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Impact of Rainfall Variability on the Yield of Sorghum and Farmers' Adoption of Climate Smart Agricultural Practices (CSAP) Towards Food Security in Bauchi State, Nigeria

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Abstract: *This study assessed the impact of rainfall variability on the yield of sorghum and farmers' adoption of Climate Smart Agricultural Practices (CSAP) towards food security in Bauchi State, Nigeria. Rainfall and sorghum yield data for 30 years (1991 – 2021) were used for the study. Three hundred and eighty-two farmers were purposively sampled using Krejcie and Morgan's sampling method. Questionnaire survey was used to elicit information from the farmers. Pearson's product moment correlation coefficient (r) was used to show the relationship between rainfall variability and the yield of sorghum in the study area. The trend lines of total annual rainfall and sorghum yield data shows an increase in rainfall and increase in the yield of sorghum. Results of the Pearson's product moment correlation coefficient (r) at 0.05 significance level shows an indirect/negative and non-perfect relationship (r=-0.3035) between rainfall and sorghum yield. The results further showed that increase in rainfall amounts led to decrease in sorghum yield at Bauchi; sorghum yield appeared to drop below normal towards the end of the period reviewed. Findings also showed that the farmers in the area adopt CSAP such as: the use of organic manure, mixed cropping, use of improved seed varieties and the application of chemical fertilizer in the production of sorghum and other related crops. The study recommended the establishment of more weather stations for more climatic data generation, seasonal forecast of rainfall characteristics and the adoption of viable CSAP by farmers to enhance productivity and food security.*
Keywords: CSAP, Rainfall, Sorghum, Variation, Yield

INTRODUCTION

Rainfall variability and its impacts are getting more severe with each passing year. These posed threats to food security in many developing nations including Nigeria because of the climate-dependent nature of agricultural systems and lack of viable Smart Climate Agricultural Practices (CSAP) (Bello, Ganiyu, Wahab and Abdulmaliq, 2012). Consequently, the concept of CSAP encompasses a suite of approaches to enhance farmers' adaptive capacity to climate variability (Opeyemi, Opaluwa, Adeleke and Ugbaje, 2021). According to Food and Agricultural Organisation (FAO, 2013), CSAP, is an integrative approach to addressing food security and climate variability threat, which ensures food sufficiency despite unsuitable climatic conditions through several soil management practices that sequester carbon in the soil, reduce greenhouse gas emissions and intensify production.

Rainfall variation refers to any changes in rainfall pattern over a period, which may occur due to either natural or human activities (Intergovernmental Panel on Climate Change [IPCC] 2008). It is the amount by which the actual rainfall at any location differs on average from its climatologically normal mean value, that being the mean of the temporal series of rainfall (Ayoade, 2008). Studies have shown that rainfall is one of the important factors determining growth and sorghum productivity. Rainfall variability is an important element of climate that influences agricultural production. This is because the distribution of rainfall varies in time and space and its variation dictates the agricultural season calendar in the country (Yamusa, 2015). Variability may be due to natural internal processes within the climate system, or to variations in natural or anthropogenic external factors (World Meteorological Organisation [WMO] 2019).

Food security and ending hunger have become major global concerns, as evidenced by the United Nations' Sustainable Development Goal 2 (SDG 2), which seeks to ensure food security and find sustainable solutions to eradicate all forms of hunger by 2030. Food security is defined as having consistent access to sufficient food, both physically and financially, to meet dietary needs for a healthy and productive life. Food insecurity is a major obstacle to the progress and prosperity of individuals, communities, and even nations, often resulting in poverty (United States of Agencies for International Development [USAID], 2022). Given the negative impacts of rainfall variability on economic livelihoods and food security in much of the developing world, helping farmers better adapt to this variability is a central concern of development and it is the best way to promote food security. This is because most farmers and governments can more readily understand the threat of variability (Cooper and Dimes 2008). Rainfall can be a challenging factor to sorghum production and can affect the productivity and sustainability of soils to sorghum yield. National Agricultural Extension Liaison Service, (NAERLS, 2004)

