

## EXPLORING THE PRAXES OF INDIGENOUS AND EXPERIENTIAL KNOWLEDGE OF CLIMATE CHANGE ON PEASANT FARMERS IN GHANA

DANIELLA DELALI SEDEGAH<sup>1\*</sup>, MICHAEL AUGUSTUS AKAGBOR<sup>2</sup>, PHYLLIS BERNICE KWARTENG-DONKOR<sup>3</sup>, BENZIES ISAAC ADU-OKOREE<sup>4</sup> AND PHILIPPA JILLY JOEL PREMKUMAR<sup>5</sup>

<sup>1</sup>Department of Sustainable Development and Policy, University of Environment and Sustainable Development, Ghana.

<sup>2</sup>Department of Sociology, University of Ghana, Ghana. <sup>3</sup>Department of Education, University of Ghana, Ghana. <sup>4</sup>Department of Development Studies, Presbyterian University, Ghana. <sup>5</sup>Department of General Studies, University of Environment and Sustainable Development, Ghana.

\*Corresponding author: [ddsedegah@uesd.edu.gh](mailto:ddsedegah@uesd.edu.gh)

Submitted final draft: 11 July 2023

Accepted: 30 July 2023

<http://doi.org/10.46754/jssm.2023.10.005>

**Abstract:** The global concern that Africa's strong economic dependency on climate-related activities makes it vulnerable is troubling as the continent is lagging in embracing scientific techniques for adapting to the changing global environment. However, challenges exist where the application of 'modern scientific' knowledge to addressing climate change appears to disregard resilient 'indigenous knowledge systems.' This study situates the praxes and experiences of peasant farmers in Ghana to explore the indigenous knowledge systems they use to navigate climate change's impact on their livelihoods. The study adopts the theoretical framework of Bruchac's 'indigenous knowledge theory' in unpacking the socio-cultural ways peasant farmers in Ghana create unique ways of 'knowing' and understanding climate change. Utilising Focus Group Discussion and interviews, the views of peasant farmers on climate change and its impact on their livelihood were explored. The study found that the transferability of indigenous knowledge passed down to participants by their ancestors has shaped their ontological reality of changing climate patterns and its impact on their livelihoods. However, challenges exist in contemporary times in applying this knowledge to their farming practices. The study pushes for synthesising indigenous knowledge systems with modern scientific knowledge systems for institutional and behavioural change regarding climate change in Ghana.

Keywords: Indigenous knowledge, climate change, peasant farmers, livelihoods, exploration.

### Introduction

Climate change has become the most disturbing and critical environmental factor affecting agricultural development discourse. However, mounting evidence demonstrates that indigenous knowledge is critical in climate change adaptation. According to Ford *et al.* (2020), indigenous people have long understood the value of their knowledge systems in coping with change. Observations of farming practices across Ghana have evidenced that farming is highly climate-sensitive. Peasant farming in Ghana is mainly rain-fed and, therefore, greatly affected by prevailing climatic conditions. Thus, agriculture is greatly affected by adverse climatic conditions. As such, any changes in climatic

patterns can affect agricultural activities. In climate discourse, the discussions have to do with the condition of wet or dry, warm or cold weather. Human activities distort the balance of the ecosystem and, subsequently, the climatic pattern of the ecology.

The Inter-Governmental Panel on Climate Change (IPCC, 2007) states that any resultant change in the climate over time is either due to the natural variability of the earth's physical evolution (Spencerian sociology) or as a result of human activity is to be considered as climate change. Agriculture is worst affected by fluctuations in average temperatures, erratic rainfall patterns with their resultant impact

on soils such as floods and drought, pests and diseases, changes in the nutritional quality of some foods, and deviations in the growing season, among other consequences (World Bank, 2008a). Besides, the climatic impact of change on agriculture is most severe for countries with higher initial temperatures, zones with marginal or already degraded lands and lower levels of development with little adaptation capacity (Keane *et al.*, 2009), which is generally the case of countries Sub Saharan Africa (SSA) including Ghana. According to the IPCC (2007b), agriculture is the primary source of employment and livelihood in developing countries and, therefore, is fundamental to millions of people's survival. Speculations regarding the projected crop yields in Africa have arisen, which suggest a potential decrease of 10% to 20% by 2050. Some projections even indicate a reduction of up to 50%, primarily because the agricultural sector in Africa is predominantly rain-fed and therefore, heavily dependent on the unpredictability of weather patterns (Jones & Thornton, 2003).

