Chelonian Conservation And Biology

Vol. 18 No. 2 (2023) | https://www.acgpublishing.com/ | ISSN - 1071-8443

DOI: doi.org/10.18011/2023.12(2).1785.1800

APPLICATION OF INDIGENOUS KNOWLEDGE SYSTEMS IN CLIMATE SMART AGRICULTURAL PRACTICES BY SMALLHOLDER FARMERS IN ISINGIRO DISTRICT, SOUTH WESTERN UGANDA

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Abstract

Indigenous knowledge Systems (IKS) is widely applied in agronomy to enhance crop productivity and boost smallholder farmers' food and income security globally. The study aimed at the documentation of the IKS options used in climate smart agriculture by smallholder farmers in meteorological drought vulnerable sub counties in Isingiro District, South Western Uganda. Focus group discussions of 18 men and 18 women aged between 30-70 years old and six key informants' interviews were conducted in six selected Sub Counties of Isingiro District, South Western Uganda. Data was tested and validated by 12 agricultural experts. Results show that practices that were ranked rational (4) in cropping systems include: Site selection to match particular crops; Selection of climate resilient seed and early maturing varieties, water retention ditches, Mulching, application of organic fertilizers, selection of tolerant banana varieties for the area, early planting to avoid harsh environmental conditions, crop rotation, planting maize in lines, intercropping and diversification of agriculture. Those practices ranked high as being rational in the prediction of drought include: increased flowering of *Bidens gratii sharff sp (*ehoongwa), increased population of butterflies, quick and sudden movement of dark clouds, much coldness in the morning, much dew formation in the morning and scanty rains (muyaaya). IKS practices ranked high and rational

(4) in predicting rainfall include: high temperature and the appearance of dark clouds in the atmosphere. Indigenous knowledge Systems are valuable in weather forecasting and climate change adaptation and mitigation. IKS are precursor for scientific knowledge and can guide science to do further investigation and expand on the knowledge database.

Keywords: Indigenous Knowledge Systems, climate smart agriculture, soil water conservation, climate change mitigation, food security, smallholder farmers' livelihoods

Introduction

Climate smart agriculture (CSA) is becoming a global concern for improving food security and farmers' income amidst climate change uncertainties. CSA involves three major pillars:-increasing productivity and incomes, enhancing crop resilience to climate change, and reducing greenhouse gas emissions to the atmosphere (1). CSA approaches contribute to UN Sustainable Development Goals, African Union Agenda 2063 (2), and Uganda Development Plan III (3). Consequently, Uganda and other developing countries have established CSA programs to strengthen and support relevant initiatives and technologies to promote the initiative (4,49-51) and enhance sustainable development and improve people's livelihoods. Farmers from various countries use different approaches/practices that are feasible and suitable in their local environments. Some of the approaches used include, inter alia, mulching, intercropping, crop rotation, crop-livestock integration, terracing, fallowing, application of organic manure, early planting, soil water conservation, and agroforestry (6–12). In the present century, CSA practices have demonstrated the potential to increase farmers' incomes (13,14), enhance crop yields (15,16), reduce greenhouse gas emissions and improve soil fertility (61-63) in several countries. Additional CSA innovations include: - early warning systems, precision agriculture, and use of disease- resistant and early maturing crops. CSA innovations are essential for meeting peoples' nutritional needs thus culminating in improved livelihoods (20,21) for the populations. Despite several CSA practices used across the globe, the application of indigenous knowledge systems in South Western Uganda is not well documented hence the need for this study. The study aimed at documentation of indigenous knowledge Systems (IKS) options applied in CSA by smallholder farmers in meteorological drought vulnerable sub counties in Isingiro District landscape.