Sorghum is a cereal grain crop mostly cultivated in Sub-Saharan African countries and other parts of the world to enhance food security, provide employment and generate income for rural farming households (Thabit, 2015). It is the world's fifth largest grain crop and it is the second most important crop in terms of tonnage in Africa. Nigeria's bulk of sorghum production is derived from the Northern Guinea and Sudan/Sahel ecologies of Northern Nigeria. Sorghum is well adapted to growth in hot, arid or semi-arid areas. Sorghum is used for food, fodder and the production of alcoholic beverages. It is drought tolerant, heat tolerant and is especially important in arid regions. Although sorghum is an indigenous crop exceptionally adapted in the region, the yields are generally less than 1.5 t/ha. There are factors that affect the yield of sorghum, among them are: rainfall variability, poor soil fertility, and the non-availability of improved varieties or hybrids with significant yields superiority over farmers land race. Sorghum requires between 500 to 750mm of well-distributed rain for conducive and proper growth (Ati and Akinyemi, 2018). Sorghum grows best in sandy-loam to clay-loam soils that are well drained and fertile for best yields (Murya, Adeoti and Shebayan, 1995).

Several studies on farmers' perception, adaptation strategies to climate change and variability have been carried out in Nigeria. These include Olanrewaju, (2010); Ogundele and Jegede, (2011); Oluyole, et al., (2013) Tiamiyu, et al., (2015) and Ayanlade, et al., 2017). It is apparently clear from these studies that rainfall variability is factual and has meaningfully impacted on agricultural production in Nigeria. However, little is specifically known about farmers' adoption of CSAP in Nigeria. According to Opeyemi et al. (2021), irrespective of the rapid uptake of CSAP by national organizations and the international community, implementation of the approach is still in its infancy and equally challenging partly due to lack of tools, limited in-depth understanding, capacity and experience in developing countries (Food and Agricultural Organisation [FAO] 2013).

Aim and Objectives

This paper aimed at analysing the relationship between rainfall variability and sorghum yield and the adoption of CSAP by farmers in Bauchi State. The objectives were, to: show the trend of rainfall in the area; examine the relationship between total annual rainfall and the yield of sorghum and identify the viable CSAP adopted by sorghum farmers towards food security in the area. The results will help to provide baseline information, which can be used in formulating new policy and supportive programmes towards adoption of CSAP by sorghum farmers in Bauchi State and Nigeria at large. This study therefore assesses the impact of rainfall variability on the yield of sorghum and farmers' adoption of CSAP towards food security in Bauchi State, Nigeria.

Study Area and methodology

Study area

Bauchi State is in the north-east geo-political zone of Nigeria and was created in 1976. The state is located between latitudes 9°30' and 12°30' North of the Equator, and between longitudes 8°45' and 11°0' East of the Greenwich meridian. It is bounded in a clockwise direction by Yobe, Gombe, Taraba, Plateau, Kaduna, Kano and Jigawa states. There are 20 Local Government Areas (LGAs) in the state, (National Bureau of Statistics, 2009).

Bauchi State covers about 49,259 Km^2 with a population of 4,653,066 according to 2006 census (National Population Commission, 2006). The state is heterogeneous, with predominant tribes like Hausa, Fulani, Jarawa, Tangale, Waja, Balewa, Sayawa and Tarewa. The major language is Hausa. The entire western and northern parts of the state are generally mountainous and rocky. This is as a result of the closeness of the state to Jos (Plateau State) (National Bureau of Statistics, 2009).

The mean daily maximum temperature ranges from 27.0°C to 29.0°C between July and August and 37.6°C in March and April. The mean daily minimum ranges from 22.0°C in December and January. The sunshine hours range from about 5.1 hours in July to about 8.9 hours in November. October to February usually record the longest sunshine hours in Bauchi. Humidity ranges from about 12% in February to about 68% in August. The rainy season months are May to September when humidity ranges from 37% to 68%. Monthly rainfall ranges from 0.0mm in December and January, to about 343mm in July. The onset of rain is often in April while rainfall end virtually by October (Wikipedia, 2008). The area is drained by River Gongola, which originates in the Jos Plateau area. The vegetation of Bauchi is Sudan Savanna type. The vegetation gets richer towards the southern part. The soil of Bauchi is a sandy loam type. Bauchi is an agricultural area by its vegetation type. Besides its vast fertile soil is an added advantage for growing crops such as maize, rice, millet, groundnut, sorghum, etc (Odiana and Ibrahim, 2015).

