using descriptive statistics and logistic regression. The results show that adverse climatic conditions are very important in the adoption of DTM as the farmers indicated early maturity, drought tolerance and high yield as the main benefits of the DTM innovation. Climate change awareness and farmers' perceptions about DTM are the major factors that influence the adoption of the innovation. The main constraints to adoption include lack of awareness, fertilizer accessibility problems and lack of access to seed. The paper concludes that DTM innovation is important for maize farmers to continue to produce under a changing climate, but more support is needed if the innovation is to be adopted by many farmers.

**Key words:** Adaptation, innovation adoption, climate change, drought tolerant maize, Nigeria, smallholder farmers

## **1 Introduction**

There is a general consensus that the climate is changing, and it poses serious challenges to food security and livelihoods in many developing countries. Countries whose economies are highly dependent on climate-sensitive sectors like agriculture, fisheries and forestry are expected to be hardest hit from the adverse impacts of climate change.<sup>1,2</sup> Nigeria is particularly vulnerable because majority of its population (about 70%) engage in agriculture as their primary occupation and agriculture in the country is mainly rain fed. Also, the country has a long (800km) coastline that is prone to sea-level rise and almost two-thirds of the country's land cover is prone to drought and desertification.<sup>3</sup> Studies have shown that Nigeria's climatic conditions have changed in the past decades,<sup>4,5</sup> and it is expected to be severe in the coming years.<sup>6</sup> Climate change is adversely affecting food production in the country and many farmers are losing their sources of livelihood. Without appropriate responses, climate change is likely to constrain economic development and poverty reduction efforts of the country.

In response to the threat of climate change, there has been an increased attention to adaptation as large reductions in adverse impacts of climate change are possible when adaptation is fully implemented.<sup>7,8</sup> Adaptation to climate change refers to “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities”.<sup>9</sup> Various adaptation options in agriculture have been suggested and these include (i) farm production adjustments such as crop diversification and altering the timing of operations; (b) market responses, such as income diversification and credit schemes; (c) institutional/ government responses such as improvement in agricultural markets; and (d) technological developments such as the development and promotion of new crop varieties and soil and water management techniques.<sup>10,11</sup> Technological innovation has been found to be a viable and important adaptation option to reduce the adverse impacts of climate change and therefore, needs to be promoted.<sup>12,13,14</sup> In view of this, many researchers are developing agricultural innovations such as new crop varieties that can tolerate climate-related shocks. Farmers are expected to adopt these innovations to be able to adapt to the changes in climate. This paper aims to analyse the adoption of one of such innovations, the drought tolerant maize (DTM) innovation by smallholder farmers. Specifically, the paper seeks to identify the factors that influence adoption of the DTM innovation, farmers' reasons for preferring the innovation and the constraints to adoption. The study was carried out in Borno state, a drought-prone area in Nigeria. It is one of the regions where the DTM innovation is being promoted.

The paper proceeds as follows. The next section provides a brief overview of maize production in Nigeria with an emphasis on the DTM innovation. Section 3 describes the study area and methods of data collection as well as the analytical approaches. The results and discussion are presented in section 4 and section 5 concludes the paper.

## **2 DTM innovation in Nigeria**

Maize is an important cereal crop produced throughout the world and has become one of the dominant crops in Africa because it can be cultivated in a wide range of agro-ecological environments and has many uses. In Nigeria, maize is an important crop which is consumed as a staple food by many households, and there is also growing utilization by industries for the production of flour, livestock feed, processed food and beverages and malt for brewing beer.<sup>15</sup> Its production also serves as a source of income and employment for the many rural households. The high demand for maize for households and industries requires increased production to satisfy the demand. According to the Food and Agriculture Organization (FAO) data, the land area planted to maize in Nigeria increased from 1.4 million in 1961 to 3.3 million hectares in 2010. This phenomenal expansion of the land area devoted to maize cultivation resulted in increased production from 1.1 million metric tonnes in 1961 to 7.3 million metric tonnes in 2010,<sup>16</sup> making Nigeria the second largest producer of maize in Africa after South Africa. Most of the maize in the country is produced in the rain forest zone but there has been an increase in production in the savannas especially the northern Guinea savanna (NGS). Most of these areas were initially cultivating maize as a backyard crop but it is now one of the most important food crops and is being substituted for traditional crops like millet and sorghum in local dishes.<sup>17</sup>

Despite the importance of maize in the country, its production is beset by several constraints. One of these is drought, which is a major cause of loss in maize yield in the country and many parts of the world. Drought stress greatly reduces yield of maize by affecting the plant at three critical stages of growth: early in the growing season (when plant stands are established), at flowering, and during mid to late grain filling.<sup>18</sup> It has been estimated that annually, drought reduces global maize yields by as much as 15 percent, and this amount to crop losses of more than 20 million tonnes of grain.<sup>19</sup> Unfortunately, the rapid changes in climate are expected to worsen this situation. Studies show that the growing conditions in most African countries is getting hotter and dryer and many varieties of maize now under cultivation will no longer be viable in the very near future and failure to transit to drought tolerant maize<sup>20</sup> (DTM) will lead to reduction in yield.<sup>21,22</sup>