Methodology

Study area

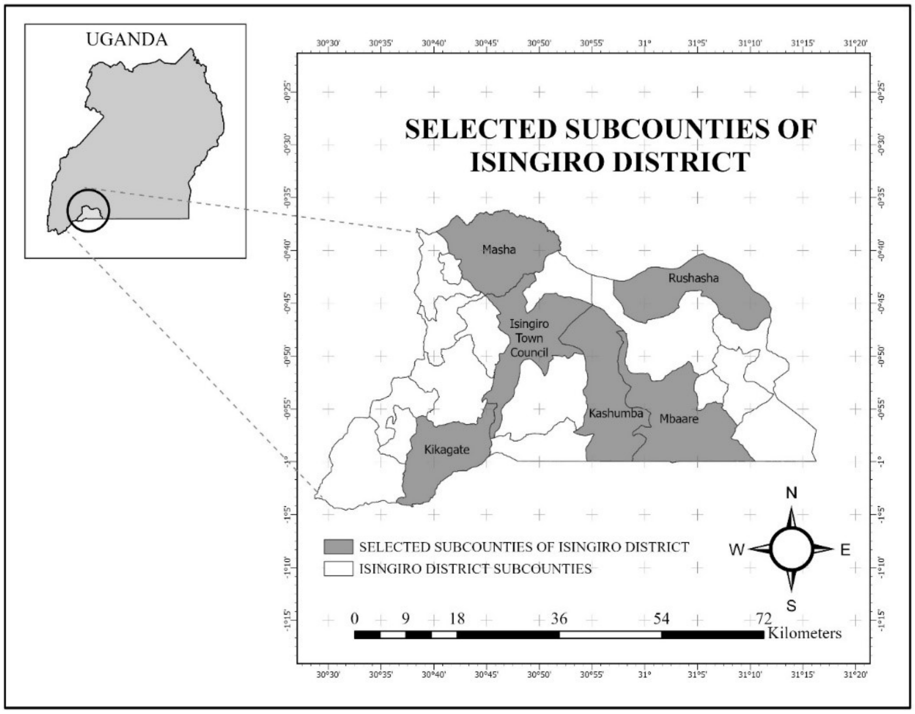

Figure 1 Map of Uganda Showing study area

The study was conducted in selected sub counties of Isingiro District including:-Isingiro Town Council, Masha, Rushasha, Kikagate, Kashumba and Mbaare (Table 1). The sub counties were purposively selected using agricultural experts based on their prominence in maize productivity and vulnerability to meteorological drought. Inhabitants in those sub counties depend majorly on maize and beans for their food and income security (22).

Table 1 Geographic coordinates of study sub counties

SN#	SC	Latitude	Longitude
1	Town Council	0°47'42.08"S	30°48'57.18"E
2	Masha	0°50'36.75"S	30°48'14.21"E
3	Rushasha	0°35'0.20"S	30°31'0.22"E
4	Kikagate	1° 2'18.09"S	30°39'48.85"E
5	Kashumba	0°53'43.83"S	30°57'51.39"E
6	Mbaare	0°56'59.98"S	31° 1'59.98"E

A focus group discussion of 18 men and 18 women aged between 30-70 years old was conducted in each Sub County. Participants were selected based on their IKS expertise (23). Additionally, six key informants were selected from selected sub counties with the help of the district agricultural officer and agronomists in charge of selected sub counties. The participants were gathered for a focus group discussion at each of the six sub county headquarters to establish the application of indigenous knowledge in climate smart agriculture for improving climate change adaptation and mitigation in the region. This was done with the help of focus groups and key informants interview guides to generate the required data for this study (24). The approach is based on the notion that elderly people are endowed with knowledge and vast experience that can build a foundation for further scientific investigations about climate mart landscape management climate change adaptation and mitigate strategies in agriculture. The IKS practices documented were tested and validated to ascertain their rational following the steps recommended by previous researchers (25). Questions and their responses were analyzed in Atlas.ti9 (26) and documented as below:

Qn1. Do you know about climate change and have you observed it changing over time?

Response: "*Yes, there has been climate change for example: • Seasons have changed, the original wet and dry seasons of March and September have changed and we no longer receive the August 15th Mary's Day rainfall, when we used to start planting our crops. Floods are being experienced in many areas and they destroy crops and infrastructure. This may be caused by deforestation and wetland reclamation •Extended dry spells have been noted across several years which affect agricultural productivity and farmers' incomes thus increasing households 'poverty levels among small holder farmers in the region. Climate change also causes high biodiversity loss (agro biodiversity) e.g. banana plantation almost dried in 2018 and banana-dependent communities hard limited food and income".* Elders' that were interviewed demonstrated awareness of climate change and explained its impact on crop productivity in their areas based on their experience and age.