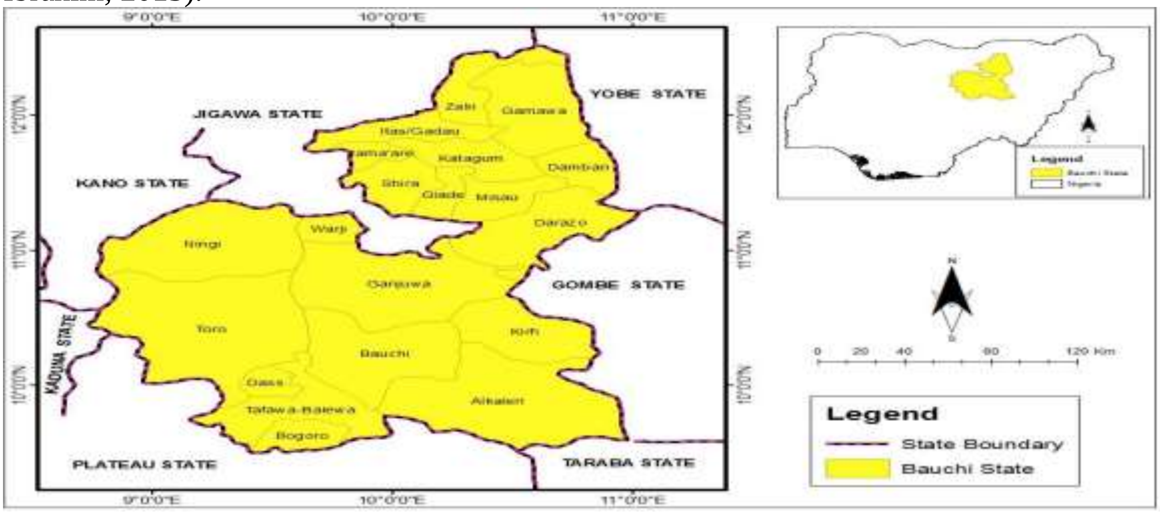

Figure 1: Bauchi State, Nigeria
Source: Adopted from Administrative map of Nigeria (2020)

Materials and Methods

Rainfall and sorghum yield data for 30 years (1991 – 2021) were used for the study. The rainfall data was used to show the trend of rainfall, while the yield data was used to show the trend of sorghum yield in the state. Three hundred and eighty-two (382) farmers were purposively sampled using Krejcie and Morgan's (1973) sampling method. Questionnaire survey was used to elicit information from the farmers. Simple random sampling was used to administer the questionnaire to the sampled respondents. Pearson's product moment correlation coefficient (r) was used to show the relationship between rainfall variability and the yield of sorghum in the area.

Data Analysis

Relative Importance Index technique (RII) was used to determine the extent of adoption of the various CSAP by grain farmers in the area. The various CSAP used by the farmers were examined and ranked in terms of their frequency using the RII (Muhwezi and Otim, 2014; Idoma, 2016).

RII is denoted by $\Sigma W / (A^{x} N)$ ---------------------- (1)

Where; W = Weight given to each factor by the respondents,
A = Highest weight (i.e., 3 in this case),
N = the total number of respondents.
The three-point scale ranged from 1 (Not at all) to 3 (Always). The higher the value of RII, the more the rate of adoption of CSAP in the area.

Results and Discussion

The questionnaire were analysed and succinctly discussed.

Demographic characteristics of the farmers

The demographic characteristics of the farmers in the area were identified, analyzed and presented in Tables 1.

Table 1: Demographic characteristics of the farmers

Distribution of Farmers by Sex		
Variable	**Respondents**	**Percentage**
Male	371	97
Female	11	3
Total	**382**	**100**
	Distribution of the Farmers by Age	
Age	**Respondents**	**Percentage**
30 – 39	92	24
40 – 49	114	30
50 – 59	99	26
60 – 69	73	19
70 & above	4	1
Total	**382**	**100**
	Religious Belief of the Farmers	
Religion	**Respondents**	**Percentage**
Islam	374	98
Christianity	4	2
Total	**382**	**100**
	Marital Status of the Farmers	
Marital Status	**Respondents**	**Percentage**
Married	352	92
Divorced	4	1
Single	15	4
Widowed	11	3
Total	**382**	**100**
	Level of Education	
Level of Education	**Respondents**	**Percentage**
Primary	69	18
Secondary	99	26
Tertiary	73	19
No Formal Education at all	141	37
Total	**382**	**100**
	Household Size of the Farmers	
Household Size	**Respondents**	**Percentage**
1 – 5	31	8
6 – 10	130	34
11 – 15	96	25

