Review Article ISSN 2766-2624

Advances in Earth and Environmental Science

The Impact of Climate Change On Some Selected Crops Under Different Agro-Ecological Zones in Katsina State, Nigeria During The 2021 Cropping Season

Abdullah, Abba Yakubu

Aquagric Ltd, 3 Awka Crescent, War College Estate, Gwarimpa, Abuja, Nigeria.

***Corresponding author**

Abdullah, Abba Yakubu,
Aquagric Ltd, 3 Awka Crescent, War College Estate, Gwarimpa, Abuja, Nigeria.

Submitted : 22 Sept 2025 ; Published : 11 Oct 2025

Citation: Abdullah, A. Y. (2025). The Impact of Climate Change On Some Selected Crops Under Different Agro-Ecological Zones in Katsina State, Nigeria During The 2021 Cropping Season. *Adv Earth & Env Sci; 6*(4):1-6. DOI : https://doi.org/10.47485/2766-2624.1075

Abstract

With the frequency and gravity of droughts, excessive heat and over reliance on rain fed agriculture, there is a mounting crisis in agricultural productivity, declining food availability of the households and the danger posed to countries whose prospect of national economies are dependent on agriculture. Nigeria is one of the nations that is confronted by the impact of climate change. Whereas most of the states in the northern part of the country that are acknowledged to be the major food producers of Nigeria, faced the climatic threats, which make them vulnerable and highly susceptible to climate change that became a major challenge to the nation food security.

Evidently, Katsina state is not exempted from the climate change effects, being in an area situated within semi-arid to Sahel in the extreme north- western part of Nigeria. The area is characterized with desertification, drought, and scanty rainfall especially the northernmost part. A recent climate change emergence was witnessed in the year 2021 cropping season. The Seasonal Climate Prediction (SCP), released by Nigeria Meteorological Agency (NIMET) projected an annual rainfall commencement from 7th–28th June 2021 and was estimated to last the length of 108 to 146 days (5 months) (Nigeria Meteorological Agency [NIMET], 2021). However, a general dry spell of 3-4 weeks was experienced from June and July, which resulted in farmers' substantial crops losses that necessitated for replanting thereby reducing both production and productivity due to late planting.

The study was therefore conducted across the State to explore the magnitudes of climate change on crop productivity, assess the affected of climate change on crops in the ecological zones and determine which crops and zone are most highly affected. The rainfall pattern and distribution indicate that rains begin from the Guinea Savannah in the southern part, by and large has the highest intensity, preceded by Sudan Savannah at the central part of the State, then to the least, Sahel Savannah in the northern part of the State, which is more prone to climate change catastrophe due to drought and desertification nature of the areas. The ecological zone majorly affected by climate change revealed that Sahel Savannah suffered most, in terms of area under cultivation, 292,200 hectares were affected (45.1%) and crops yield loss of 267,100 mt. (42.1%). This was followed by the Sudan Savannah with an area affected, 216,100 ha (33.3%) and crop loss of 209,000 mt. (33%) while the Northern Guinea Savanah was the least affected, even though significant, with an affected area of 140,000 ha (21.6%) and crop loss of 157,850 Mt. (24.9%). More so, the findings of the study in Table 3 revealed that sorghum, mostly grown in the Sahel Savannah, was most affected in terms of area affected, 190,250 ha (18%), however, crop loss was minimal at 8% (148,850 mt). This signified the resilience nature of Sorghum which makes it most suitable crop for climate change resiliency. Millet was also affected similar to Sorghum, with area affected of 190,800 ha, however suffered the greatest loss of 761,000 mt. (43%) of the year's production. Others like maize; 178,650 ha (17%) affected, a crop loss of 37,100 mt (8%), rice had 160,925 ha (15%) area affected and a crop loss of 92,000 mt. (5%). Soybean and cowpea (late maturing) had 153,750 ha (14%), crop loss of 105,100 mt (6%) and 140,833 ha (13%) affected and crop loss of 200,000 mt. ((6%) respectively. Groundnuts (peanuts) was the least affected by area; 67,833 ha (6%) but with a loss of 310,000 mt. (18%) crop loss.

