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ANALYSIS OF EFFECTS OF CLIMATE-SMART AGRICULTURAL TECHNOLOGIES ON CEREAL CROP PRODUCTION IN BENUE STATE, NIGERIA

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Abstract

This study analyzed effects of climate-smart technologies on cereal crop production in Benue State, Nigeria. A sample size of 180 respondents was selected through multistage sampling techniques. The data for the study were collected using structured questionnaire and analyzed using descriptive and inferential statistics. The results on socioeconomic characteristics of cereal crop farmers showed that majority (70.6%) of the respondents were males, mean age was 48.86years, married (45.6%) with a household size of 7.85persons, spent an average of 15years in school, major occupation was farming (69.4%)with average farm size and farming experience of 3.29hectares, and 28.71years, respectively. The average annual output was 4205.55kg with mean annual income of N2, 429,450.00.Majority (86.1) of the respondents belonged to cooperatives, 79.4% had extension contacts and 85.0% had used climate-smart agricultural technologies. The propensity scores matching result on the effects of climate-smart agricultural technologies on cereal crop yields showed a chi-square (3.18) significant at (P<0.1), which implies that climate-smart agricultural technologies affects cereal crop yields. The difference of -2436.042 units indicates that adopters had much lower yields than non-adopters before matching, which was significant (P<0.05). It was recommended that the government should provide credit facilities to cereal crop farmers to enhance their usage of climate-smart agricultural technologies during drought and dry season farming.

Keywords: *Analysis, Effects,Climate-smart, Technologies, Cereal crop.*

1.0 Introduction

Nigeria, like many other countries, is experiencing significant changes in its climate that are impacting agricultural productivity. The nation's climate variability is characterized by increased temperatures, irregular rainfall patterns, and more frequent extreme weather events such as floods and droughts (Murtaza *et al.,* 2019). These

changes are particularly critical for agriculture, a sector that remains the backbone of Nigeria's economy and sustains the livelihoods of a significant portion of its population (Soom *et al.*, 2024). The shifting climate conditions pose a substantial threat to food security and reduce the yields of cereal crops, which are crucial for both local consumption and economic stability (Fadina and Barjolle, 2018).

Nigerian farmers are highly vulnerable to these climatic shifts due to their reliance on rain-fed agriculture. Changes in precipitation patterns and increased temperature variability have led to challenges such as soil degradation, reduced soil moisture, and increased pest and disease incidences, which in turn affect crop productivity (Muhammad *et al*., 2020). The unpredictability of rainfall, coupled with prolonged dry spells, has disrupted the cultivation cycles of cereal crops, leading to reduced agricultural output and economic hardship for farmers (Shaba, 2021). The changing climate has profound effects on farming, particularly on the production of cereal crops. Increased temperatures and altered rainfall patterns are leading to a reduction in soil moisture and increased evaporation rates, which negatively affect crop growth and yields (Totin *et al*., 2018). Moreover, extreme weather events such as heavy rains and flooding can cause soil erosion and loss of arable land, further diminishing agricultural productivity (Ojoko *et al*., 2017).

The impact of climate change is also evident in the increased incidence of pests and diseases. Warmer temperatures create a conducive environment for pests like the fall armyworm, which devastates maize crops, and for diseases such as rice blast and maize streak virus, which have become more prevalent (Iornongo, 2021). These challenges are exacerbated by the limited capacity of many Nigerian farmers to adapt to changing conditions due to a lack of access to resources, information, and climate-resilient

technologies. Consequently, the changing climate is not only reducing the yields of cereal crops (like maize, rice, and sorghum) but also increasing the vulnerability of farmers to food insecurity and economic instability (Soom *et al*., 2024).

In the face of rapidly changing climate conditions, Nigerian farmers must adopt climate-smart agricultural practices to sustain crop production and ensure food security (FAO, 2020). Climate-Smart Agriculture (CSA) is described as agriculture that sustainably increases production and income, resilience as a result, and eliminates greenhouse gas emissions (mitigation), which heightens the accomplishment of national food security, developmental objectives, and reduced poverty. Agriculture, is considered to be climate-smart when it achieves a sustainable increase in agricultural production and income; acclimatizes and builds resilience to climate alteration; and reduces or eliminates greenhouse gas (GHG) emission (Ekpa *et al*., 2021). Farmers need to be equipped with the knowledge and skills to implement adaptive measures such as soil conservation techniques, efficient water management practices, and the use of drought-resistant crop varieties. With climate-smart technologies, farmers can improve their capacity to cope with adapt to the adverse effects of climate change, ensuring the long-term viability of their agricultural activities (Soom *et al.,* 2024).