16 – 20	69	18
21 – 25	34	9
26 & above	23	6
Total	**382**	**100**
	Farmers' Years of Residency	
Years of Residency	**Respondents**	**Percentage**
20 – 30	153	40
31 – 40	126	33
41 & above	103	27
Total	**382**	**100**

The results show that 97% of the sampled farmers were male, while 3% were female. That majority of the farmers were male might be because, male have a dominant role to play in the family as household heads in providing the households basic needs such as food. The age distribution of the farmers as presented in Table 1, shows that 24% fell within 30 – 39 years; 30% were within 41 – 49 years; 26% were within 51 - 59 years; 19% fell within 61 – 69 years and 1% fell within 70 years and above. Majority (75%) of the farmers fell within the age of 41 and above. According to Deressa, Hassan, Alemu, Yesuf and Ringler (2008), the age of the respondents represent experience on climate change issues. The older the respondent, the more experienced he was in knowledge of climate variability and change, the more exposed to past and present climatic conditions over a longer horizon of his lifespan. These results imply that the sampled farmers in the study area were above the dependent age.

Table 1 further indicates that 98% of the farmers are Muslims, while 2% are Christians. The religious belief/faith of the respondents plays a major role on their perception of climate change and adaptation measures, especially on what causes climate change. According to Constable (2016), the influence of religion, especially the Christian principles was evident in her study area (Jamaica) in the assertion that climate change is an act of God, a punishment for man's disobedience and a sign to end of the world.

The result (Table 1) shows that 92% of the sampled farmers were married, about 1% were divorced, while 4% were single and 3% were widowed. These indicate that majority of the farming household members were married. This suggests that married household members have many mouths to feed, therefore, they engage more in farming activities in order to provide food and income for the family than singled and divorced household members.

More so, Table 1 presented that 18% of the farmers attended primary school; 26% attended secondary school; 19% attended higher institution at various levels, while 37% had no formal education at all. The results further indicate that most of the respondents received various forms of education in the area. According to Enete, Madu, Mojekwu, Onyekuru, Onwubuya and Eze (2011), education has a positive and highly significant relationship between the farmers' level of education with the level of investment in indigenous and emerging climate change adaptation practices. This is to be expected as educated farmers may better understand and process information provided by different sources regarding new farm technologies, thereby increasing their allocation and technical efficiency.

Family labour is recognized as a major source of labour supply in smallholder crop production in most parts of Africa, including Nigeria. This comprises the labour of all males, females including children in a household, who contribute their mental and physical efforts to the household holdings. More so, Table 1 shows the family size distribution of respondents. The result show that majority (34%) of the farmers are within the household size of 6 - 10, followed by 25% which fell within the household size of 11 to 15; 18% are within the range of 16 to 20 household size; 9% fell within the range of 21 to 25 household size, while 6% fell within the household size of 26 household members and above.

Trends in Total Annual Rainfall in Bauchi

The trend in Total Annual Rainfall (TAR) for Bauchi (Figure 2) showed an irregular, fluctuating pattern of rainfall. Overall, the results showed an increasing amount of TAR (y = 8.735x + 942.37**)**. The maximum amount recorded within the period (1991 – 2021) was 1655.1 mm (2020) while the minimum was 672.1mm (2014). That the TAR of the study area is increasing agrees with the observation made by Building Nigeria's Response to Climate Change (BNRCC, 2011) which reported that Nigeria is now experiencing wetter conditions in recent years. This result is supported by Ati, Stiger, Iguisi, and Afolayan (2009) who stated that evidence from nine stations in northern Nigeria, shows that there is a significant increase in annual rainfall amount in the last decade.