Whereas variations of loses exist within the zones, as in the case of Northern Guinea Savannah (maize and rice) were least affected and being the large potential production area (29). On the other hand, in both Sudan and Sahel Savannahs crops such as sorghum, millet, cowpea, rice, soybean, groundnut and maize were mostly affected. The findings of the study further indicated that 60% of farmers in the State experienced one loss of crop or the other, ranging from 50–100%. Accordingly, results of the analysis in Table 3 assert that, Millet, Groundnut, Cowpea, were amongst the top major crops affected by highest losses, all of which are majorly produced in the Sahel savannah agro- ecological zone.

Introduction

The current pattern of climate change is an important concern for many socio-economic and climate-sensitive sectors such as agriculture and food production that documented approximately about 1.2–1.5 billion hectares of global land area are under crop production (Ahmed et al., 2021). Similarly, agriculture is largely dependent on climate and therefore, climate change has caused a shortage and instability in food supply, with manifestation of severe competition for limited resources, even between man and crop (Guntukula, 2020). Agriculture is an industry highly sensitive to climate change (Cui, 2020). This concurred with a vast literature on crop production that documented a negative impact of climate change on crop outputs and apparent threat to food security (Aryal et al., 2020; Kumar & Sharma, 2022).

Climate change impacts on food sufficiency and livelihoods thereby frightening and touching millions of smallholder farmers in sub-Saharan Africa (Food and Agriculture Organization [FAO], 2016). With frequency and gravity of droughts, excessive heat and over reliance on rainfed agriculture, there is a mounting crisis in agricultural productivity, declining food availability of the households and the danger posed to countries whose prospect of national economies are dependent on agriculture (Ouédraogo et al., 2019). Nigeria is one of the nations that is confronted by the impact of climate change. Scholars like (Arora, 2019; Arora & Negeso, 2020) discovered that uncertainty of rainfall distributions and variation, excessive heat stress and drought can unfavorably affect food production and result in food scarcities. Whereas most of the states in the northern part of the country that was acknowledged to be the major food producers of Nigeria, faced the climatic threats, which make them vulnerable and highly susceptible to climate change that became a major challenge to the nation food security (Haider, 2019). In the same note, Haider et al. (2020) postulated that irregular and unpredictable rains were amongst the major features of climate change manifestation bedeviling the north, causing serious crops failures.

Evidently, Katsina state is not exempted from the climate change effects, being in an area situated within semi-arid to Sahel in the extreme north- western part of Nigeria. The area is characterized with desertification, drought, and scanty rainfall (Danjuma et al., 2018). A recent climate change emergence was witnessed in the year 2021 cropping season. The Seasonal Climate Prediction (SCP), released by Nigeria Meteorological Agency (NIMET) projected an annual rainfall commencement from 7th–28th June 2021 and was estimated to cover the length of 108 to 146 days (5 months) (Nigeria Meteorological Agency [NIMET], 2021]. However, a general dry spell of 3-4 weeks was experienced from June and July, which resulted in farmer substantial crops losses that necessitated for replanting thereby reducing both production and productivity due to late planting (Katsina State Agricultural and Rural Development Authority [KTARDA], 2021).

Previous studies on the phenomenon in Katsina state were found in the works of; (Musa et al., 2019) who examined the effects of maize producers' cultural practices, leading to climate change. Also, Abdulrashid and Ibrahim, (2018) evaluated the perspectives of farming communities on impact of desertification and climate change on woody vegetation. Whereas Hazo (2019) assessed climate change awareness and risk perception among rural people and in addition, (Maiwada & Hassan, 2019) analyzed people's perceptions of the changing climate and human influence in Katsina state. In another perspective, Galadima et al. (2020) determined awareness of climate change and its dangers among local farmers. On the other hand, Murtala et al. (2020) surveyed the implications of climate change for rural resource elements. However, none of these studies has attempted to investigate the impact of climate change on crop production and the effects of climate change in the agro-ecological zones of the state, this study is therefore the first empirical study that covers the three agro-ecological zones in the state. The following are the objectives of the study:

1. Assess the affected of climate change on crops in the ecological zones.
2. Explore the magnitudes of climate change on crop productivity in the area.
3. Determine which crops are most highly affected.