According to Shaba (2021), several climate-smart agricultural technologies have been developed to enhance the productivity and resilience of cereal crops such as maize, rice, sorghum and millet in the face of climate change. One such technology is the use of improved crop varieties that are drought-resistant and heat-tolerant, which can thrive under adverse weather conditions and ensure stable yields. The International Institute of Tropical Agriculture (IITA) (2020) reported that, development of drought-tolerant maize varieties by IITA has significantly improved maize production in many parts of

the country prone to erratic rainfall. Similarly, the introduction of high-yielding, flood-tolerant rice varieties has helped mitigate the effects of flooding in rice-growing areas [National Cereal Research Institute (NACRI), 2018]. Viira and Oladipo (2023) were of the view that another crucial climate-smart agricultural technology is conservation agriculture, which includes practices like minimum tillage, crop rotation, and the use of cover crops. These practices help maintain soil health, increase water retention and reduce soil erosion, thereby enhancing the resilience of cereal crops to climate variability. Additionally, precision climate-smart agriculture technologies such as drip irrigation and smart weather forecasting systems enable farmers to optimize water use and make informed decisions about planting and harvesting times (Yurkushi, 2015).

Some studies, such as Soom *et al.* (2024); Iornongo (2021); Ekpa *et al.* (2021); Ojoko *et al.* (2017); Shaba (2021); and Obianefo *et al.* (2024), have been carried out concerning climate-smart agricultural practices and cereal crop production. Despite these studies carried out, little is done concerning analysis of effects of climate-smart technologies on cereal crop production in Benue State, Nigeria. The research gap lies in the lack of empirical evidence on the effectiveness and adoption of climate-smart technologies for cereal crop production in Benue State. This study aims to fill this gap by providing a detailed analysis of effects of climate-smart agricultural technologies on cereal crop production in Benue State, thereby offering insights that can inform targeted interventions and policy frameworks to support sustainable agricultural development in Benue State, Nigeria.

2.0 Objectives of the Study

The broad objective of the study was to analyze effects of climate-smart agricultural technologies on cereal crop production in Benue State, Nigeria. The specific objectives were to:

i. describe the socio-economic characteristics of the respondents in the study area, and

ii. determine effects of climate-smart agricultural technologies on selected cereal crop yield in the study area.

The following hypothesis was tested.

Ho_1: Climate-smart agricultural technologies have no significant effect on cereal crop yield in the study area;