As part of a concerted effort to curb these losses, scientists from two Consultative Group on International Agricultural Research (CGIAR) centers; International Maize and Wheat Improvement Center (CIMMYT) and International Institute of Tropical Agriculture (IITA) have been working with national partners in sub-Saharan Africa to develop drought tolerant varieties. Several varieties have resulted from this initiative, and there are about one million hectares of land planted to these varieties.<sup>23</sup> Many development-oriented institutions are also supporting the dissemination of this innovation to farmers. For instance, IITA and national partners from Borno state in Nigeria received funding from the Canadian International Development Agency (CIDA) to conduct the project *Promoting Sustainable Agriculture in Borno State* (PROSAB) from 2004 to 2009 with a goal of contributing to improved rural household livelihoods in the project areas of the state. This project identified drought as a major constraint to maize production in the area, hence, developed and disseminated DTM to farmers. Also, with support from Bill & Melinda Gates Foundation and Howard G. Buffet Foundation, CIMMYT and IITA established the *Drought Tolerant Maize for Africa* (DTMA)

project in 2006 with the aim of making drought tolerant maize easily available to millions of smallholder growers in 13 sub-Saharan African countries where droughts are expected to become common and more severe. A recent study by La Rovere et al<sup>24</sup> on the potential impacts of DTM in Africa indicates that it can bring a cumulative economic benefit of about US\$ 0.9 billion to farmers and consumers in project countries during 2007 to 2017 assuming a high rate of adoption. There are, therefore, increasing efforts to promote the DTM innovation but to be able to successfully do this, understanding of the determinants of its adoption are required.

At the time of the survey, six different DTM varieties were being promoted in the study region. These were EV DT 99 STR, 99 TZEE-Y STR, 99 TZEE-W STR, TZE Comp 3DT W, TZE Comp 5 W and 2000 Syn EE-W. The dominant varieties were TZE Comp 3DT W and EV DT 99 STR. These two varieties had the advantages of being tolerant to drought conditions and early maturing. They also had higher yield potentials because they mature later than the extra-early varieties and are, therefore, able to accumulate more dry matter and partition more biomass to the grain.<sup>25</sup> Other maize varieties in the study region were hybrid (e.g. Oba Super 1, Oba Super and New Kaduna) and recycled improved varieties (Pool 16, Suwan 1 and TZB-SR). The hybrid seeds were produced and marketed by private seed companies in Nigeria, mainly Premier Seed Limited. The available hybrid varieties in the study area had high yielding and disease resistance qualities but were not drought tolerant. The recycled varieties were very late maturing (4-5 months to maturity), grew very tall and had low tolerance to climatic stress.

### **3 Methodology**

#### **3.1 Study design and data**

The study was conducted in Borno state of north-east Nigeria. The state is demarcated into four agro-ecological zones (AEZs): the Northern Guinea Savanna (NGS) and Southern Guinea Savanna (SGS) in the south, the Sudan Savanna (SS) in the southern and central parts of the state, and the Sahel in the north. A larger part of the state lies in the Sahelian zone. The annual precipitation ranges from less than 600 mm in the north to 1500 mm in the south. Rainfall, however, varies from year to year but has tended to decrease over the last two decades. Borno state was chosen for this study because of the high incidence of drought and the promotion of DTM in different AEZs within the state.

Within Borno state, the study was conducted in the Biu and Gwoza Local Government Areas (LGAs) which are located in the NGS and SS AEZs, respectively. NGS has an average annual rainfall of about 900-1200 mm while that of SS is low, about 700 mm with a prolonged dry season of about 6-9 months. Rainfall has a unimodal distribution in both agro-ecologies. The inhabitants depend mainly on agriculture for their livelihoods. Apart from maize, the major crops cultivated in the region include sorghum, cowpea, soybean, groundnut and rice. Some of the farmers are involved in dry season vegetable farming from November to April.