The influence of climate change on soils is a multifaceted one. Várallyay (2010), for instance, argues that the "most important direct impact is the aggregate-destructing role of raindrops, surface runoff and filtrating water frequency and intensity of which are characteristic features of climate change" (p.386). Additionally, climate change impacts on the soil are surface runoff causing erosion and structure destruction, low rainfall reducing downward infiltration, hence, acidification and salination, and "unfavourable changes in the biogeochemical cycles of plant nutrients and pollutants" due to extreme rainfall and temperature patterns" (Várallyay, 2010: 394).

The acknowledgement that climate change threats to agriculture imply direct representational threats to the quality of life globally. The issue of sustainable agriculture has become increasingly pressing, calling for implementing strategies to adapt to and mitigate the challenges posed by this concern (Howden *et al.*, 2007; McCarl, 2010). Subsequently, farmers have developed an indigenous understanding of

climate change over the years, enabling them to respond to climatic and weather pattern changes in managing their agricultural activities. This indigenous knowledge has materialised because of centuries of social, cultural and physical evolution and environmental adaptation and signifies peasant farmers' accumulated wealth of experiences. As a systematic body of knowledge, this epistemological reality of their lived world has been acquired by local people through the accumulation of experience, informal experiments, and a unique but teleological adaptation and understanding of their environment (Tella, 2007). Therefore, it is crucial to understand the farmers' views regarding how they mitigate climate change impacts on the soils they plant on and their livelihoods. Yaro (2013) opines that knowledge base, assets, and capabilities influence strategies chosen by farmers.

### **Problem Statement**

Agriculture is the primary source of employment and livelihood in developing countries and is fundamental for survival (IPCC, 2007). However, with the continuing rise in climate change, crop yield in Africa may fall by 10% to 20% by 2050 or up to 50% (Jones & Thornton, 2003). According to Pareek (2017: 137), the trigger "drivers of climate change such as moisture, temperature and carbon dioxide are expected to have variable effects on various soil processes and properties having relevance in soil fertility and productivity and agriculture can contribute to climate change mitigation through farm management practices". Africa's and Ghanaian agricultural systems have been deduced to be largely rain-fed, dependent on the weather and, therefore, have displayed signs of vulnerabilities due to their sensitivity to changing climate patterns.

Therefore, climate change discussions must not be limited to academic discourse but must involve the farmers who experience the phenomenon the most. Even though most of these farmers are considered illiterate (in formal academic terms), they possess various

indigenous experiences that, if harnessed, can inform policymakers to mitigate the impact of the climate change problem on farming activities and farmers' livelihoods. Unfortunately, in discussing climate change matters, such 'local' knowledge systems have been relegated to the background, focusing mainly on academics and political constructions. There is an urgent need, therefore, to revisit and re-centre the ontological dimensions of the local knowledge systems of these farmers (whose livelihoods are on the verge of collapse) at the heart of any meaningful measures that seek to mitigate the impact of climate change on agricultural soils and their farming activities.

### Objectives

In exploring the experiential knowledge of farmers, the study:

1. Explored farmers' awareness of the occurrence of the phenomenon of climate change.
2. Examined how farmers explain the phenomenon of climate change.
3. Explored the sources of information on climate change for farmers.
4. Examined the various indigenous farming practices adopted by farmers and their effectiveness in mitigating the impact of climate change on their agricultural soils and livelihoods.