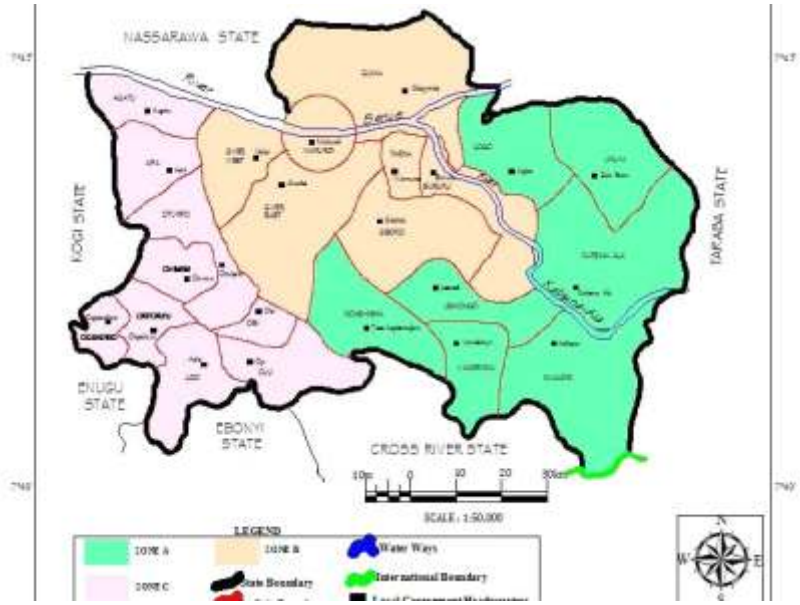
3.0 Methodology

3.1 The Study Area

The study was conducted in Benue State, one of the thirty-six States in Nigeria (Figure 1).The State capital is Makurdi. Benue State lies within the lower river Benue trough in the middle belt region of Nigeria. Benue State lies between Latitudes $6^0$25'N and 8 08'N of the equator and Longitudes $7^0$47' and 10^0E (Ministry of Land and Survey, 2016). It has a total Land area of 30, 783 km^2) and population of 6,141,300 (NPC, 2022), with an average population density of 99 persons per square kilometer. The State is blessed with a great loamy soil for agricultural activities. Shares boundaries with five other States, namely: Nasarawa State to the North, Taraba State to the East, Cross-River State to the South, Enugu State to the South-west, and Kogi State to the West. The State also shares a common boundary with the North-West Province, claimed by both Ambazonia and the Republic of Cameroon on the Southeast. Benué State consists of twenty-three (23) Local Government Areas grouped into 3 agricultural zones: A, B, and C, respectively. The major food crops produced are yam, rice, cassava, maize, soybean, sesame, cowpea and groundnut at the subsistence level.

The State is populated by several ethnic groups, such as Tiv, Idoma, Igede, Etulo,

Abakpa, Jukum, Hausa, Igbo, Akweya and Nyifon. Benue State has a tropical climate, which manifests two seasons. The rainy season is from April to October, while the dry season is from November to March. Annual average rainfall varies from 1750 mm in the Southern part of the State to 1250 mm in the North (BNARDA, 2020). The State stretches across the transition belt between the forest and savanna vegetation. Much of the area consists of undulating hills or grassy open space in the North and a derived savanna in the South.



Selected Local Governments

Population and Sampling Techniques

The population of the study comprises a total of 90,071 arable crop farmers in Benue State, who are involved in the cultivation of rice, maize, sorghum, and millet (BNARDA, 2024). The sample size for the study was 180 respondents. Multi-stage random sampling technique was used to select respondents for the study (Table 1).In the first stage, the

State was stratified into 3 agricultural zones: Zones A, B and C, respectively. Second stage involved random selection of one Local Government Area each from each of the zone: Vandeikya from Zone A, Tarka from Zone B and Otukpo from Zone C. Finally, proportional allocation of 0.2%was usedon sampling frame to select a total sample size of 180 respondents (Table 1).

Table 1: Sample Size Selection Plan

Agricultural Zones	LGAs	Sampling frame	Sample size (0.2%)
A	Vandeikya	29,877	60
B	Tarka	30,518	61
C	Otukpo	29,676	59
Total		90,071	180

Source: BNARDA (2024)

Method of Data Analyses

Data for the study were analyzed using both descriptive and inferential statistics. Frequency, percentages, mean, and standard deviation were used to analyze objectives I and II. Hypothesis I was tested using the Chi-square. According to Guo and Fraser (2015), propensity score matching is stated below and was used to determine the effect of climate-smart agricultural technologies on the yield and income of cereal crop farmers.

$$e(X) = \frac{e^{\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\cdots+\beta_{17}X_{17}}}{1+e^{\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\cdots+\beta_{17}X_{17}}}$$

Where:

e = yield of maize, rice, and sorghum

β_0 is the intercept.

$\beta_1, \beta_2, \ldots, \beta_k$ are the coefficients of the predictor variables $X_1, X_2, \ldots, X_k$

X_1 = improved seeds for planting (use=1, otherwise=0)

X_2 = Use of herbicides (use=1, otherwise=0)

X_3 = Application of pesticides (use=1, otherwise=0)

X_4 = Application of inorganic fertilizers (use=1, otherwise=0)

X_5 = Application of organic fertilizers (use=1, otherwise=0)
X_6 = Zero tillage operations (use=1, otherwise=0)
X_7 = Use of favorable planting dates (use=1, otherwise=0)
X_8 = Integrated soil fertility management (use=1, otherwise=0)
X_9 = Crop rotation (use=1, otherwise=0)
X_{10} = Crop diversification (use=1, otherwise=0)
X_{11} = Use of harvesters (use=1, otherwise=0)
X_{12} = Use of modern storage facilities (use=1, otherwise=0)
X_{13} = Application of advanced processing technologies (use=1, otherwise=0)
X_{14} = Erosion control (use=1, otherwise=0)
X_{15} = Integrated pest management practices (use=1, otherwise=0)
X_{16} = Application of irrigation practices during dry season farming (use=1, otherwise=0)