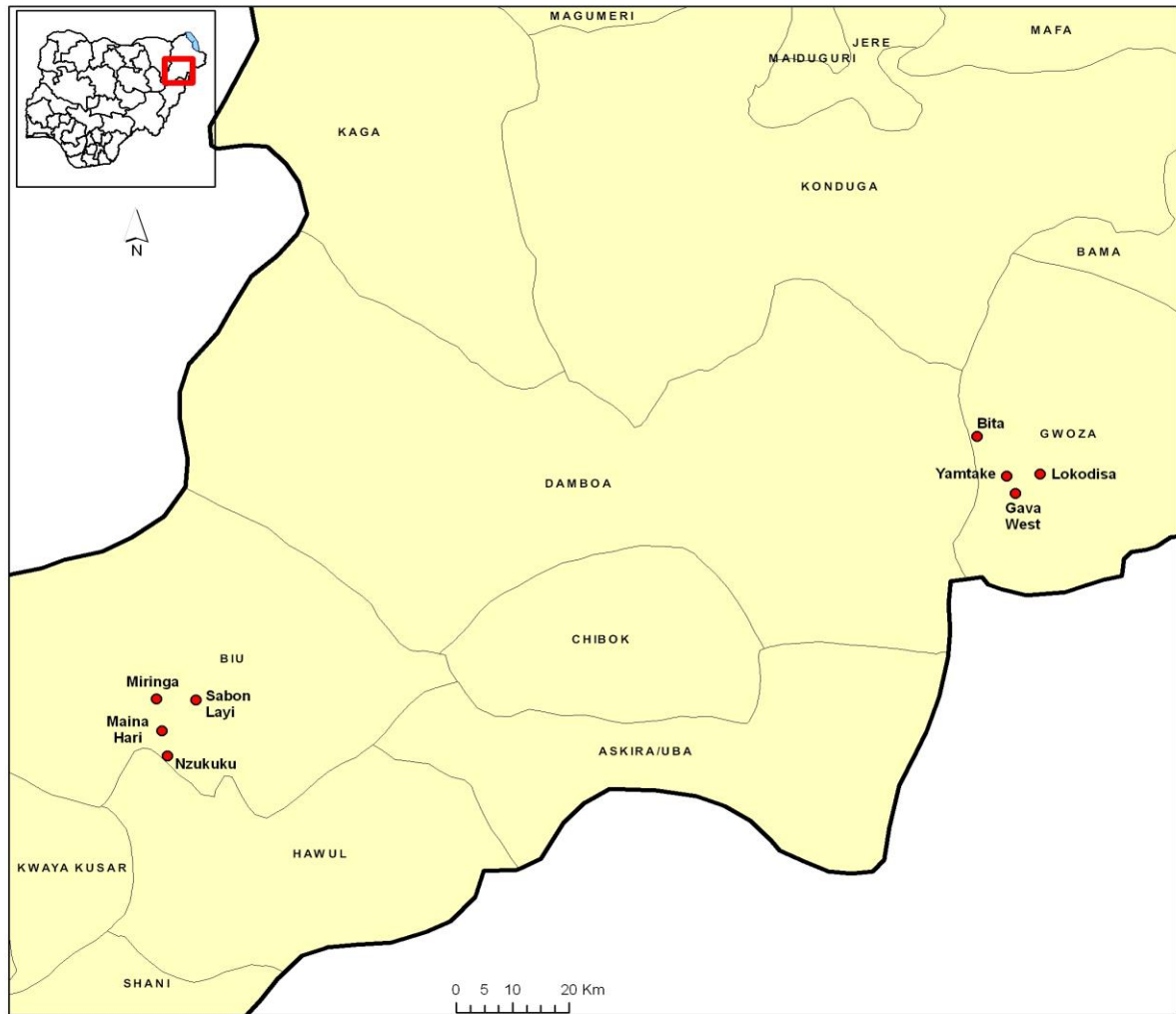


Figure 1: Map showing the location of the selected communities within the study area  
 Source: IITA GIS-unit, Ibadan, Nigeria

Data were collected from April to August 2010. The sample consists of 200 farm households with 100 selected from each AEZ using a multi stage sampling technique so as to obtain a sample that is representative of maize producing households in the study area. At the first stage, two LGAs where DTM were being promoted were selected. These are Gwoza and Biu, located in the SS and NGS AEZs, respectively. Then four communities were selected from each of the two AEZs based on the importance of maize cultivation. The communities are Lokodisa, Yamtake, Bita and Gava West in SS, and Miringa, Maina Hari Sabon Layi and Nzukuku in NGS as shown in figure 1. In the last stage, households that cultivate maize were randomly selected for interview using a structured questionnaire. Information obtained with the questionnaire include household socio-economic characteristics, type of farm and non-farm activities, DTM production activities, access to extension services and credit facilities, participation in associations and on-farm demonstrations, perception on the characteristics of DTM and constraints in the production and adoption of DTM. Data obtained were based on 2009/2010 cropping season.

### 3.2 Analytical approaches

In the determination of farmers' perception of the benefits of DTM, households were asked to indicate in order of importance, three main reasons for preferring DTM varieties. The reasons were ranked by assigning weights. The most important response was assigned 5 points, the second most important 3 points and the third most important 1 point. The total rank score for each reason mentioned by the farmers was then calculated by summing up the number of households that mentioned a particular reason multiplied by the rank score assigned as shown in equation 1.

$$TS_i = \sum_{j=1}^3 F_{ij} J \dots\dots\dots(1)$$

Where

TS<sub>i</sub> = the total score for the *i*th reason

J = rank score (5= most important, 3= important, 1= less important)

F<sub>ij</sub> = Frequency of the *i*th reason mentioned with a rank score *j*.

The reason with the highest total score was assigned the highest rank and so on.

The logit model was used to analyze the factors influencing farmers' decision to adopt a DTM variety. Following Gujarati,<sup>26</sup> the model is specified as

$$\ln\left(\frac{P_i}{1 - P_i}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots\dots\dots + \beta_n X_n \dots\dots\dots(2)$$

Where *P<sub>i</sub>* is the probability that the *i*<sup>th</sup> farmer will adopt a DTM and 1- *P<sub>i</sub>* is the probability of non-adoption of DTM by the *i*<sup>th</sup> farmer. The probability that a farmer will adopt DTM is a function of the vector of explanatory variables X<sub>1</sub> to X<sub>n</sub> with the unknown parameters β<sub>0</sub> to β<sub>n</sub>.