### Theoretical Framework

For most of the 20th and 21st centuries, social sciences have rooted their research within positivist paradigms that investigate and contextualise phenomena as observable and measurable based on their 'objective' quantitative methods and methodologies (Snively & Corsiglia, 2001; Goduka, 2012; Smith, 2021). This process of scientific methodology that relies on specific laws to project scientific 'truths' has often restricted the opportunity to gain knowledge through research of alternative epistemological

paradigms, worldviews, and approaches. Especially participatory and non-traditionalist paradigms that allow for incorporating indigenous-based methods in the production of knowledge aimed at addressing specific socio-environmental challenges of non-westernised societies (Aikenhead & Ogawa, 2007; Goduka, 2012; Held, 2019). In the attempt to contextualise and position this study within its appropriate ontological, epistemological, and praxiological dimensions of the lived experiences of peasant farmers in Ghana as regards the mitigating impact of climate change on agricultural soils and their livelihoods, the study adopts the theoretical approach of Bruchac's (2014) indigenous knowledge theory as a framework. The relational importance of this theoretical frame to the study is grounded in Bruchac's argument that;

*“Indigenous knowledge is conveyed formally and informally among kin groups and communities through social encounters, oral traditions, ritual practices, and other activities. They include oral narratives that recount human histories; cosmological observations and modes of reckoning time; symbolic and decorative modes of communication; techniques for planting and harvesting; hunting and gathering skills; specialised understandings of local ecosystems; and the manufacture of specialised tools and technologies”*

(Bruchac, 2014: 3814)

This theoretical approach provides an appropriate exploratory guide for unpacking the diverse socio-cultural ways traditional peasant farmers in Ghana create unique ways of knowing and understanding the impact of the climatic changes on their natural and farming environments (Aikenhead & Ogawa, 2007). While acknowledging the importance of agriculture to the development of the country and the complex changing world of the enterprise - climate change, technology, and markets (Kanyama-Phiri *et al.*, 2017), the

study's engagement with indigenous knowledge theory as a standpoint of the research allows for the exploration of the "actualities of every day from within that lived experience" (Kwaymullina, 2017:15), rather than the deployment of certain 'scientific' predetermined concepts and categories as modes of explaining the experiences of the farmers. The theoretical analysis of indigenous knowledge thus aids in understanding how local knowledge informs decision-making as societies interact and adapt to their natural surroundings within the Spencerian evolutionary process. The strength of this theory in application to this study is that it centres squarely on the ontological and epistemological knowledge of the local people and their understanding of their ecosystem and the climate as the standpoint from which any conscientisation on issues affecting them regarding climate change can begin.

### **Materials and Methods**

This study received ethical clearance from the Ethics Committee of the Presbyterian University College in Ghana. It is a qualitative study that forms part of a broader study looking at the experiences of Ghanaian farmers, the epistemological underpinnings guiding their knowledge of climate change and adaptation through Indigenous Knowledge (IK) farming practices, and their praxes in adapting to the changing climate patterns to mitigate its impact on their livelihood. Focus Group Discussions (FGDs), personal interviews, and narrative inquiry were used to solicit information for the broader studies. The data presented in this paper is derived only from the FGDs and personal interviews held in five communities in Ghana's Bono, Bono East, and Ahafo regions. These regions represent the transitional and forest belts of the country. The recruitment of respondents was done utilising the purposive and snowball sampling technique from registered peasant farmers' households and registered farmers working with agricultural extension officers in the five purposively selected communities of Sunyani West, Techiman North, Tano North,

Kwaebibrem, and Birim Central. Respondents were selected based on their availability and preparedness to participate in the research. The number of respondents per FGD was eight, the average number Krueger and Casey (2008) recommend as appropriate for facilitating easy discussions for an FGD.

A thematic guide was utilised in the discussion and interviews, as well as recorders and field notes to record data. A thematic analysis of data was performed utilising Patton's (2005) approach, which involved the preliminary examination of the data by reading through the transcripts and writing memos, the coding of the data by segmenting and labelling the text, connecting and interrelating the themes pertinent to the focus of the study; and the construction of a narrative. The goal was to search for patterns in the data, including knowledge of climate change, recurrent farming practices, traditional belief systems, indigenous knowledge, and institutionalised practices.

### ***Implications of the Study***

Agricultural soils have attracted less attention in the climate change discourse, even though it is fundamental to a basic human need for survival. However, soil conservation techniques largely militate against the changing pattern of precipitation and temperature in climate change (Juana *et al.*, 2013). This resonates with Tesfay's (2014: 2) view that "a better understanding of the local dimensions of climate change is important to develop appropriate adaptation measures and policies." As such, any knowledge of the adaptative methods by which smallholder farmers make meaning of their natural environment must be tackled within the challenges of climate change. The fact that peasant farmers can achieve climate change mitigation through their use of indigenous and experiential knowledge is laudable (Pareek, 2017). Climate change mitigation is closely linked to the high on-farm biodiversity typical of traditional farming systems. Lastly, the findings from the study indicate that indigenous knowledge offers valuable insights and complements scientific

data and should be considered a critical key to moderating institutional change and climate change awareness among farmers in Ghana.

