Climate Services

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The use of climate services (CS) for the provisioning of climate information for informed decision-making on adaptation action has gained momentum. CS is a scientifically-based information and products that enhance users' knowledge and understanding about the impacts of climate on their decisions and actions.) "Climate services, involve the timely production, translation, and delivery of useful climate data, information and knowledge for societal decision-making and climate-smart policy and planning".

Keywords: climate change ; agriculture ; adaptation

1. Types of Interventions and Climate Information Provided through CS

The types of interventions provided in the African agriculture sector through CS were thematically grouped into 11 categories (**Figure 1**). Most of the interventions are within the thematic group of analysis of adoption pathways (19%). The type of interventions within this group mostly focussed on analyzing the adoption pathways for effective CS uptake in the agriculture sector [1][2][3]. To optimize CS adoption by relevant actors' across scales in the African agriculture sector, project implementers employ several strategies including socioeconomic characterization of households to identify efficient and effective information dissemination pathways [1][4][5][6], while some projects used peer-to-peer and social learning to promote and facilitate CS use awareness among potential users [5][7]. Some projects chose an economic pathway by analyzing households willingness to pay for CS to identify the cost-effective strategy for promoting CS' adoption in the agriculture sector [8][9].

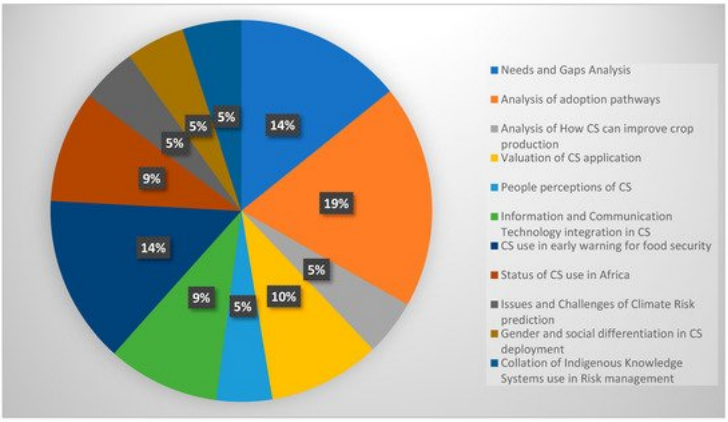

Figure 1. Thematic groupings of CS according to issues of focus.

The second most common thematic groups of interventions are needs and gaps analysis (14%) and early warnings for food security (14%). In the context of needs and gaps analysis, CS is used to specifically target the local contextual needs of farmers/users concerning their information needs for livelihood system adaptation to climate change. In the context of early warning, CS is used for timely and relevant information communication to users to facilitate their early preparation for various risks including drought, wildfire, erratic rainfall, etc., to help ensure food security at household and community levels. The third most common thematic group of intervention is the valuation of CS' application in the agriculture sector (10%). Interventions within this thematic group are mostly focused on the evaluation of CS' contribution to the economic viability of agricultural practices and CS' contribution to agriculture productivity, e.g., crop yield. The fourth most common thematic group of interventions are Information and Communication Technology (ICT) integration in CS (9%) and status of CS use in Africa (9%). Interventions focusing on ICT integration mostly focused on the investigation of options for using ICT to enhance farmers' access to relevant climate information in a cost-effective and timely manner. These types of studies are relatively recent but are growing exponentially in number. A positive trend was observed between the year of project implementation and the type of intervention the projects provide. This is especially true for project interventions focused on ICT integration in CS applications. Although this type of intervention is currently the least common, nevertheless, most of the projects providing this type of intervention are recent, with most occurring between 2011 to 2019. This is a strong indication that this type of intervention is steadily growing and may become the dominant type of intervention in the future. Other thematic groups of interventions that are sparingly provided through CS include: analysis of how CS can improve crop production (5%), people's perceptions of CS (5%), issues and challenges of climate risk prediction (5%), gender and social differentiation in CS deployment (5%), and collation of indigenous knowledge systems use in risk management (5%).

2. Types of Climate Information Provided through CS

There are three main types of climate information commonly provided through CS. These are forecasts, agrometeorological services, and early warnings.