The coefficients estimated from a logit model will not measure marginal effects of the explanatory variables but only show if any of the variables has a significant influence on the adoption of DTM. Marginal analysis was, therefore, carried out to obtain the effects of the explanatory variables on the probability of adopting DTM. Following Maddala,<sup>27</sup> the marginal effect was estimated as follows:

$$\frac{\partial P_i}{\partial X_{ik}} = \frac{e^{\beta_0 + \beta_1 X_{1i} + \dots\dots\dots + \beta_{ni}}}{(1 + e^{\beta_0 + \beta_1 X_{1i} + \dots\dots\dots + \beta_{ni}})^2} B_k \dots\dots\dots(3)$$

Where *B<sub>k</sub>* are the estimated coefficients

The dependent variable was defined as: 1= the use of at least one DTM variety during the 2009/2010 cropping season, and 0 otherwise. The explanatory variables (X<sub>1</sub> to X<sub>n</sub>) hypothesized to influence the DTM adoption decision were obtained from literature.



The literature about agricultural innovation adoption has shown that adoption decision depends on a number of factors. The factors that are usually considered include the following: (i) Farmer characteristics such as farm size, age, wealth, education and tenure. (ii) Institutional factors such as access to extension, credit, market and information. (iii) Technological characteristics e.g. yield, storability, availability and cost (iv) Farmers perception of the technology (v) Risk and uncertainty and (vi) Biophysical characteristics e.g. farm size, soil type, and slope.<sup>28,29,30,31</sup> The factors selected for a particular study depend mainly on the purpose of the study,<sup>32</sup> and the underlying agricultural technology adoption theory.<sup>33</sup> The present study focuses on three main categories of adoption determinants: household and farm characteristics, institutional factors, and farmers' perception about the technology. The household and farm characteristics that are expected to influence adoption of the DTM include farming experience and educational level of head of household, and farm size. Regarding institutional factors, access to extension services and credit, distance to market and membership of farming association are considered. Farmers' perception about yield, pest and disease resistance and availability of DTM seed fall under the perception category. Two other factors that are climate-related are also considered. These are agro-ecological zone to account for spatial heterogeneity and farmers' awareness of climate change.

## **4 Results and discussion**

### **4.1 Descriptive analysis**

Table 1 and 2 present some descriptive statistics of the sampled households. The age of the household heads ranged from 18 to 80 with an average age of 38 years. On average, household size comprised of about 10 people, but only 4 people worked on the farm. Most households supplemented family labour with hired labour. The population was almost entirely Muslim with very few women involved in farming and at the same time served as household heads; hence, only one female-headed household took part in the survey. The illiteracy level was found to be very high with about 52% of the household heads never having any formal education. There were more educated people in Biu LGA (NGS) than Gwoza LGA (SS). Most of respondents had only attended Quranic and primary school with very few reaching the tertiary level. Only few households depended solely on farming for their livelihood. Most of them were involved in non-farming business activities especially during the dry season. The non-farm activities were mainly self-employed activities such as trading in agricultural and non-agricultural products, masonry, carpentry, handicrafting, tailoring and blacksmithing. Very few civil servants were encountered. Majority of the youth engaged in transport business using motorcycle (locally known as *achaba*). Most of the households owned livestock and poultry. The main livestock were cattle and goat. The sizes of land cultivated were very small with an average of 3 hectares (ha) per household with 90% of the respondents cultivating less than 5ha. The small holding is a result of most farmers obtaining land through inheritance, which results in fragmentation. The rest of the farmers

obtained their farm lands mainly by purchasing or hiring. Larger farm sizes were observed in SS than NGS.

Variables	Total (n=200)		SS (n=100)		NGS (n=100)	
	Mean	SD*	Mean	SD	Mean	SD
Age	38.18	10.73	38.11	9.48	38.25	11.9
Education	4.77	5.6	4.32	5.39	5.21	5.79
Farming experience	18.9	10.16	20.03	9.31	17.77	10.88
Household size	9.58	5.61	10.2	5.68	8.96	5.51
Family labour	3.57	3.05	4.37	3.15	2.77	2.74
Distance to market (km)	19.12	12.21	26.27	12.25	11.97	6.81
Farm size	2.95	7.45	4.21	10.29	1.69	1.54
Frequency of extension contact	3.55	5.78	4.36	4.68	2.74	6.63
Off-farm income in 2009 (Naira <sup>34</sup> )	60780	97367	64940	111174	56620	81621

Table 1: Summary statistics of continuous variables

\*SD=standard deviation

Table 2: Summary statistics of discrete variables

Variables	Total (n=200)	SS (n=100)	NGS (n=100)
	% of farmers	% of farmers	% of farmers
Adoption of DTM	58	59	56
Use of hired labour	79	80	78
Off-farm income	65.5	61	70
Ownership of livestock	86	84	88
Received remittances	13.5	7	20
Access to extension services	56.5	62	51
Access to credit for farming	13	12	14
Awareness of climate change	50.5	46	55
DTM yield potential	75.5	78	73
DTM seed availability	28	18	38
DTM resistance to pest and disease	54.5	45	64