## Results and Discussions

Climate change reduces agricultural output and threatens food security, impacting economic growth (Montalbano *et al.*, 2015). Agriculture is a sector that supports food security, provides raw materials for manufacturing, and generates jobs, so this industry must find a way to adapt to the risks posed by climate change while utilising the farmer's indigenous knowledge and practices. This study concentrated on the latter, bringing out the farmers' indigenous knowledge and experiences in addressing the climate change concerns discussed here.

### *Farmers' Knowledge of Climate Change*

From the Focus Group Discussions, farmers agreed that climatic conditions have changed over time but significantly over the past two decades. They believed that rainfall in the past was more regular and predictable, enabling them in their farming activities and ensuring a good harvest. However, due to the current changes in the rainfall pattern and weather conditions, they experience longer dry seasons and shorter rainy seasons, leading to low agricultural production. Accordingly, any changes in rainfall volumes, timing, or patterns could significantly impact Ghana's farming practices and crop yields (Baffour-Ata *et al.*, 2021). As one female maize farmer from the Bono Region says:

*"We now don't even know when to plant anymore, we never get it right. We are either too early or too late".*

This unpleasant observation confirms Lasco *et al.* (2011) that 'rainfall pattern affects crop cultivation by influencing the length of the growing period.' According to the respondent farmers, the common indicators of evidence of climate change are temperature rise, increase in the intensity of the wind, desertification, changed rainfall pattern, delay in the onset of

rain, water bodies drying up, extreme weather conditions, invasion of new breeds of pests- such as the very recent outbreak of fall armyworm in Ghana and increase pests and diseases. Climate change is manifested in precipitation and temperature fluctuations, as well as the effects of droughts and floods, which have a negative impact on agricultural productivity and result in low agricultural production in Ghana (File, 2015). Arndt *et al.* (2015) forecasted that by 2050, maize crop yields in Ghana will have decreased by around 18% and that agriculture's share of the country's GDP will have dropped from 35.1% in 2007 to 20.1%. Crop losses will result in lower productivity and higher food costs (Arora, 2019), with people experiencing poverty and women being most badly affected.

Farmers are aware of climate change and its impact on agriculture and what causes climate change. According to the farmers, the leading causes of climate change are deforestation and improper application of fertilisers. Literature abounds about the evidence of the relationship between deforestation and climate change and how the impacts of climate change are occurring faster than many scientists first predicted (Archana, 2013). The availability of non-organic fertilisers facilitates an increase in food production, responsible for feeding about half of the current human population (Esriman *et al.*, 2008). However, the extensive utilisation of chemical fertilisers and pesticides in crop and livestock production is the primary source of water and soil pollution. Chemical fertilisers are the primary anthropogenic sources of nitrous oxide (N<sub>2</sub>O), which can change the soil's pH and make it infertile, upset beneficial microbial ecosystems, increase pests, and cause the release of greenhouse gases (GHG) (Bahar & Ebru, 2017).

The various indicators of climate change, as validated by scientific research in the literature, are comparable to those identified by the farmers in this study. For instance, as stated by the respondents, Adimo *et al.* (2011) have termed these "vulnerability indicators". These indicators acknowledged by the farmers

show that they have local and perceived knowledge of the development of the climatic conditions within their locality. Such climatic scenarios make farmers in especially developing countries such as Ghana vulnerable due to their dependence on nature. Primarily, those whose livelihoods depend on natural resources, as characterised by many African populations of which Ghana is no exception, feel the impacts of climate change, according to Stringer *et al.* (2009). The fact that the respondents of this research are farmers from rural communities indicates their vulnerability because of their heavy reliance on rain-fed agriculture and their possession of less or no sustainable alternative livelihoods.