Forecasts use in farming operations: Several CS projects in the African agriculture sector have applied forecasts of varying timescale in providing risk warning and risk response advisory services to farmers [10][11][12]. The literature synthesis and mapping process identified five timescale forecasts as the most widely used forecasts in the production of climate risk warnings and risk response advisory services: (1) Weather forecasts (daily to weekly), (2) Seasonal forecasts (on a timescale of 1–6 months), (3) Short-term forecasts (1–5 years), (4) Intra-decadal/Medium-term forecasts (5–10 years), and (5) Decadal forecasts. The most commonly used among these forecasts are short-term, seasonal, and weather forecasts [4][13][14]. Intra-decadal and decadal forecasts are sparingly used in agricultural risk management, even though they may be more useful for making a strategic decision and anticipatory adaptation plans [15][16][17].

Table 1 presents a summary of how these forecasts are used in risk warning and risk response advisory services for informing stakeholders in the agriculture sector. We also present additional information on how the forecasts are used in decision making and the identified gaps based on users' information needs and the type of information communicated to them [18].

Table 1. Observed forecasts and their use in the agriculture sector.

Forecast	Typical Content	Application in Decision Making	Gaps	Reference
Weather forecasts (daily to weekly)	**They normally contain detailed likelihood of the occurrence of climate events, e.g., rainfall possibility**	**Decision making on daily farming operations: Timing of fertilizer and chemical applications, timing of fungicide applications.**	**None identified**	[19][16][20]
Seasonal forecasts (on a timescale of 1–6 months)	**Seasonal rainfall onset and cessation, the rainfall amounts, rainfall duration, rainfall distribution, and anticipated extreme weather events such as drought, flood, fire risk, strong wind/wind gusts, hail, frost, among others.**	**Used in making tactical decisions on the scheduling of: When to plow the fields, when to sow, when to add fertilizers, when to irrigate, when to provide pesticides, when to harvest, when to sell, and choice of seed variety for planting.**	**Desired but not widely available information include optimal sowing date, evapotranspiration, insolation, soil water availability (to inform the scheduling of irrigation).**	[19][21][22][10][8][12]
Short-term forecasts (1–5 years)		**Mostly used in the livestock sector for preparedness messages and education on: fodder availability, water resource availability, potential disease occurrence zone.**	**Desired but not yet widely available information includes: Forecasts of parasite and animal diseases**	[21][22][10][3][8][9][12]
Intra-decadal/Medium-term forecasts (5–10 years)	**Sectoral decision making**			[19][21][9]
Decadal forecasts			**No record of the use of decadal to medium-term projections. Although it acknowledged that such could inform future agricultural research investments, irrigation and water resource management planning, and training needs for agricultural extension staff.**	[9][23]

The generation of timescale forecasts that are relevant to the timeline at which decisions are made in the agriculture sector is increasingly relying on the nature of the partnership and collaboration among the transdisciplinary actors (climatologists, meteorologists, and agriculturalists) operating in the agriculture and climate information space. Although this partnership has played a key role in advancing the uptake of CS in the Africa agriculture sector, there are, however, gaps reported in the selected studies concerning differences between the type of information desired by users and the type of information they receive via the CS.

Most of the reported gaps are associated with seasonal forecast usage. This includes several additional important pieces of information to optimize the resilience of agricultural operations to climate change's impact. An example is a desire for information on crop water requirements and evapotranspiration rate, which users believe will enhance the efficiency of the use of irrigation systems as a climate change response strategy [24][20]. There were also identified gaps in the literature that are associated with the use of short-term forecasts. Many studies reported the absence of forecasts on the precise occurrence of parasite and/or livestock disease as a result of climate change. Users believe that such information will enable them to anticipate and adjust their management strategy to manage climate change's impact on their livestock [25][26]. There are, however, differences in the extent to which seasonal and short-term forecasts are used across African countries. For example, a study in Malawi reported that there is no availability of models to predict the different periods when the rains can set in [27][28], whereas this type of limitation is not an issue in many other African countries [1]. In general, we did not record any gap associated with the use of intra-decadal and decadal forecasts in the agriculture sector; this is largely because such forecasts are currently seldom used in the African agriculture sector.