Only about 57% of the surveyed households had access to extension services. The extension officers visited households on an average of about 4 times in 2009. There were more extension contacts in SS than NGS, and this can be attributed to the ongoing DTMA project which uses extension officers for the training of farmers and dissemination of information. Very few farmers (13%) obtained credit for farming. This was attributed to unavailability of credit providers in the area, high interest rate, lack of collateral and the difficulty in accessing loans due to lack of education. Few farmers, however, indicated religious reasons for not obtaining loan as their Islamic religion frown on obtaining loans requiring interest payments. Most of the loans were obtained from relatives and friends with very few farmers obtaining it

in the form of seeds and fertilizers from ongoing projects in the area. Forty-two percent of the farmers were members of Community Based Organizations (CBOs) or associations in the study area but only few of them were very active members of these associations. Majority of the farmers (75.5%) perceived that DTM varieties were better than other available maize varieties while only 28% considered DTM seeds to be easily accessible. About half of the respondents were aware of climate change.

About 58% of the sampled households have adopted DTM varieties. The non-adopters used either hybrid, recycled hybrid or recycled improved varieties. Out of the 115 farmers that adopted DTM, only 25% of them were partial adopters. This suggests that conditional on adoption, most farmers are likely to grow mainly DTM varieties. The reasons for partial adoption include shortage of seeds, inability to afford complementary inputs, risk aversion and the interest of keeping the traditional varieties from going extinct in the near future. There were more adopters of DTM in SS (59%) than NGS (56%), and this can be attributed to the significance of drought in the former AEZ. Compared to NGS, SS is more drought-prone and experiences low annual rainfall, hence, farmers in this zone are more in need of the early maturing and drought tolerant varieties.

Part of the data used for this study captured farmers' perceptions on climate change and their adaptation practices. The results show that nearly all the farmers interviewed (99%) have noticed at least a change in long term temperature or rainfall in the area. A large share of them (92%) perceived changes in temperature over the past 20 years. Over three-quarters of the farmers surveyed have noticed an increase in temperature. Very few farmers indicated a decrease in temperature (8%) and no changes in temperature (6.5%). Furthermore, about 60% of them have noticed both a decrease in rainfall and changes in the timing of the rains. About 24% have noticed a decrease in the volume of rainfall or a shorter rainy season while 12% have observed high inter-and intra-annual variability. Overall, the farmers perceived drier and hotter climate. The farmers' adaptation practices can be categorized into: diversification of crops and crop varieties; changing the time of planting/sowing; irrigation; tree planting; soil and water conservation practices; and off-farm income diversification. The predominant adaptation methods involved the use of drought tolerant or early maturing varieties (52%) and shift in dates of planting (47%). Lack of information on climate change and the suitable adaptation measures and lack of credit were the main barriers to adaptation. A more detailed discussion of the results on the farmers' perceptions and adaptation measures can be found in Tambo and Abdoulaye<sup>35</sup>.

#### **4.2 Adopters perception of the benefits of DTM**

The DTM varieties are not only drought tolerant or early maturing but have other important attributes. Adopters of DTM were asked to indicate and rank three main reasons for a preference for DTM varieties. Their responses were weighted and the result is presented in table 3. The ranking indicates that the three most important traits farmers preferred about the DTM varieties were early maturing, drought tolerance and high yielding. The choice of early maturing and drought tolerance as first and second traits respectively indicate that the farmers are concerned about the risk of climate failure which is a major constraint of farming in the

study region. Results from past adoption studies revealed that farmers often desire high yielding with very low consideration for drought resistance when selecting maize seeds for planting.<sup>36,37</sup> This result, therefore, indicates that in an environment where drought is a problem, farmers will adopt DTM not only because it is high yielding but more importantly because of its potential to adapt to drought conditions. This result also corroborates the findings of Kamara et al.<sup>38</sup> which showed that most farmers in Kano, a Nigerian state with low annual rainfall, consider earliness of crop maturity than high yielding traits when selecting maize seeds for planting. Other DTM varietal attributes important for farmers were better taste when used in preparing food or when boiled, and high flour content. Farmers attested that compared to other maize varieties, more flour is obtained from DTM after milling. Other DTM traits include: resistance to lodging because of its short height; good grain size; resistance to pests and diseases; and ability to store longer and resist weevil attack because of their hard seed coats.