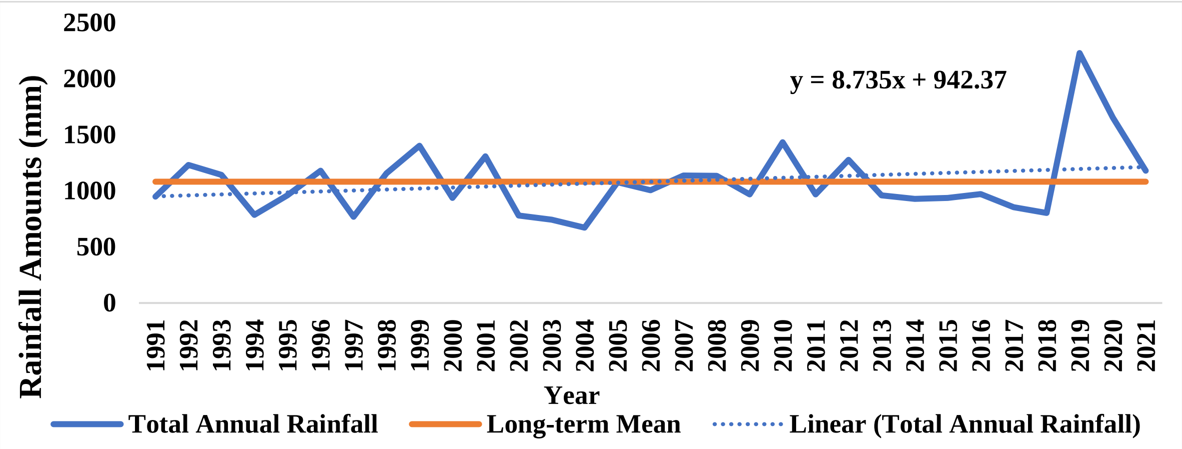

Figure 2: Trend in Total Annual Rainfall Amount for Bauchi State

The result further coincided with the findings of Sawa (2010) and Nnachi (2014) which reported that most parts of northern Nigeria experienced an increase in rainfall between 1990 and 2000. According to Olaniran (2001), Nigeria is characterized by alternating wet and dry conditions with rainfall anomaly showing wetter than normal rainfall conditions. This increasing TAR could positively or negatively affect the yield of crops.

According to Ati and Akinyemi (2018), sorghum requires 500 – 750mm of well distributed rainfall for conducive and proper growth. That means where rainfall totals fall below 500mm, effective sorghum production may be affected. It also implies that sorghum production may also be affected where the amount of rainfall exceeds the require maximum.

Sorghum Yield

The trend line in yield for sorghum for Bauchi showed that sorghum yield is increasing (y = 0.001x + 1.1784). This result confirms the findings of Ikpe (2021) which reported that sorghum yield is increasing in Sokoto State. Part of the reasons for the increase in yield was attributed to increase in the TAR and the adoption of viable adaptation strategies by grain farmers.

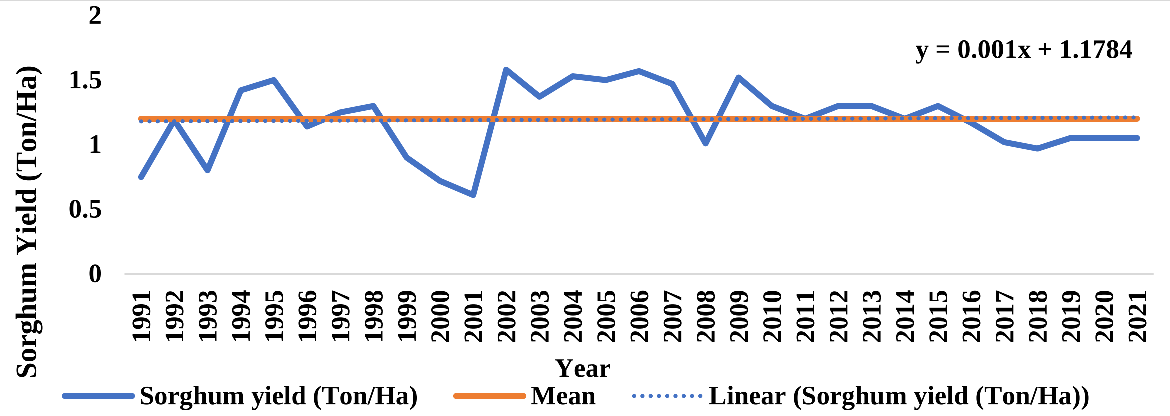

Figure 3: Sorghum Yield for Bauchi State

Correlation between rainfall and sorghum yield

Using Pearson product moment correlation coefficient (r) at 0.05 significance level, the result showed that r = -0.3035, this implies that indirect/negative and non-perfect relationship exist between rainfall and sorghum yield. The result implies that increase in rainfall amounts led to decrease in sorghum yield at Bauchi. Sorghum yield appeared to drop below normal at the end of the data. This result corroborated with the findings of Emeghara (2015) which stated that there was no significant relationship between sorghum yield and TAR in Sokoto State. This result disagrees with the findings of Bello et al., (2012) who reported a significant and positive correlation between TAR and sorghum yield at Kano, Nigeria.