Materials and Methods

The research was conducted in Katsina state that has 34 Local Government Areas (LGA) divided into three ecological zones. The State is situated between Latitude 12°15'00" and 12°25'00" N and Longitude 7°30'00" and 7°500"00" E (Map 1).

Map 1: Katsina State of Nigeria

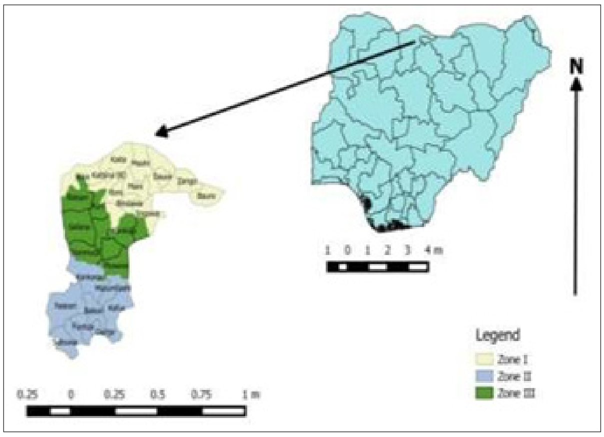
Temperatures ranged between 27^{o}C to 40^{o}C in the month of March and May and 18^{o}C to 25^{o}C in the month of November to early February. The annual rainfall is usually about 50-150 mm. The vegetation is the Sudan Semi- Arid enriched with varieties of grasslands, Shrubs, trees, and the sparce drought resistant trees (Butu & Emeribe, 2019).

This research adopted a cross-sectional survey design and the data for the study were collected using a questionnaire administered to the respondents. Two hundred (200) enumerators, comprising the Village and Block Extension Agents were trained and used as enumerators, while the Local Government Extension Officers coordinated the exercise. A multi-stage sampling technique was employed. The first stage involved classifying the state into three ecological zones. The second stage comprises random selection of three villages from each 34 LGAs to give (102 villages). The third stage was accomplished, based on the lists of farmers (26,589) frame, obtained from Katsina State Agricultural and Rural Development Authority (KTARDA), twelve thousand (12,000) farmers were selected proportionately for the study, using systematic random sampling technique.

Results and Discussion

Katsina State spans across three distinct agro-ecological zones, which transition from semi-arid conditions in the north to more humid conditions in the south. This variation directly impacts the types of vegetation and the agricultural practices across the state.

The three agro-ecological zones are unique, each having unique physical characteristics (Map 2).



Map 2: Agro-ecological Zone of Katsina State

The three agro-ecological zones are characterized by the following geographic, climatic and vegetation attributes:

1. **Sahel Savannah:** This zone covers the northernmost areas of the state. It is a semi-arid region characterized by lower annual rainfall, ranging from 450 to 700 mm. The vegetation consists of shrubs, grasses, and drought-resistant trees. Crops like millet, sorghum and livestock are the mainly grown in the area.
2. **Sudan Savannah:** This is in the central part of the state; this zone has a moderate climate compared to the north. It receives between 800 and 1,000 mm of annual rainfall and is characterized by a mix of grasslands, shrubs, and trees. Agricultural practices include cereals cultivation, mostly millet, sorghum, maize and legumes.
3. **Northern Guinea Savannah:** This zone is found in the wetter southern part of the state and has higher production potential for agriculture. It supports the cultivation of various crops, including maize, sorghum, and millet. This zone has the highest agricultural productivity where maize, rice, soyabean are mainly cultivated.
4.

Table 1: Characteristics of Katsina's Agroecological Zones

Characteristic	Sahel Savannah (North)	Sudan Savannah (Central)	Northern Guinea Savannah (South)
Annual Rainfall	450–700 mm	800–1,000 mm	More than 1,000 mm
Vegetation	Sparse grassland, shrubs, and drought-resistant trees	Grassland and a variety of shrubs and trees	More lush vegetation, including taller grasses and more diverse tree species
Agricultural Practices	Arid-adapted crops like millet are grown, often with a reliance on irrigation. Livestock grazing is also a significant activity.	Cultivation of cereals like millet, sorghum, and maize, along with legumes.	Higher agricultural productivity, with a focus on cereals such as maize, rice, soyabeans
Climate Challenges	Prone to desertification, high temperatures, and irregular rainfall.	Variable rainfall and high temperatures during the dry season.	Generally favorable climate for farming, though still impacted by the uni-modal rainy season.