4.0 Results and Discussion

4.1 Socioeconomic Characteristics of cereal crop (maize, rice, sorghum) farmers

Table 2. shows that, majority (70.6%) of cereal crop farmers were males, while 29.4% were females. This indicates that males were more involved in cereal crop farming in the study area than females. The reason could be that most of these cereal crops were cash crops and their production were geared towards income earning, since males were household heads and own most of the resources like land. This agrees with the findings of Soom *et al*. (2024) and Akanbi *et al*. (2022), who reported that males were mostly engaged in farming activities.

Table 2 also reveals average age of 48.8 years for cereal crop farmers in the study area. This indicates that most of the cereal crop farmers were still in their productive age to be actively involved in farming cereal crops such as rice, maize and sorghum. Cereal crop farmers within this age range who actively involved in farming were most likely to use climate-smart agricultural technologies. This is in line with Akanbi *et al.* (2022), who reported that most rice crop farmers were around 30 years of age. This was supported by

Agyo and Oman (2021) and Ayegba and Ayopo (2020), who reported arable crop farmers within the working age bracket of between 45-55 years.

Table 2 further reveals that, 45.6% of the cereal crop farmers were married, 28.9% were singled, 18.9% were divorced and 6.7% were widows. This implies that most of the cereal crop farmers were married and involved in the production of cereal crops. Most married farmers are involved in farming cereal crops as an occupation to obtain income and food for their families. This is in agreement with the findings of Akanbi *et al*. (2022) and Soom *et al*. (2024), who reported that most rice farmers in Benue State were married. Also supported by Agyo and Man (2021) who stated that most farming households in Taraba State were married.

Table 2 also showed that, 36.1% of the respondents were between the household size of greater than or equal to 10 persons and, 32.3% had less than or equal to5 persons, and 31.7% had between 6 and 10 persons. The mean household size of 8.0 persons per household showed that cereal crop farmers had a reasonable household size, which could be used for family labor on cereal farms. This, by implication, showed that a larger household size is most applicable to farming households to have more hands on the farm. This is in line with the findings of Agyo and Oman (2021), who reported a mean household of 7 persons among farming households in Taraba State. This was not supported by Soom *et al*. (2024) and Akanbi *et al*. (2022), who reported household sizes of between 4-6 persons among arable crop farmers in Nigeria.

Table 2 also showed that, 46.1% of the cereal crop farmers spent between 7 and 12 years in school, 37.2% spent 13 years and more, 10% had non formal education, and 6.7% spent between 1-6 years in school, with an average years spent in school of 15.6 years. This implies that, cereal crop farmers in the study area were literate and had attained a

level of education to understand the relevance and importance of using climate-smart agricultural technologies. This coincides with Soom *et al*. (2024) and Akanbi *et al*. (2022), who agreed that most arable crop farmers attained a level of education to be literate.

Table 2 showed further that, majority (69.4%) of the cereal crop farmers were engaged in farming, 10.6% in civil service and 20.0% in trading. This implies that Benue State is an agrarian State, and as such, most of the people were into farming, which could be either crop or livestock farming. These findings were in line with Akanbi *et al*. (2022), Agyo and Oman (2021), and Soom *et al*. (2024), who reported farming as the major occupation of the indigenes of Benue State. The result on farm size showed that 39.4% of the cereal crop farmers had between 1.51 and 3.00 hectares, 26.7% had 4.51 hectares or more, 18.9% had between 3.01 and 4.50 hectares, and 15.0% had 1.5 hectares or less. The average farm was 3.29 hectares. This farm size implies that most cereal crop farmers were small-scale farmers, cultivating on small and fragmented portions of land. This happens to be the nature of farm sizes due to the stringent land tenure system, where most lands are communal lands. This is in line with Akanbi *et al*. (2022), who reported that rice farmers were small-scale farmers, operating on small farm sizes between 1-5hectares. This finding disagrees with Soom *et al*. (2024), who reported less than 3 hectares of farm sizes and between 2.5 hectares used by arable crop farmers.