***Qn*2.Do you think climate change affects soils? If so how?**

Response: "*Yes, climate change affects soils • Soil loses its fertility and develop a hard pan which is difficult to cultivate and does not support vegetation growth • Prolonged droughts increase pests prevalence like fall army worm and heavy rainfall increases termites' populations that affect maize and fruit trees •Much heat destroys grass and crops hence leaving soils bare and unproductive, exposed to floods resulting into soil erosion, landslides that destroy infrastructure and loss of soil nutrients •Floods from uphill move downhill and cause washing away of top soil with nutrients from one area to another and leaching of nutrients into deeper layers inaccessible to crops• High evaporation rates from the soil is caused by lot of heat caused by climate change •Less rain is received hence little water in the soil that affects crop growth and development that results into reduced yields •Formally, landscapes were self-regenerating, soil were fertile and there was no need to add fertilizers for replenishment before climate change affected us but now we must add fertilizers to increase crop productivity"* Interviewees explained how climate change affects soil structure and functions that results in reduced crop productivity.

Qn3. How does climate change affect soil water?

Response • *"Drought affects the planting seasons leading to reduced crop yields, destruction of the seeds (causing low germination rates) due to water shortage in soils hence in the long run affecting the overall crop productivity and farmers' incomes • Prolonged drought increases maize pests e.g. fall arm worm, reduce yields due to low rainfall thus resulting into loss of soil fertility and poor crop yields".* Participants described how climate change negatively affects soil water resulting into reduced crop yields and smallholder farmers' income.

Qn4. How do you use your IK to improve soil and keep it fertile for years?

Response: "*Clearing and burying the residues in the soil would enhance soil fertility. This was abandoned because of advancement of knowledge/technology, attitude change and high vested interests in maximum and quick gains •Terracing reduces runoff and nutrient losses •Fallowing and allowing land to rest for some seasons enables replenishment of soil nutrients over time •Alternating legumes with other crops in the same garden in different seasons enhances soil nutrients where legumes are planted in a given season • Matching particular land with crop residues adds nutrients to the soil and improves its fertility • Addition of soil amendments like farmyard manure, crop residues, maize stalks, bean/coffee husks, chicken/rabbit droppings and dry grass increased soil fertility. • Adding cow dung, burning of grass and crop residues would add nutrients like Potassium to the soils. •Tree planting protects soils and modifies climate, irrigation using plastic bottles all protect soils and keep them intact and fertile*". Participants described various indigenous options they used to enhance soil fertility and keep it fertile for a long period of time.

Qn5. How does climate change affect farmers' crop production?

Response: *"Drought proliferates crop pests and diseases that affect crop growth and development. It affects the planting calendar, affects seed germination rates and growth culminating into low yields, increased household food and income insecurity. •Too much rainfall affects beans and maize yields due to rotting while floods uproot crops from soils and carry them away from their gardens"* Participants explained how climate change affects farmers crop production resulting into their loss of income and enhance household poverty levels in their communities.

Qn6. How does climate change affect maize yields and how?

Response: "*Increases pests and diseases e.g. fall army worm and aphids• Loss of soil fertility, Stunted growth and reduced yields •Poor ear filling due to water scarcity".* Interviewees explained how maize yields are negatively affected by climate change resulting into increased food insecurity in their region.

Qn7. How does climate change affect bean yields and how?

Response: *"Increased pests in the beans •Chlorosis of beans due to either low rains or high temperature •Rotting of bean ponds •Beans being highly vegetative and do not bear pods resulting into increase in maize and bean pests".* Participants explained that climate change negatively affect bean yields thus their nutrition, food and income security for their households.

Qn8.Does climate change affect farmers' income?

Response: *"Yes, reduction of crop yield affects agricultural-dependent communities' food and income security".* Most of the smallholder farmers in the district are dependent of rain-fed agriculture and therefore, climate change badly affects their income base hence their livelihoods and incomes.

Qn9. Does climate change influence maize pests and diseases? How?