Table 3: Adopters perception of the benefits of DTM (n=115)

Characteristics	1		2		3		Total score	Overall rank
	Freq <sup>*</sup>	Score	Freq	Score	Freq	Score		
Early maturing	46	230	33	99	17	17	346	1
Drought tolerance	30	150	14	42	20	20	212	2
High yielding	19	95	26	78	23	23	196	3
Better food taste	6	30	11	33	19	19	82	4
More flour	9	45	5	15	7	7	67	5
Less lodging	4	20	8	24	12	12	56	6
Large cob and grain size	5	25	7	21	8	8	54	7
Pest and disease resistance	0	0	7	21	0	0	21	8
Good storability	1	5	1	3	2	2	10	9
Grain colour	1	5	0	0	2	2	7	10

\* Frequency (Number of farmers)

### 4.3 Determinants of DTM adoption

Table 4 below presents the result for the determinants of DTM adoption. The likelihood ratio as indicated by chi-square value of 107.19 is highly significant ( $p=0.0000$ ), suggesting that the model has a strong explanatory power. Eight out of the 13 explanatory variables included in the model are statistically significant. Off-farm income, distance to market, extension contact, awareness of climate change, AEZ and perceptions of yield potential, seed availability and pest & disease resistance are the determining factors influencing the probability of adopting DTM in the study area. The result shows that farmers' perception about DTM and climate change related variables are the main factors that influence the adoption of the innovation. The farmers' socio-economic characteristics have little influence on adoption with off-farm income as the only significant variable.

The coefficient of off-farm income is positive and statistically significant at 1%, and these indicate that households with higher off-farm income are more likely to adopt DTM. This result is consistent with the argument that off-farm income influences the adoption of new agricultural technologies.<sup>39</sup> Households with off-farm income can afford to purchase seeds and other inputs associated with DTM production. This result suggests that expanding farmers' access to off-farm sources of income in the study area will increase the probability that they will invest in the cultivation of DTM.

Table 4: Determinants of DTM adoption

Variable	Coefficient	Std. Error	Marginal effect
Education (years)	-0.010	0.023	-0.004
Farming experience (years)	-0.007	0.012	-0.003
Off-farm income (Naira)	0.005***	0.002	0.002
Farm size (hectares)	-0.002	0.017	-0.001
Distance to closest market (km)	-0.037***	0.014	-0.014
Extension contacts (times per year)	0.064*	0.037	0.024
Credit (dummy)	0.141	0.398	0.051
Membership of association (dummy)	0.125	0.251	0.047
Yield potential (dummy)	1.340***	0.326	0.497
Seed availability (dummy)	0.575*	0.306	0.201
Pest and disease resistance (dummy)	0.563**	0.264	0.209
Awareness of climate change (dummy)	0.849***	0.237	0.309
Agro-ecological zone (dummy, 1=SS)	0.871**	0.357	0.316
Constant	-1.650***	0.420	
Log likelihood = -82.776528			
LR chi2(13) = 107.19			
Prob > chi2 = 0.0000			
Pseudo R <sup>2</sup> = 0.3930			
n=200			

\*, \*\* and \*\*\* refer to statistically significant at 10%, 5% & 1%, respectively

Out of the four institutional factors included in the model, distance to market and extension contacts significantly influence DTM adoption. Distance to market has a negative effect on adoption, which indicates that the longer the distance to market, the less likely the adoption of DTM. Some of the farmers obtained their seeds from markets and also all the sampled farmers purchased farm inputs from markets which were not located in their dwelling villages. Some of the farmers even learnt about DTM through agro-dealers in the markets. The roads linking the two main markets (Biu and Gwoza) in the study area and the sampled communities were very poor and hindered easy movement and accessibility of farmers to technologies. Farmers who stay close to the markets are more likely to adopt DTM due to the proximity to information, seed sources and other farm inputs. This suggests the need to increase efforts in supplying seeds and inputs close to the vicinity of the farmers. Extension

contact, which is very important for technology dissemination, positively influences the adoption of DTM. Extension agents have been the main source of information on new technologies in the study area and the two projects use them for the promotion of DTM. The cultivation and seed production of DTM require knowledge on management techniques and the extension officers are mainly involved in delivering these services to the farmers. Therefore, farmers who have frequent contacts with the extension agents will learn about the innovation and its potential benefits, hence, are more likely to become adopters.

All the three factors related to farmers' perception of technological attributes: yield potential, pest and disease resistance, and seed availability, are significant at 1%, 5% and 10%, respectively. All these attributes are positively related to adoption decisions. Farmers who perceive that DTM has a greater yield potential are very likely to adopt DTM than those who do not. This confirms the earlier result in section 4.2 that the yield of DTM is also very important to farmers apart from its ability to tolerate drought. Knowledge of good seed source is very important for DTM adoption especially for farmers outside the project villages as they complained of difficulties in getting seed for sowing. Seed availability has a positive effect on adoption which indicates that there is an increased probability of DTM adoption if farmers can easily get seeds in their localities. Farmers who perceive that DTM is more resistance to pests and diseases than other available varieties are also more likely to adopt the innovation.