Table 2 also showed that, 34.4% of the cereal crop farmers had farming experience of between 26-40 years, 23.3% had less than 10 years' experience, and 20.0% had between 11 and 25 years' experience in farming. The average farming experience of cereal crop farmers was 28.71 years. This, by implication, showed that as an agrarian State, farmers have been involved in farming for a long period enough to encourage the

use of climate-smart agricultural technologies in an era of climate change. This aligns with the findings of Azembeh (2022), who reported a farming experience of between 25 to 35 years for arable crop farmers in Benue State, but disagrees with Soom *et al*. (2024) and Akanbi *et al*. (2022), who reported an average farming experience of 8 years and 10 years, respectively.

Annual output results showed the average cereal crop annual output was 4,205.55kg. This, by implication is likened to small-scale production levels with low levels of output. This is in line with Musa and Adeola (2021) who reported low output levels for rice farmers in Nigeria. Also supported by Mwangi and Njoroge (2019) and Oduntan *et al*. (2022) who reported low annual output by arable crop farmers.

Table 2 shows that, the average annual income of cereal crop farmers was N2, 429,450.00. This indicates that cereal crop farmers earn a reasonable annual income from selling their output to markets and cottage industries. The annual income is above the earnings of smallholder farmers of N1, 500,000 (FAO, 2015) due to hyperinflation in the country.

Table 2 further shows that, majority (86.1%) of the respondents belonged and to cooperatives and only 13.9% did not belong to cooperative societies. This implies that a good number of cereal crop farmers were members of cooperative societies. These societies were contact groups for an extension to carry out awareness campaigns on climate-smart agricultural practices. This is in line with Ayegba and Ayopo (2020) and Agyo and Oman (2021), who reported that farmers belong to cooperative societies.

Table 2: Socioeconomic Characteristics of Cereal Crop Farmers (n=180)

Variables	Freq.	Percentage(%)	Mean (ᵡ)
Sex			
Male	127	70.6	
Female	53	29.4	
Age (years)			
<30	16	8.9	48.86
31-40	30	16.7	
41-50	38	21.1	
51-60	74	41.1	
>60	22	12.2	
Marital Status			
Single	52	28.9	
Married	82	45.6	
Widow	34	6.7	
Divorced	12	18.9	
Household Size			
<5	58	32.3	8.0
6-10	57	31.7	
>10	65	36.1	
Years in School			
Non formal	18	10.0	15.6
1-6	12	6.7	
7-12	83	46.1	
>13	67	37.2	
Major Occupation			
Farming	125	69.4	
Civil service	19	10.6	
Trading	36	20.0	
Farm size (hectares)			
<1.5	27	15.0	3.29
1.51-3.00	71	39.4	
3.01-4.50	34	18.9	
>4.51	48	26.7	

Table2 contd.

Farming experience (years)			
<10	42	23.3	28.71
11-25	36	20.0	
26-40	62	34.4	
>40	40	22.2	
Annual Output (Kg)			
<1000	50	27.8	4205.55kg
1001-11,000	124	68.9	
>41,001	6	3.3	
Annual Income (₦)			
<500,000	22	12.2	2,429,450.00
500,001-2,000,000	59	32.8	
2,000,001-3,500,000	75	41.7	
3,500,001-5,000,000	6	3.3	
>5,000, 000	12	6.7	
Membership of Cooperative	6	3.3	
Yes	155	86.1	
No	25	13.9	
Extension Visit			
Yes	143	79.4	
No	37	20.6	
Use of CSAT			
Yes	153	85.0	
No	27	15.0	

Source: Field survey (2024)

4.2 Effects of Climate Smart Agricultural Technologies on Cereal Crop Yields

The results of effects of climate-smart agricultural technologies on cereal crop yields in the study area were presented in Table 3. Propensity scores matching were used to determine the effects of climate-smart agricultural technologies on cereal crop yields. Tobit regression embedded in propensity scores matching was adopted, using climate

agricultural technologies. The log-likelihood value was -107.50688, and the associated Chi-square value (3.18) was statistically significant at P>0.1 level of probability. This implies that the model can be relied upon to explain the probability of climate-smart agricultural technologies on cereal crop yields. Furthermore, the significance of the associated Chi-square at P>0.01 level of probability implied that climate-smart agricultural technologies significantly have an effect on cereal crop yield in the study area, hence the null hypothesis I which states that "climate-smart agricultural technologies have no significant effect on cereal crop yields in the study area" was rejected and the alternative hypothesis accepted.