The Magnitudes of Climate Change on Crops Productivity within the three ecological zones of the State

Result of the climate forecasts released from NIMET revealed that the annual rainfall will commence from 7th–28th June 2021, starting from the southern part towards the northern axis. However, 3-4 weeks short of rainfall was recorded at the peak of recommended planting date of the major crops usually mid-June to mid- July. This drastically hindered crops performance due to insufficiency of moisture that resulted in crops failure in high magnitude, and consequently, farmers had to replant their crops in late-July, this was considered as late planting.

Further manifestation of climate change emanates via early cessation of rains in the second week of September in most parts of the state, against the predicted time from 10th–27th October 2021, and this contribute to greater crops failure such as Sorghum, Millet, Cowpea, Rice, Soybeans, Groundnut, and Maize. Table 2 documented that 648,300 hectares cultivated hectares were lost and recorded a loss of assorted food to the tune of 633,950 tons, due to climate change scourge. This corroborates with Ray et al. (2019); Pareek et al. (2020); Malhi et al. (2021), and consistence to this, (Sultan et al., 2019) studied on the evidence of crop production losses in West Africa due to historical global warming in two crop models postulated that these altered climate change conditions have led to regional average yield reductions of 10–20% for millet and 5–15% for sorghum. Further analysis on the average annual production loss in monitory terms across the region from 2000 – 2009, accounted for 2.33–4.02 billion USD for millet and 0.73–2.17 billion USD for sorghum.

The Effects of Climate Change Based on Cultivated Hectares and Crop Losses within the Three Agro- Ecological Zones of the State

Generally, climate change has differing effects on a particular place and is influenced by agro- ecological variability in terms of rainfall distribution, vegetation cover and other natural endowments bestowed to each area within the domain. Katsina state is divided into three Agro-ecological zones namely, Sahel Savannah, the Sudan Savannah and the Northern Guinea Savannah. The rainfall pattern and distribution indicated that rains began from the Guinea Savannah in the southern part, by and large had the highest intensity, preceded by Sudan Savannah at the central part of the State, then to the least, Sahel Savannah in the northern part of the State, which is more prone to climate change impact due to drought and desertification nature of the areas (Katsina State Agricultural and Rural Development Authority [KTARDA]. 2021). The result of the research in Table 2 on comparisons of the ecological zones majorly affected by climate change revealed that Sahel Savannah suffered most, in terms of area under cultivation, 292,200 hectares were affected (45.1%) and crops yield loss of 267,100 mt. (42.1%). This was followed by the Sudan Savannah with an area affected, 216,100 ha (33.3%) and crop loss of 209,000 mt. (33%) while the Northern Guinea Savanah was the least affected, even though significant, with an affected area of 140,000 ha (21.6%) and crop loss of 157,850 Mt. (24.9%).

Affirmatively, soil type, climatic and vegetation characteristics of the area favored the actualization of climate change impact. The finding concurred with Sanogo et al. (2020) who pointed that climate change remains the main factor that threatens the livelihoods of rural farming families in the Sahel region of West Africa. In the same context, Zakari et al. (2022) noted that climate change and variability considerably hinder crop production, particularly in the Sahel drought-prone areas, where farmers relied solely on rainfall that is scanty and unreliable.

Table 2: The Effects of Climate Change According to Hectares Affected within the Three Agro-ecological Zones of the state.