### ***Sources of Knowledge***

Farmers are better informed on climate change and its subsequent impacts based on the phenomenon's availability and accessibility of information. The study found that farmers have acquired knowledge on climate change based on personal observation, indigenous knowledge, interaction among fellow farmers, agriculture extension officers, media (mainly radio), and organised and sponsored training workshops. Although climate change has no local term in most African languages (Eguavoen, 2013), including Ghanaian languages, farmers have observed and are therefore conscious of its local manifestations in terms of rainfall and temperature patterns (Acquah-de Graft & Onumah, 2011; Fosu-Mensah *et al.*, 2012). Media, and in the case of this study, radio, has proved to be a powerful tool in disseminating agricultural information to farmers.

The FAO (2001) has recognised radio as the most essential medium for communicating with the rural populations of developing countries. Agricultural extension officers are generally supposed to play educational roles by providing and disseminating information to farmers. They are involved in creating awareness of climate change issues by building resilience capacities among farmers and encouraging the broad participation of all stakeholders in addressing

climate change issues (FAO, 2003). However, the impact of extension officers in information sharing has been modest due to logistical, infrastructural, and financial constraints, making extension officers unable to access their clientele fully.

### ***Indigenous Practices Adopted by Farmers to Mitigate the Impact of Climate Change***

Farmers were asked to describe practices they undertake to mitigate the impact of climate change on their farms. Their responses reflected their indigenous farm practices. These indigenous knowledge and skills have been acquired over the years based on experiences of what works and what does not (Zhu *et al.*, 2010), which translates into sustainable agricultural production (FAO, 2009). The farmers reported that they undertook exercises such as mulching, use of cover crops, agroforestry, use of early-yielding varieties, planting cover crops and adapting organic forms of farming. Kassam *et al.* (2009) noted that mulching is the most frequently mentioned farm practice because it helps conserve soil moisture and fertility for a year-round organic cover. However, mulching is much less likely in farms where "free cattle grazing" on plots after harvest is common (Owenya *et al.*, 2011; Graef *et al.*, 2014).

The study areas are primarily crop farming areas with scattered areas of grazing. An interesting practice is what the farmers call "proka". "Proka" is a merging of two Akan language words, "pro" and "ka", meaning rot and leave, respectively. This practice involves cutting down the forest and weeds without the usual burning. The crops are planted on the farm as the debris starts rotten. The debris serves as a kind of mulch to suppress the growth of new weeds, but as it decomposes, it replenishes the soil fertility. It also provides a suitable environment for the growth of soil microorganisms to speed up fertility restoration and improve the soil's structure. Farmers also use early-yielding crop varieties to manage climate change risks. A male farmer from the Ahafo Region said:

*“Because we cannot predict the weather now, we prefer crop varieties that mature early so we do not lose much when the rains fail”.*

The primary benefit of early-yielding crops or varieties lies in their ability to generate a viable agricultural output during limited periods of rainfall.

The farmers were conscious of the negative impacts of some modern farm practices in aggravating the ill effects of climate change. Farmers noted avoiding practices such as excessive mechanised agriculture, avoiding agrochemicals, and preventing chain-saw operations. In place of using pesticides, participants reported that they instead opt for and adopt biological means of weeds and pest control, such as using chilli pepper powder or soap solution as an insecticide, as corroborated by a male extension officer from the Eastern Region who said:

*“One thing I notice when I visit the farms is that some farmers spray chilli pepper solution as a remedy for dealing with the pests”.*

The farmers were mindful of water bodies’ role in providing moisture to the soil. They, therefore, consider the protection of vegetation around them by avoiding bushfires significant. They contended that it would be helpful if the traditional way of protecting water bodies through taboos that generated fear of reprisals from the gods of the water bodies were still effective. The fear of the unknown kept the farmers from weeding on the banks of the water bodies. The implementation enabled the banks to be shielded by the foliage, thereby mitigating the effects of evaporation and silt deposition on the adjacent water bodies.

Participants from the group’s discussions have some challenges that have hindered the complete application of these indigenous knowledge practices reported above. Even though they know the benefits of organic farming against synthetic fertilisers and pesticides, farmers admit to using the latter despite its

negative consequences due to the growing cost of hired labour. Pesticides have short-term and long-term toxic effects on soils, the food chain, habitat loss, and climate change. Farmers who hitherto depended on youthful labour within their families now use hired labour because of rural-urban migration. The migration of skilled young workers raises concerns concerning the ageing and feminisation of rural populations and the increased work burden on those left behind. The situation has been exacerbated by land degradation and climate change, leading to significant risks to agricultural output and the livelihoods of rural African communities (FAO, 2016).