Agrometeorological services: Agrometeorological services are the second most common type of climate information provided by the CS [10][29]. Included in this category is information provided to manage the impact of both climate change and climate variability. This includes advisory information on the scheduling of planting operations, weeding, fertilizer applications, etc. CS is also, in some cases, used to provide information on climate-smart agriculture practices (CSA). The type of CSA information communicated includes conservation farming practices like ridging, minimum tillage, soil conservation practices, etc. [26][30]. The use of CS to communicate agrometeorological services and CSA to farmers is acknowledged as a valuable innovation to assist decision-making and develop farmers' specific adaptive capacities [10]. **Table 2** presents a summary of how agrometeorological services are used in farming operations and the associated benefits. The benefits associated with agrometeorological services integration in farming operation decision-making can be summarized by an increase in crop productivity and a decrease in cropping costs in terms of inputs and working time [10][31].

Table 2. Commonly used agrometeorological services.

Farming Operation	Agro-Meteorological Services	CSA	Benefits	References
Land preparation	**Advice on weather and seasonal forecasts, and crop calendar**	**Land conservation practices**		[10][32]
Weeding	**Soil moisture and weather forecasts**	**Land conservation practices to reduce weed infestation**		[26][30]
Sowing	**Forecasts on onset and offset of rain seasons with sowing calendar**		**Avoid loss due to crop failure to germinate or establish because of dry spells**	[7][26][33]
Crop variety choice	**Insight from forecasts on rain distribution, average annual rainfall, and seasonal forecasts in combination with crop calendar is used to advise farmers on crop type and variety to sow**			[8][26]

Early warning interventions: The third type of climate information provided through CS are early warnings. Early warning intervention provisioning is commonly used for drought, flood, and wildfire risk warnings [16][2][7][26][30]. Early warnings are rarely solely disseminated to users; rather, they are provided in combination with agrometeorological services [14][10][31][8]. The early and timely delivery of early warnings is increasingly being facilitated through the integration of ICT CS dissemination strategy.

3. Extent of Scientific and Indigenous Knowledge Systems Integration in CS

The entry of studies to understand the extent to which scientific and indigenous knowledge systems are integrated into CS revealed that knowledge system integration is not yet an issue of significant emphasis in CS adoption in the African agriculture sector. Of the reviewed studies, 72% applied only scientific knowledge systems and did not in any way integrate indigenous knowledge system CS applications [1][19][4][3]. However, 17% of the reviewed studies collated indigenous practices of climate risk prediction and risk response strategy [34][21][33]. Although the documented indigenous knowledge system is not included in the content of information disseminated via the CS, they are nevertheless, on rare cases, used to fine-tune the statistical forecast of risks and risk response strategy [32][35].

Nonetheless, indigenous knowledge systems are not entirely neglected in the current model of CS deployment. Eleven percent of the reviewed literature reported the inclusion of indigenous knowledge holders in the process of a forecast's translation into relevant climate information for actors in the agriculture sector. The study deduces that the inclusion of indigenous knowledge holders in the process of CS deployment is mainly for two purposes. The first is to promote the acceptance of CS by rural farmers, because rural farmers in Africa overwhelmingly rely on indigenous knowledge systems for their operations [16][3][32]. The second purpose is for the fine-tuning of statistical forecasts to suit the local context of climate risk warning and risk response strategy.

Resistance to information adoption often occurs when new knowledge interplays negatively with old knowledge [36][35][37]. This assertion can be attributed to the challenge of meteorological forecasts' acceptance, especially by rural farmers in many African countries where CS is sometimes rejected in favor of the old way of farming because the new information tends to interfere with the traditional way of farming [32]. This type of resistance is very common among the elderly, who tend to favor the traditional way of farming that is rooted in their indigenous knowledge system [38]. However, there is a growing trend towards the co-production of forecasts, whereby indigenous knowledge holders collaborate with researchers and meteorologists to generate plausible forecasts for their locality [34][16][18]. The approach currently tends to focus on using a participatory process for consensus on plausible risk scenarios for the local community as a way of securing the people's trust and confidence in the disseminated information [16][28]. As a result, most CS' lack information on the indigenous system of risk prediction and risk response.

The study, therefore, infers that an actionable point of entry for indigenous knowledge system integration into CS would be to integrate scientific risk response strategy with local sociocultural farming coping practices. Integration must occur across all three phases of the CS value chain. This means much needs to be done to encourage integration at forecasts production and forecast translation phase.

4. CS'Role in Facilitating Two-Way Learning for Robust Adaptation Action

To analyze how the adoption of CS has facilitated two-way learning (bottom-up and top-down) about climate change mitigation and adaptation in the agriculture sector, we analyzed the selected literature for information on methods used to facilitate a feedback relationship among actors in the value chain of CS. This is because the production and dissemination of contextual climate information for actors in the agriculture sector relies mainly on the structure and feedback loop of the network of relations that exists among the actors [39][40].