Agro-ecological Zone	Area Affected. (‘000 ha).	% Affected	Crop Loss (‘000 Mt,)	% Loss
Sahel Savannah	292.2	45.1	267.1	42.1
Sudan Savannah	216.1	33.3	209	33.0
Northern Guinea Savannah	140	21.6	157.85	24.9
Total	648.3	100	633.95	100

Most Affected Crops by Climate Change

Conducive climatic conditions and soil fertility enabled different crops to thrive within various ecological entities, which facilitates cereals and legumes production in commercial quantities across the state. The findings of the study in Table 3 revealed that sorghum, mostly grown in the Sahel Savannah, was most affected in terms of area affected, 190,250 ha (18%), however, crop loss was minimal at 8% (148,850 mt). This signifies the resilience nature of Sorghum which makes it most suitable crop for climate change resiliency. Millet was also affected similar to Sorghum, with area affected of 190,800 ha, however suffered the greatest loss of 761,000 mt. (43%) of the year’s production. Others like maize; 178,650 ha (17%) affected, a crop loss of 37,100 mt (8%), rice had 160,925 ha (15%) area affected and a crop loss of 92,000 mt. (5%). Soybean and cowpea had 153,750 ha (14%), crop loss of 105,100 mt (6%) and 140,833 ha (13%) affected and crop loss of 200,000 mt. ((6%) respectively. Groundnuts (peanuts) was the least affected by area; 67,833 ha (6%) but with a loss of 310,000 mt. (18%) crop loss. Whereas variations of loses exist within the zones, as in the case of Northern Guinea Savannah (maize and rice) were least affected and being the large potential production area (Abdullah et al., 2022). On the other hand, in both Sudan and Sahel Savannahs crops such as sorghum, millet, cowpea, rice, soybean, groundnut and maize were mostly affected. The findings of the study further indicated that 60% of farmers in the State experienced one loss of crop or the other, ranging from 50–100%. Accordingly, results of the analysis in Table 3 assert that, Millet, Groundnut, Cowpea, were amongst the top major crops affected by highest losses, all of which are majorly produced in the Sahel savannah agro- ecological zone.

Table 3: The Effects of Climate Change on Crops Production in Katsina State.

Crops	Area Cultivated ('000 Ha)	% Area Cultivated	Area Affected ('000 Ha)	% Area Affected	Crop Loss ('000 Mt.)	% Crop Loss
Sorghum	190,250	18	114,000	18	148,850	8
Millet	190,800	18	114,500	18	761,000	43
Maize	178,650	17	107,000	17	137,100	8
Rice	160,925	15	96,000	15	92,000	5
Soybean	153,750	14	92,000	14	105,100	6
Cowpea	140,833	13	84,500	13	200,000	11
Groundnut	67,166	6	40,300	6	310,000	18
Total	1,082,374	100	648,300	100	1,754,050	100

Source: Field survey 2021

Conclusion

This assessment of climate change's impact on crop production in respect to 2021 cropping season in Katsina State has established the monumental losses caused by climate change based on cultivated hectares and crops in tons. It further unveils the ecological zone that had the most devastating effect, and crops that were majorly hindered. Hence, climate change has become a foremost threat especially to the rural dwellers that relied on agriculture as the main sources of livelihoods. Thus, urgent steps need to be taken to avoid forced migration and its attendant menaces of criminal activities, starvation and malnutrition that emanate from food insecurity.

The study therefore recommends that

- The Government extension system should intensify climate resilient agricultural practices via constant capacity building training of extension agents for effective delivery of information to the farmers in that respect.
- Farmers should be educated on climate predictions and abide by it in their farming practices.
- The Government should further reinforce the synergy with research institutes to provide seed varieties that are early maturing, resistant and adaptable to varied ecological zones.
- Efforts should be intensified on dry season farming by building more irrigation infrastructure to complement wet season production.

Acknowledgement

This research has the blessings and full support by the Katsina State Government in terms of funding and other logistics. In addition, the extension agents of the State Agricultural Development Program (ADP) serve as enumerators in administering questionnaires to farmers. Also, the National Metrological Agency has contributed a lot towards providing requisite weather information.