The coefficient of CST was negative (-0.109) and statistically significant at P<0.1, indicating that the use of climate-smart agricultural technologies was associated with a slight reduction in cereal crop yields by 0.109 units. This implies the result was not highly robust, but there's weak evidence of a negative relationship. This finding contradicts the expectation that CST should enhance productivity by improving resilience to climate variability. One possible explanation could be that CSTs require a learning curve or that the benefits of CST, such as long-term soil health or resilience to extreme weather, may not translate into immediate yield increases. Also, most cereal crop farmers were dependent on rain for farming even in times of drought, farmers had no safety nets. These findings disagree with Andati *et al*. (2023), who reported adoption of climate-smart technologies had a positive effect on crop yields.

To evaluate the effects of climate-smart agricultural technologies on cereal crop yields, we estimated propensity scores matching (PSM) using the nearest neighbour matching strategy, and the result was presented in Table 3. In the unmatched sample, there was a large and statistically significant yields difference between climate-smart

agricultural technology adopters (treated) and non-adopters (controls). The difference of -2436.042 units indicates that adopters had much lower yields than non-adopters before matching, which was significant ($P<0.05$). This large difference highlighted potential selection bias, as those using climate-smart agricultural technologies might differ systematically from non-adopters (e.g., in terms of farm size and access to resources). After applying nearest neighbour matching (NNM) to control for confounding variables, the yield gap narrows. The climate-smart agricultural technologies users (treated group) still had lower yields (2486.792) compared to the climate-smart agricultural technologies nonusers (control group) (4307.547), but the difference (-1820.755) was reduced. This difference was also statistically significant ($P<0.05$), although less pronounced than in the unmatched sample. The matching process reduces the bias but does not eliminate the yield disadvantage for CST adopters. This reduction suggests that matching improves the balance between treated and control groups but does not eliminate the difference in yields. This reduction in the yield gap after matching confirms the importance of controlling for selection bias when evaluating the effects of CST. The findings disagree with Amadu *et al*. (2020), who found 53 % increase in maize yield among climate-smart agricultural technology adopters in the drought year of 2016 among households in Malawi. Also, Asrat and Simane (2017) found that households in northwest Ethiopia that adopted and maintained CSA technology between 2015 and 2017 boosted farm-level production by 22 % above non-adopters due to lower climate change-related risks.

Table 3 : Propensity Score Matching results on the effect of climate-smart agricultural technologies on cereal crop yield

Variable	Coefficient	Std. Err.	-	- >/- /	95% confidence interval	
CST	-0.109*	0.061	-1.780	0.075	-0.229	0.011
Constant	-0.187	0.222	-0.840	0.399	-0.621	0.248
LRChi^2	3.18 (0.0747)*					
Pseudo R^2	0.0146					
Log-likelihood	-107.50688					
Variable sample	Matching strategy	Treated	Controls	Difference	S.E.	T-stat
Annual output unmatched	NNM	2486.792	4922.835	-2436.042**	1422.240	-1.710
Annual output matched	NNM	2486.792	4307.547	-1820.755**	1228.271	-1.480

*significant at 10%; ATT: average treatment effect on the treated; untreated (70.5%), treated

5.0 Conclusion and Recommendations

5.1 Conclusion

Based on the findings of the study, it was concluded that climate-smart agricultural technologies were used by cereal crop farmers, who adopted improved seeds for planting, herbicides and pesticides, crop rotation, and crop diversification as some of the climate-smart agricultural technologies adopted .

Recommendations

Based on the findings of the study, the following recommendations were made:

i. Non-governmental organisations should provide credit facilities to cereal crop farmers to enhance their usage of climate-smart agricultural technologies during drought and dry season farming and

ii. Agricultural extension agents should educate and create awareness campaigns on relevant climate-smart agricultural technologies to enhance adoption by cereal crop farmers.

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