Farmers who have heard or read about climate change are more likely to adopt DTM than those who have not, and this result is highly significant. With increased incidence of changing climate, farmers are being educated on possible adaptation options and this result is interesting as it shows that the education of farmers on climate change adaptation is having positive impacts. This result concurs with the findings of Deressa et al.<sup>40</sup> who argued that farmers' awareness of climate change through information dissemination influences the uptake of adaptation options such as use of different crop varieties. Nhemachena and Hassan<sup>41</sup> also asserted that farmers who are aware of the changing climate have a higher probability of uptake of adaptation measures. AEZ has a significant and positive effect on DTM adoption, implying that farmers in SS are likely to adopt DTM than those in NGS, and this can partly be attributed to the climatic differences in the two AEZs. This result is consistent with previous findings that AEZ is very important and should be considered in the promotion of improved maize technologies.<sup>42</sup>

The marginal effects explain the percent changes in the probability of adoption of DTM in response to changes from zero to one for the dummy variables and elasticities at the means for the continuous variables. Yield potential has the highest marginal effects of 0.497 suggesting that if the farmers perceive that DTM is superior to other maize varieties in terms of yield, adoption will increase by about 50% in the study area. A 1km increase in the distance from household's house to market will lead to 0.014% decrease in adoption while a 10% increase in the number of extension contacts will enhance the probability of adopting DTM in the study area by 2.4%. Households who perceive that DTM is easily available and superior to other maize varieties in terms of pest and disease resistance are about 20% and

21% likely to adopt DTM, respectively. Farmers who have read or listened to discussions on climate change are about 31% likely to adopt DTM, and those located in SS AEZ are 32 % more likely to adopt DTM relative to those in NGS.

#### **4.4 Constraints to adoption of DTM**

Eighty-five of the sampled farmers were not using DTM varieties. Consequently, they were asked to provide reasons for non-adoption and their responses are summarised in figure 2. The main reason for non-adoption of DTM is lack of access to seed which was stressed by 43% of the non-adopters. This is not surprising as access to seed has been identified as one of the main constraints to maize production in Nigeria and other African countries.<sup>43</sup> This further supports the econometric result which shows that the perceived availability of seed is an important determinant of DTM adoption. Constraints in accessing fertilizer is also a major reason limiting DTM adoption. The farmers acknowledged that fertilizer is needed to achieve optimal yields, but there is low utilization due to lack of access and financial constraints. There are fertilizer subsidies for farmers in Nigeria, but these are characterised by constant problems of late delivery, insufficiency, unfair distribution and diversion from targeted beneficiaries. The high price of retailed fertilizers is also beyond the reach of the farmers, as most of them are poor. About 19% of the non-adopters were not aware of the existence of DTM, and this can partly be attributed to the poor extension system in the study region and Nigeria as a whole. Access to extension services is critical in the transmission of agricultural information and provision of advisory services to farmers, but with dwindling funding for extension work in Nigeria, all these services are hardly provided. The econometric result in section 4.3 also confirms the importance of extension services in DTM adoption. Some of the farmers also stated high cost of DTM seed and high labour requirements relative to other maize varieties as reasons for non-adoption. About 14% of the non-adopters were happy with the current maize varieties they cultivate and were reluctant to shift to DTM varieties.

Figure 3 shows the problems faced by the 115 adopters in the use of the innovation which might lead to disadoption or limit the extent of adoption. The major constraint which was reported by 68% of the adopters is fertilizer accessibility. Difficulties in seed accessibility, high cost of seed as well as high labour and management practices requirements are other constraints faced by adopters of the innovation. Almost 29% of the adopters, however, reported that they do not experience problems in the cultivation of DTM.

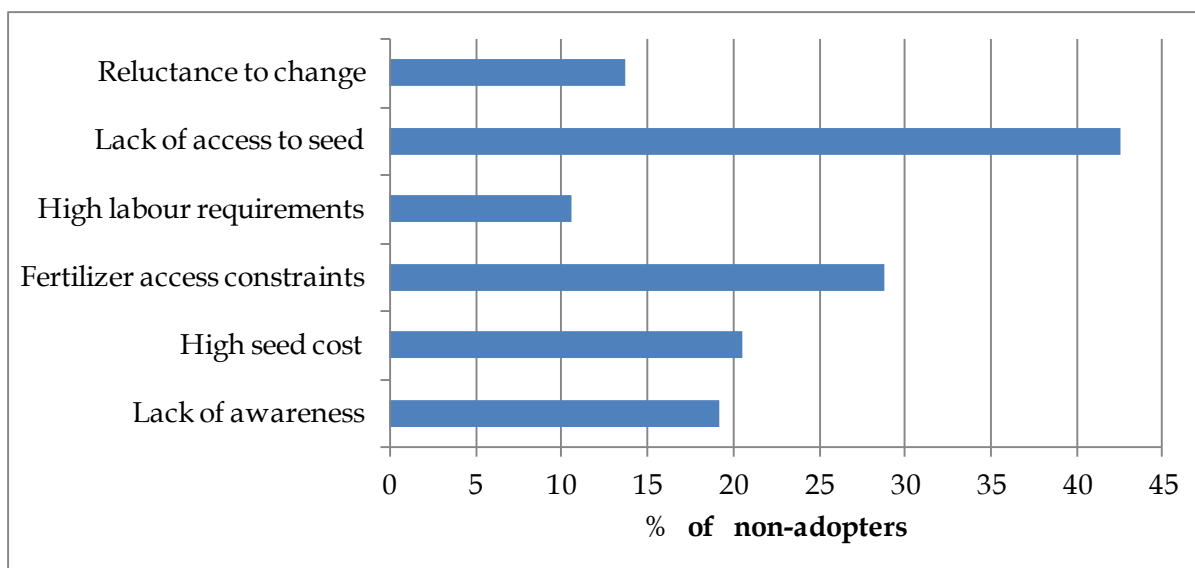


Figure 2: Reasons for non-adoption of DTM (n=85) (*Multiple responses recorded*)