According to Adeshina and Odekunle (2011) through CSAP, it is possible for farmers to adapt to the effect of climate variability in the semi-arid regions of Nigeria. Ikpe (2014) further stated that through viable CSAP, farmers have been able to effectively cultivate grains in Goronyo, Sokoto State. Ejeh (2014) further reported that farmers in Kano State are coping with the effects of climate change through various adaptation strategies.

Farmers' adoption of CSAP

Table 2 shows thirteen CSAP used by farmers in the study area. The following criteria were used to rank the rate of adoption: RII > 0.8 = Highly adopted, 0.7-0.8 = High, 0.6-0.69 = Fairly high, 0.5-0.59 = Fairly low and <0.5 = very low. The result revealed that out of the 13 practices, 9 were "highly adopted" by the farmers as reflected in their RII scores greater than 0.8. These CSAP included use of organic manure, use of inorganic fertilizer, planting of pest and disease resistant crop that are well acclimatized, planting of cover crops, use of early maturing seeds, use of weather resistant varieties and mixed cropping systems (Table 2). Adoption of mixed farming practices was high, soil conservation and water were fairly high, contour ploughing around farmland was fairly low, while reforestation/afforestation was very low. The results are consistent with Iheanacho (2000); Ikpe, Ejeh and Idoma (2018) and Farauta, Egbule, Idrisa and Agu (2011) who affirmed fairly high adoption of CSAP in semi-arid tropics of West Africa. Results from previous studies agrees with the analysed ranking of CSAP where farmers of the area emphasized that mixed cropping is farmers' friendly because of its numerous benefits of multiple harvest, crop/food security and the extra sources of income it provides to the farmers.

Table 2: CSAP used by Farmers in the Study Area (n=382)

S/N	CSAP	Always	Rarely	Not at all	RII	Rank
1	Soil conservation and water	57	161	163	0.6	11
2	Use of organic manure	323	39	20	0.9	2
3	Use of inorganic fertilizer	274	73	73	0.9	2
4	Planting pest and disease resistant crop	268	86	28	0.9	2
5	Crop varieties that are well acclimatized	307	68	7	0.9	2
6	Contour ploughing around farmland	67	51	264	0.5	12
7	Planting of cover crops	283	78	21	0.9	2
8	Reforestation/Afforestation	9	35	338	0.4	13
9	Use of herbicide, insecticide etc.	296	47	37	0.9	2
10	Use of early maturing crop varieties	340	40	2	0.9	2
11	Use of weather-resistant variety	296	78	8	0.9	2
12	Mixed farming practices	141	145	96	0.7	10
13	Mixed cropping	373	8	1	1.0	1

Conclusion

This study has evaluated the impacts of rainfall variability on the yield of sorghum and farmers' adoption of CSAP towards food security. The study has established that the TAR and sorghum yield is on the increase. The result also show that increase in rainfall amounts led to decrease in sorghum yield, which presented a non-perfect relationship between rainfall and sorghum yield. This study has also established that there are CSAP that will help the farmers in enhancing sorghum yield. Thirteen CSA practices were used by farmers in the study area, with mixed cropping being the most adopted towards food security.

Recommendations

Despite the challenges posed by rainfall variability in the area, there are possibilities for addressing the impact of rainfall variability and assisting farmers to adopt CSAP in order to increase productivity and food security in Bauchi State and Nigeria in general. Particularly the following has been recommended:

1. There is need for putting in place policies and programmes that will make the farmers to be proactive in the use of resources and at the same time adapting to rainfall variability.

2. There is the need for the government and NGOs to continue supporting the farmers to increase their adaptation capacities by providing grants, subsidies and agricultural inputs to the farmers; use of farm extension workers for agricultural education and updates and provision of improved seed varieties.

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