Response: *"Yes, increased pests and diseases such as fall army worm, aphids, cause stunted growth and reduced maize yields due to increased sunshine or rainfall".* The participants descried how climate change increases maize pests and diseases by boosting their populations thereby reducing maize productivity, the source of their livelihoods' support.

Qn10. Does climate change influence bean pests and diseases? How?

Response: *"Drought increases pests and diseases by providing a conducive environment for their proliferation".* Interviewees explained that climate change increases the spread of bean pests and diseases which undermine their productivity thereby negatively affecting farmers' food and income security.

Qn11. How do you use your IKS to control pests and diseases?

Response: *"Use of traditional methods e.g. scare-crows in the gardens and use of wood ash to chase caterpillars and fall army worms, hanging banana leaves used for cooking at the tips of maize plants to chase them away • Use of thorny plants that would pierce the pests and they die •Early planting and timely weeding would minimize crop pests and diseases".* Participants explained innovative options through which they control crop pets and diseases. Such innovations need further scientific testing and validation before they can be accepted and rolled out to other regions.

Qn12. How do you tell it is going to rain or not using IKS?

Responses: *"Clear clouds, flowering of Bidens grantii sherff sp (ehongwa RR), birds flying in certain direction, spread of black ants, frogs songs increase before it rains", oozing of water from the rock in Kabingo Town Council predict the coming of rainfall in the near future".* Participants descripted interesting and innovative IKS options that need scientific testing and validation to be incorporated into the body of scientific knowledge.

13. How do you use IKS to tell drought/heavy rains may occur in future?

Responses: *"Increased stars in the sky• High increase in temperature at night • Increase in some birds population e.g. egrets and ekisamutuutu RR • Changes in body e. g allergies •Appearance of the dark moon• Dark clouds in the sky• Increase in population and sounds of frogs • Movement of bees in swarms •Movement of many butterflies •Presence of click beetle insects making clicks when touched • Flowering of Bidens gratii sharff sp herbs •Quick and sudden movement of the clouds in certain directions• Scanty rains carried away by winds".* Participants explained how the human instincts, flora and fauna, other living organisms and non-living organisms in the environment can be used to predict the future climate based on IKS. These claims can be used as a source of further scientific research to generate new finding to support early warning systems, crop productivity, and food and income security for smallholders farmers in the region.

Qn14. How do you prepare yourself for droughts/heavy rain seasons?

Response: *"Proper spacing •Growing in the lines (maize) • Diversification (however, farmers are advocating for mono cropping)".* Participants explained how they prepare themselves to mitigate the impacts of anticipated droughts and heavy rains in the near future. Their preparations help them to reduce severe damages that would be caused by rains or drought incidences in their area,

Qn15.How do you apply IKS in maize-legume intercropping to increase yield and income?

Response: *"Improved (NAADS" maize and beans are easily affected by storage pests and diseases and cannot be re-planted in subsequent seasons hence not preferred by farmers".* Participants expressed their dissatisfaction with improved seeds provided by government and seed companies because they result into decreased yields on subsequent re-planting and finally they produce almost nothing. They advocated for their indigenous seed which can be re-planted several times without reducing yields or improved varieties that can be re-planted and keep production level high.

The indigenous knowledge systems collected were tested and validated by 12 agricultural experts based on the standard validation method recommended by previous agronomic experts (Table 2). The validation report is provided in Table 3.

Table 2 Testing and Validating ITS practices used in CSA (Source: Pandey et al, 2017)

Continuum	**Weight**
Very rational	5
Rational	4
Undecided	3
Irrational	2
Very irrational	1

Essentially, the IKS practices that were ranked highly as being rational (4) in cropping system include: Site selection to match particular crops; Selection of seed varieties, water retention ditches, Mulching, application of cow dung manure, application of goat droppings, application of maize stocks, selection of banana variety tolerant for the area, early planting to avoid harsh environmental conditions, adding crop residues to enhance soil fertility, crop rotation, planting maize in lines, intercropping, diversification of agriculture. Those practices ranked high as being rational in prediction of drought include: increased flowering of *Bidens gratii sharff sp (*ehongwa RR), increased population of butterflies, quick and sudden movement of clouds in certain directions, much coldness in the morning, much dew formation in the morning and scanty rains (muyaaya). The lowest ranked as irrational (2) was presence of click insects (enkomera RR). Practices ranked high and rational (4) in predicting rainfall include: high temperature (heat wave and sweating at night) and appearance of dark clouds in the atmosphere. The rest were ranked as undecided.