### ***Improving the Transfer of Knowledge on Climate Change***

Recent studies have shown that indigenous knowledge of ecological zones, natural resources, agriculture, forest, and farm management is more sophisticated than previously assumed. They also offer new development models that are both ecologically and socially sound (Posey, 1985). Conservation is a tool in climate change mitigation, and peasant farmers, such as those involved in this study, are considered excellent conservators. As Mooney (1992) puts it:

*The formal sector is only starting to open its eyes to the fact that farmers innovate and local communities can contribute to conservation and breeding. Suppose the world is properly to conserve and use genetic resources for both present and future generations. In that case, the informal sector of the Third World, that is, the farmers, herbalists, gardeners, and pastoralists, must lead us into the next agricultural revolution.*

To Mooney (1992) and Bruchac (2014) and their raised arguments, Indigenous Knowledge (IK) should be considered a critical key to moderating climate change awareness among farmers in Ghana.

### Conclusion and Recommendations

The reliance on ‘scientific’ or ‘positivist’ knowledge traditions about global climate concerns and the lack of orientations to include indigenous and traditional knowledge in the global climate change discourse is one of the most visible manifestations of the global dominance of ‘science’ and its apparent disregard of indigenous knowledge within climate change policy, research and decision-making (Adger *et al.*, 2014 & IPCC 2014b). However, indigenous knowledge offers valuable insights and complements scientific data. The paper explored indigenous and practical knowledge of peasant farmers in mitigating the impact of climate change on agricultural soils and farmers’ livelihoods. Farmers’ responses indicated that they hold in stock acquired knowledge passed down to them through the generations by their forbears in mitigating the effect of climate change on their livelihoods. However, their challenge was applying them due to constraints such as the growing cost of hired labour and disrespect for taboos that hitherto facilitated the preservation of natural resources such as forests and water bodies. The study recommends that governmental and non-governmental agencies sensitise the youth on the attractiveness of agriculture to make labour available on the farms. Providing some basic amenities to keep the youth in the communities will be a step in the right direction. Scientific researchers should also take up the responsibility of documenting farmers’ indigenous knowledge to improve upon them or propagate their application in mitigating the effect of climate change on rural livelihoods.

### Limitations and Further Study

The study relied on farmers’ recollection of past climatic and weather conditions to ascertain awareness of climate change which was a potential limitation. To overcome this limitation, the researchers probed more during questioning to assist them in recalling past conditions. The authors plan to undertake similar research in the Savannah region of Ghana to undertake a comparative analysis of the findings.

### Acknowledgements

The authors are grateful to the Presbyterian University College, Ghana Ethics Committee, for the clearance to undertake this research. The authors acknowledge the assistance the Agricultural Extension Officers of the Ministry of Food and Agriculture provided in the selected regions for mobilising the farmers to partake in this research. The authors received no funding for this study.

### References

- Acquah-de Graft, H., & Onumah, E. (2011). Farmers’ perceptions and adaptations to climate change: An estimation of willingness to pay. *Agris*, 3(4), 31-39.
- Adger, W. N., Pulhin, J. M., Barnett, J., Dabelko, G. D., Hovelsrud, G. K., Levy, M., Oswald, S. U., Vogel, C. H., *et al.* (2014). Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. In C. B. Field, *et al* (Eds.), *Human Security Climate Change 2014: Impacts, adaptation, and vulnerability* (pp 755-91). Cambridge: Cambridge University Press.
- Adimo, A. O., Njoroge, J. B., Claessens, L., & Wamocho, L. S. (2011). Land use and climate change adaptation strategies in Kenya. *Mitigation and Adaptation Strategies for Global Change*, 17, 153-171.
- Aikenhead, G. S., & Ogawa, M. (2007). Indigenous knowledge and science revisited. *Cultural Studies of Science Education*, 2(3), 539-620.
- Archana, K. (2013). Impact of deforestation on climate change. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 4(2), 2319-2399. www.Iosrjournals.Org www.iosrjournals.org.
- Bahar, C. E., & Ebru, G. S. (2017). Presence of climate change, the use of fertilizers and the effect of income on agricultural emissions.