References

1. Ahmed, Z., Guha, G. S, Shew, A. M., & Alam, G. M. (2021). Climate change risk perceptions and agricultural adaptation strategies in vulnerable riverine char islands of Bangladesh. Land use policy, 103, DOI: https://doi.org/10.1016/j.landusepol.2021.105295
2. Guntukula, R., (2020). Assessing the impact of climate change on Indian agriculture: Evidence from major crop yields. *Journal of Public Affairs, 20*(1), DOI: https://doi.org/10.1002/pa.2040
3. Cui, X., (2020). Climate change and adaptation in agriculture: Evidence from US cropping patterns. *Journal of Environmental Economics and Management*, 101, DOI: https://doi.org/10.1016/j.jeem.2020.102306
4. Aryal, J. P., Sapkota, T. B., Khurana, R., Khatri- Chhetri, A., Rahut, D. B., & Jat, M. (2020). Climate change and agriculture in South Asia: Adaptation options in smallholder production systems. *Environment, Development and Sustainabilit, 22* (6), 5045-5075. DOI: https://doi.org/10.1007/s10668-019-00414-4
5. Kumar, A., & Sharma, P. (2022). Impact of climate variation on agricultural productivity and food security in rural India; Available at SSRN 4144089. DOI: https://dx.doi.org/10.2139/ssrn.4144089
6. FAO. (2016). The State of Food and Agriculture. Food and Agriculture Organization of the United Nations; Climate Change, *Agriculture And Food Security*, https://www.fao.org/family-farming/detail/en/c/447860/
7. Ouédraogo, M., Houessiono, P., Zougmoré, R., & Partey, S. T. (2019). Uptake of climate-smart agricultural technologies and practices: Atual and potential adoption rates in the climate-smart village site of Mali. *Sustainability, 11*(17), 4710. DOI: https://doi.org/10.3390/su11174710
8. Arora, N. K. (2019). Impact of climate change on agriculture production and its sustainable solutions. *Environmental Sustainability, 2*(2), 95-96. DOI: https://doi.org/10.1007/s42398-019-00078-w
9. Ketema, A., & Negeso, K. D. (2020). Effect of climate change on agricultural output in Ethiopia. Journal Perspektif Pembiayaan Dan *Pembangunan Daerah, 8*(3), 195-208. DOI: https://doi.org/10.22437/ppd.v8i3.9076
10. Haider, H. (2019). Climate change in Nigeria: Impacts and responses. Knowledge evidence and learning for development, https://opendocs.ids.ac.uk/articles/report/Climate_Change_in_Nigeria_Impacts_and_Responses/26429638?file=48078583f