Table 3 ITK Approaches used for CSA in the study sub counties of Isingiro District

[redacted]

Discussion of results

Based on the interviewees responses, previous studies agree with the findings that climate change has been observed taking place across the globe and affecting crop productivity for decades and even centuries (27–30). Similarly, previous researchers affirm that climate change has been observed through increased CO_2 concentration and other greenhouse gases in the atmosphere and increased temperature from 1950s to date. In addition, studies pointed out that change has resulted into significant impact on soils properties, soil water, species diversity, crop productivity, farmers' food and income security hence their livelihoods many counties across the globe, developing countries being mostly affected due to their limited adaptive capacity and technical personnel (31–34). The study further agrees with previous studies who reported that climate change affects hydrology, underground water, surface runoff, soil moisture, precipitation, evapotranspiration and the general water cycle which affects crop productivity in many countries (35–37). Previous studies also pointed out that climate change affects crop productivity, famers' incomes and food security thus affecting the livelihoods of many rain-fed dependent smallholder farmers across the globe (38–42). The findings from this study also agree with previous researchers who reported that indigenous soil management practices are essential in integrated soil fertility management, water conservation, soil structure restoration, soil aeration and floods mitigation (43–46). Furthermore, the findings agree with previous researchers who reported that IKS have been used for centuries in CSA and crop productivity improvement, weather forecasting, onset of rains, drought prediction, early warning systems, crop pests and diseases control, identification of climate resilient seed and drought tolerant seed, fisheries, disaster risk management and rain harvesting (24,45,47–53). Moreover, IKS have been used in many countries in climate change mitigation and adaptation options for improving crop productivity and improving food and nutrition security among smallholder farmers across the globe (54–61), which is agreement with this study. Results also agree with previous researchers that IKS have been employed by smallholder farmers in various countries across the globe for integrated soil fertility management options and crop productivity enhancement (62).

Conclusions and recommendations

Climate change is a historical, current and future unavoidable phenomenon that affect humans, the environment, and other living organisms. It affects crop productivity, famers' food and income security across the globe. Indigenous Knowledge Systems are valuable in weather forecasting and climate change adaptation and mitigation. Indigenous Knowledge Systems are a precursor for scientific knowledge and can guide science to do further investigation and discover new knowledge. Several CSA practices and technologies have their deep roots from indigenous knowledge systems obtained from our great grandparents who never attained formal education. They predicted weather by their own instincts, used early warning systems from the natural environments, including birds, vegetation, insects, earth worms, amphibians, bats, inter alia. They managed well their soils, soil water, soil nutrients, crop pests and diseases and harvested water using IKS before scientific knowledge was discovered. The study recommends that more site specific IKS approached and technologies be identified, validated, documented and tested to prove their authenticity before applied by farmers in different countries for enhancing crop productivity and farmers' incomes.

Acknowledgements

I thank the African Centre of Excellence for Climate Smart Agriculture and Biodiversity Conservation management for the funding support they provided through World Bank which enabled me pursue my PhD study at Haramaya University. I thank the Professor Maud Kamateni-Mugisha for giving me a study leave to pursue PhD, FAEST dean and AAE staff for their moral support and standing in the gap when I went for further studies. Special thanks go to all my academic advisors for supervising my PhD study and providing technical support during my study. God bless you all, *Our God Reigns!*

Authors' contributions

Wycliffe Tumwesigye:-PhD student who conducted the study and wrote the manuscript

Professors: Tesfaye Lemma Tefera, Bobe Bedadi and Majaliwa Mwanjalolo Jackson-Gilbert supervised my proposal writing and gave technical guidance during data analysis.

Funding

Funding was provided by ACE, Haramaya University, Ethiopia

Competing interests

The authors declare that they have no competing interests

Declaration

Authors declare no conflict of interest

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