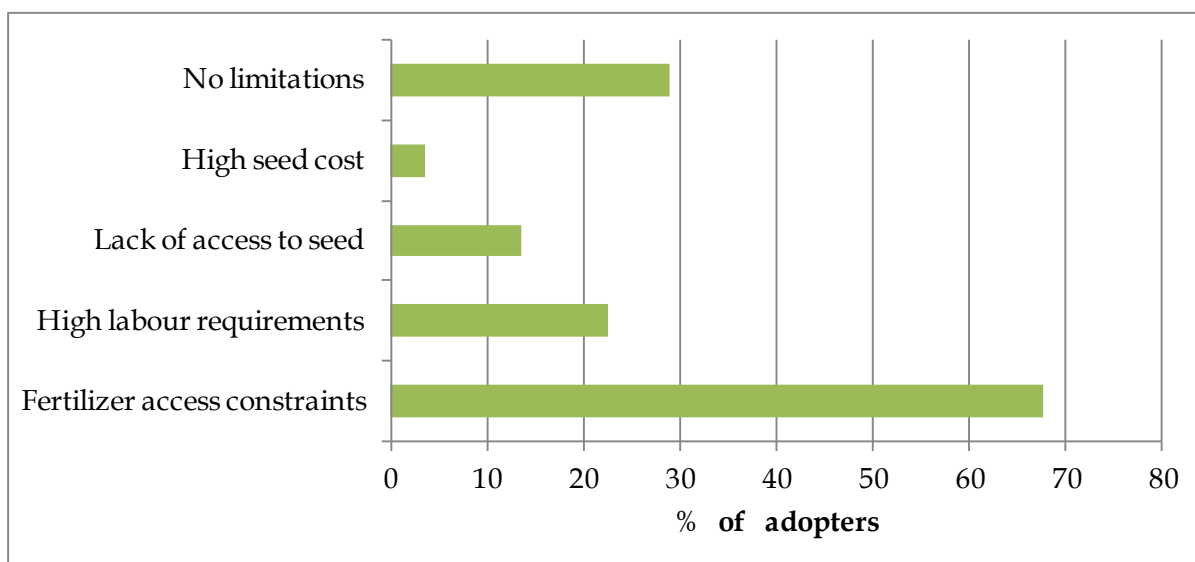


Figure 3: Constraints faced by adopters of DTM (n=115) (*Multiple responses recorded*)

## 5 Conclusions

This paper analyses the adoption of drought tolerant maize (DTM) innovation which is being promoted in north-east Nigeria to help maize farmers adapt to climate change. The paper shows the perceived benefits, determinants, and constraints of adoption of the innovation by rural smallholder farmers. The results indicate that out of the 200 sampled households, only 58% have adopted the innovation despite the increasing promotional efforts and the many benefits of the DTM innovation. Also, adverse climatic conditions are very important in the adoption of DTM with farmers indicating early maturity, drought tolerance and high yield as the main benefits of the DTM innovation.



Analysis of the determinants of DTM adoption indicates that farmers' perception about DTM and climate change related variables are the main factors that influence the likelihood of adopting the innovation. Perception of DTM superiority to other maize varieties in terms of yield and resistance to pests and diseases are likely to influence the adoption of the innovation. The perception of easy availability of seed also influences the decision to adopt DTM. Farmers staying closer to markets are more likely to be adopters because of easy access to the innovation. The income from off-farm employment which assists farmers to purchase seeds and complementary inputs also positively influences DTM adoption. Farmers who are aware of climate change as well as those located in drier agro-ecological regions are more likely to adopt DTM innovation. Also, frequent agricultural extension agents' visits to farmers will increase the likelihood of adopting the innovation. The main reasons for non-adoption and problems of adopters of DTM include fertilizer accessibility problems and lack of access to seed. Other constraints to DTM adoption are reluctance to change from existing varieties, high seed cost and lack of awareness of the existence of the DTM innovation.

The findings of this paper suggest that in the context of the changing climate, the DTM innovation is important for maize farmers, but there is a need for more dissemination efforts for the innovation to reach many farmers in the study region. For instance, involving more extension officers in the provision of technical support to farmers will promote adoption of the innovation. Addressing seed access constraints by providing seeds close to farmers through agro-dealers will also enhance adoption. Improvement in off-farm income earning opportunities and provision of credit facilities to farmers will assist in the purchasing of seeds and the needed complementary inputs required for DTM production. Finally, although the study is specific to north-east Nigeria, the findings provide insights into policies and institutional interventions necessary to promote the development and dissemination of agricultural innovation in smallholder farming systems where households' livelihoods are challenged by climate change.

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