11. Azare, I. M., Abdullahi, M. S., Adebayo, A. A., Dantata, I. J., & Duala, T. (2020). Deforestation, desert encroachment, climate change and agricultural production in the Sudano-Sahelian Region of Nigeria. *Journal of Applied Sciences and Environmental Management, 24*(1), 127-132. DOI: https://doi.org/10.4314/jasem.v24i1.18
12. Danjuma, M. N, Mohammed, S., & Karkarna, M. Z. (2018). Farmers' participation in agroforestry system in Northwestern Nigeria. *Nigerian Journal of Environmental Sciences and Technology (NIJEST), 2*(2), 257-265. https://nijest.com/wp-content/uploads/2019/03/257-265_93_Vol-2-No.-2_NIJEST.pdf
13. Nigeria Meteorological Agency (NIMET). (2021). Seasonal Climate Prediction (SCP) of Katsina state, Nigeria. 24. https://nimet.gov.ng/scp
14. Katsina State Agricultural and Rural Development Authority (KTARDA). (2021) Crop production Annual Reports, Published by Katsina printing Press. 67.
15. Musa, J., Ala, A. L., Yakubu, A. A., Musa, M., Beli, S. A., & Bara, S. S. (2019). Maize producers' cultural practices exacerbating climate change in Katsina state, Nigeria. The Way Forward." Building a Resilient and Sustainable Economy through Innovative Agriculture in Nigeria." 53rd Annual Conference of Agricultural Society of Nigeria. 21st -25th October 2019. NCRI, Badeggi, Nigeria; https://www.researchgate.net/publication/358880701_Building_a_Resilient_and_Sustainable_Economy_through_Innovative_Agriculture_in_Nigeria_Maize_Producers'_Cultural_Practices_Exacerbating_Climate_Change_in_Katsina_State_Nigeria_The_Way_Forward
16. Abdulrashid, L., & Ibrahim, Y. Z. (2018). Perspectives of farming communities on impact of desertification and climate change on woody vegetation in Semi-Arid areas of Katsina state. *Dutse Journal of Pure and Applied Sciences (DUJOPAS), 4(*2), 454 – 468. https://fud.edu.ng/journals/dujopas/2018_JUNE_Vol_4_issue_2/070%20edited%201-2.pdf
17. Hazo, A. I., Sawa, B. A., & Mamman, M. (2019). Assessment of climate change awareness and risk perception among rural people in Funtua local government area, Katsina state, Nigeria. *International Journal of trends in scientific research and development, 3*(2), 29-37. DOI: https://doi.org/10.31142/ijtsrd20289
18. Maiwada, A. S., & Hassan, M. (2019). People's perceptions of the changing climate and human influence in Katsina state, North- Western Nigeria. *FUDMA Journal of Sciences. 3*(2), 245-249. https://fjs.fudutsinma.edu.ng/index.php/fjs/article/view/1510
19. Galadima, A., Moy, I S. I., & Lawal, A. M. (2020). Awareness of climate change and its dangers among local farmers of Katsina State, Nigeria. International Journal of Science for Global Sustainability, 6(3), 7-7. DOI: https://doi.org/10.57233/ijsgs.v6i3.75
20. Murtala, A. M., Weli, V. E., & Arokoyu, S. B. (2020). Implications of climate change for rural resource elements in Katsina State. *J Climatol Weather Forecast, 8*(1), 250. https://www.iomcworld.com/abstract/implications-of-climate-change-for-rural-resource-elements-in-katsina-states-52924.html
21. Butu, A. W., & Emeribe, C. N. (2019). Spatial patterns of climatic variability and water budget over Sudan Savannah region of Nigeria. *African Journal of Environmental Science and Technology, 13*(12), 465-481. DOI: https://doi.org/10.5897/AJEST2019.2726
22. Ray, D. K., West, P. C., & Clark, M., (2019). Gerber JS, Prishchepov AV, Chatterjee S. Climate change has likely already affected global food production. *PloS one, 14*(5), DOI: https://doi.org/10.1371/journal.pone.0217148
23. Pareek, A., Dhankher, O. P., & Foyer, C. H. (2020). Mitigating the impact of climate change on plant productivity and ecosystem sustainability. *Journal of Experimental Botany, 71*(2), 451-456. DOI: https://doi.org/10.1093/jxb/erz518
24. Malhi, G. S., Kaur, M., & Kaushik, P. (2021) Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability, 13*(3), 13-18. DOI: https://doi.org/10.3390/su13031318
25. Sultan, B., Defrance, D., & Iizumi, T. (2019). Evidence of crop production losses in West Africa due to historical global warming in two crop models. Scientific reports, 9(1), 1-15. https://www.nature.com/articles/s41598-019-49167-0
26. Katsina State Agricultural and Rural Development Authority (KTARDA). (2021). Data of rain fall distribution patterns within agro-ecological zones of the state. Published by Katsina printing Press. 57.
27. Sanogo, K., Dayamba, D. S., Villamor, G. B., & Bayala, J. (2020). Impacts of climate change on ecosystem services of agroforestry systems in the West African Sahel: A review. *Agroforestry for Degraded Landscapes*, (4), 213-224. DOI: https://doi.org/10.1007/978-981-15-4136-0_7
28. Zakari, S., Ibro, G., Moussa, B., & Abdoulaye, T. (2022). Adaptation strategies to climate change and impacts on household income and food security: Evidence from Sahelian region of Niger. *Sustainability, 14*(5), 2847. DOI: https://doi.org/10.3390/su14052847
29. Abdullah, A. Y., Rimi, T. A., & Mohammed, M. S. (2022). Strategic Assessment of Climate Change Impact on Production of Some Selected Crops: Evidence from 2021 Cropping Season in Katsina State, Nigeria. *International Journal of Environment and Climate Change. 12,* (12), 569-578. DOI: https://doi.org/10.9734/ijecc/2022/v12i121494