- Sustainability*, 9, 1989. doi:10.3390/su9111989, www.mdpi.com/journal/sustainability
- Bruchac, M. (2014). Indigenous knowledge and traditional knowledge. In Smith, C. (Ed.), *Encyclopedia of global archaeology* (3814-3824). New York: Springer.
- Eguavoen, I. (2013). Climate change and trajectories of blame in northern Ghana. *Anthropological Notebooks*, 19(1), 5-24. [http://www.drustvo-antropologov.si/AN/2013\\_1\\_eng.html](http://www.drustvo-antropologov.si/AN/2013_1_eng.html)
- Erismann, J. W., Sutton, M. A., Galloway, J., Klimont, Z., & Winiwater, W. (2008). How a century of ammonia synthesis changed the world. *Nature Geoscience*, 1, 636-639.
- Fosu-Mensah, B. Y., Vlek, P. L. G., & McCarthy, D. S. (2012). Farmers' perception and adaptation to climate change: A case study of Sekyedumase district in Ghana. *Environment, Development and Sustainability*, 14, 495-505. <http://dx.doi.org/10.1007/s10668-012-9339-7>
- FAO. (2016). *Addressing rural youth migration at its root causes: A conceptual framework knowledge materials*. Food and Agriculture Organisation of the United Nations, Rome.
- FAO. (2003). *World Agriculture toward 2015/2030*. An FAO Perspective, Rome.
- Food and Agricultural Organization. (2009). *Adaptation to climate change in agriculture, forestry and fisheries: Perspective, framework and priorities*. Food and Agriculture Organization of United Nations. Rome, Italy.
- Ford, J. D., King, N., Galappaththi, E. K., Pearce, T., McDowell, G., & Harper, S. L. (2020). The resilience of indigenous peoples to environmental change. *One Earth*, 2, 532-43.
- Goduka, N. (2012). From positivism to indigenous science: A reflection on world views, paradigms and philosophical assumptions. *Africa Insight*, 41(4), 123-138.
- Graef, F., Sieber, S., Mutabazi, K., Asch, F., & Biesalski, H. K. (2014). Framework for participatory food security research in rural food value chains. *Global Food Security*, 3, 8-15.
- Held, M. B. (2019). Decolonising research paradigms in the context of settler colonialism: An unsettling, mutual, and collaborative effort. *International Journal of Qualitative Methods*, 18, 1609406918821574.
- Howden, S. M., Soussana, J. F., Tubiello, F. N., Chhetri, N., Dunlop, M., & Meinke, H. (2007). Adapting agriculture to climate change. *Proc. National Academy of Science USA*, 104, 19691-19696.
- Huq, N., Hugé, J., Boon, E., & Gain, A. K. (2015). Climate change in agricultural communities in rural areas of coastal Bangladesh: A tale of many stories. *Sustainability*, 7, 8437-8460.
- IPCC. (2014b). Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. In C. B. Field, et al, (Eds.), *Summary for Policymakers Climate Change 2014: Impacts, adaptation, and vulnerability* (pp 1-32). Cambridge: Cambridge University Press.
- IPCC (Intergovernmental Panel for Climate Change). (2007a). Climate Change 2007: The Fourth Assessment Report. Impacts, adaptation and vulnerability. [[https://www.ipcc.ch/publications\\_and\\_data/publications\\_ipcc\\_fourth\\_assessment\\_report\\_wg2\\_report\\_impacts\\_adaptation\\_and\\_vulnerability.htm](https://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg2_report_impacts_adaptation_and_vulnerability.htm)]
- IPCC. (2007b). Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Summary for Policymakers. [<http://www.ipcc.ch/pdf/assessmentreport/ar4/wg2/ar4-wg2-spm.pdf>]

- Jones, P. G., & Thornton, P. K. (2002). Croppers to livestock keepers: Livelihood transition to 2010 in Africa due to climate change. *Global Environmental Change, World Health Organization*, Geneva, Switzerland.
- Juana, S., Kahaka, Z., & Okurut, N. (2013). Farmers' perceptions and adaptations to climate change in Sub-Sahara Africa: A synthesis of empirical studies and implications for public policy in African agriculture. *Journal of Agricultural Science*, 5(4). doi:10.5539/jas.v5n4p121.
- Kanyama-Phiri, G., Wellard, K., & Snapp, S. (2017). Introduction: Agricultural systems in a changing world. *Agricultural Systems: Agroecology and Rural Innovation for Development* (2nd ed.).
- Kassam, A., Friedrich, T., Shaxson, F., & Pretty, J. (2009). The spread of conservation agriculture: Justification, sustainability and uptake. *Int. J. Agric. Sustain.*, 7, 292-320.
- Keane, J., Page, S., Kergna, A., & Kennan, J. (2009). Climate change and Developing Country agriculture: An overview of expected impacts, adaptation and mitigation challenges, and funding requirements.
- Kide, G. T. (2014). *Smallholder farmers' adaptation strategies to climate change in Ethiopia: evidence from Adwa Woreda of Tigray region* (Doctoral dissertation, Mekelle University).
- Krueger, R. A., & Casey, M. A. (2008). *Focus groups: A practical guide for applied research* (4th ed.). New York: SAGE.
- Kwaymullina, A. S. T. (2017). *Indigenous standpoints, indigenous stories, indigenous futures: Narrative from an indigenous standpoint in the twenty-first century and beyond* (PhD Thesis, The University of Western Australia).
- Lasco, R. D., Habito, C. M. D., Delfino, R. J. P., Pulhin, F. B., & Concepcion, R. N. (2011). *Climate change adaptation for smallholder farmers in Southeast Asia*. Los B a ñ o s , Philippines: World Agroforestry Centre.
- McCarl, B. A. (2010). Analysis of climate change implications for agriculture and forestry: An interdisciplinary effort. *Climate Change*, 100, 119-124.
- Mooney, P. R. (1992). Towards a folk revolution. In David Cooper, Renee Vellve & Henk Hobbelink (Eds.), *Growing diversity: Genetic resources and local food security* (Pp. 125-138). London: Intermediate Technology Publications.
- Morton, J. F. (2007). The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the National Academy of Sciences*, 104(50), 19680-19685.
- Owenya, M. Z., Mariki, W. L., Kienzle, J., Friedrich, T., & Kassam, A. (2011). Conservation agriculture (CA) in Tanzania: The case of the Mwangaza B CA farmer field school (FFS), Rhotia Village, Karatu District, Arusha. *Int. J. Agric. Sustain.*, 9, 145-152.
- Pareek, N. (2017). Climate change impact on soils: Adaptation and mitigation. *MOJ Eco Environ Science*, 2(3): 00026. DOI: 10.15406/mojes.02.00026
- Patton, M. Q. (2005). Qualitative research. *Encyclopedia of Statistics in Behavioural Science*.
- Posey, D. A. (1985a). Management of Tropical Forest ecosystems: The case of the Kayapo Indians of the Brazilian Amazon. *Agroforestry Systems*, 3(2), 139-158.
- Smith, L. T. (2021). *Decolonising methodologies: Research and indigenous peoples*. Bloomsbury Publishing.
- Snively, G., & Corsiglia, J. (2001). Discovering indigenous science: Implications for science education. *Science Education*, 85(1), 6-34.
- Stringer, L. C., Dyer, J. C., Reed, M. S., Dougill, A. J., Twyman, C., & Mkwambisi, D. (2009). Adaptations to climate change, drought and desertification: Local insights to enhance policy in Southern Africa. *Environ. Sci. Policy*, 12, 748-765.

- Tella, R. D. (2007). Towards promotion and dissemination of indigenous knowledge. A case of NIRD. *Int. Inf. Library*, 39, 185-193.
- Várallyay, G. (2010). The impact of climate change on soils and their water management, *Agronomy Research*, 8(Special Issue II), 385-396, 385.
- World Bank. (2008a). World Bank data on agricultural value added as a share of GDP in 2008.
- Zhu, T., & Ringler, C. (2010). Climate change implications for water resources in the Limpopo River Basin. *Discussion Paper 00961; International Food Policy Research Institute (IFPRI)*. Washington, DC, USA.