The analysis of the selected literature indicates that the relationships among the actors in the CS value chain operate mainly on a participatory collaborative process. This collaborative process is primarily through workshops and participatory scenario planning meetings. The participatory collaborative process is used for the production of relevant climate information, development of appropriate channels for information dissemination, and promotion of local ownership in climate information production and dissemination [1][18][41]. This ultimately influences learning and revisiting to ensure the relevancy, suitability, and usability of information disseminated via the CS [28][42][43]. **Table 3** provides a summary of recorded evidence of how the participatory process approach in CS deployment facilitates two-way learning (bottom-up and top-down).

Table 3. Evidence of participatory process influence in CS application.

Case	Key Impact	Reference
The participatory process is targeted at facilitating the relationship between CS providers and local farmers to enable CS providers to understand the user's socio-cultural context to provide contextual information	**User's context**	[4][3]
The participatory process was used to spur farmers group interest in CS which resulted in them taking ownership and initiative of the process of CS dissemination and application in farming practices in their locality	**Ownership and taking the initiative**	[44][4][13][18]
The participatory process was used to improve local people understanding of and trust meteorological weather and climate forecasts	**Trust and confidence in meteorological forecasts**	[18]
There are several recorded case studies where participatory processes have successfully been used to improve the rate of CS application in farming practices by local farmers	**CS usage**	[19][18]
There are several recorded case studies where participatory processes have successfully been used to provide inclusive training to users to enhance their capacity to understand and apply disseminated information via the CS	**Capacitation of users**	[19][16]

Nevertheless, the cost and difficulty of gathering all relevant stakeholders in a workshop are limiting the effectiveness of this approach. This is evident in the reported gaps (**Table 1**) in the information disseminated through the CS [45][2]. CS providers, therefore, need to be proactive in interacting with the farmers regarding their needs for climate information and in determining a more suitable feedback mechanism for maintaining the relevancy of CS [46][47]. To this end, several methods for reaching smallholder farmers have been attempted by various agencies, but a scalable solution has yet to be found [40][22]. The internet and mobile phone (SMS) are the two prominent new and innovative methods being used to facilitate collaborations among the actors. They are, however, still in infancy and need a lot of research to improve their efficiency. The use of the internet, for example, has been constrained by lack of facilities and, in some cases, by unwillingness on the part of the local people to pay the internet fee for accessing CS [7][48]. SMS, on the other hand, has also been constrained by poor signal/reception in many regions and, in most cases, the feedback communication between

CS providers and users via SMS has been reported to be inefficient and inadequate [49]. There is, therefore, a need for further investigation for insight on appropriate modalities for facilitating impactful and sustainable reciprocated relationships among the actors along the CS value chain via the use of SMS and the internet, particularly within the context of African rural communities.

References

1. Tall, A.; Coulibaly, J.Y.; Diop, M. Do climate services make a difference? A review of evaluation methodologies and practices to assess the value of climate information services for farmers: Implications for Africa. Clim. Serv. 2018, 11, 1–12.
2. Singh, C.; Daron, J.; Bazaz, A.; Ziervogel, G.; Spear, D.; Krishnaswamy, J.; Zaroug, M.; Kituyi, E. The utility of weather and climate information for adaptation decision-making: Current uses and future prospects in Africa and India. Clim. Dev. 2018, 10, 389–405.
3. Ouédraogo, M.; Barry, S.; Zougmoré, R.B.; Partey, S.T.; Somé, L.; Baki, G. Farmers' willingness to pay for climate information services: Evidence from cowpea and sesame producers in Northern Burkina Faso. Sustainability 2018, 10, 611.
4. Tall, A.; Jay, A.; Hansen, J. Scaling Up Climate Services for Farmers in Africa and South Asia Workshop Report; CCAFS Working Paper no. 40; CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS): Copenhagen, Denmark, 2013; Available online: https://cgspace.cgiar.org/bitstream/handle/10568/27833/WP40.pdf?sequence=1&isAllowed=y (accessed on 5 December 2018).
5. Cornell, S.; Berkhout, F.; Tuinstra, W.; Tàbara, J.D.; Jäger, J.; Chabay, I.; de Wit, B.; Langlais, R.; Mills, D.; Moll, P.; et al. Opening up knowledge systems for better responses to global environmental change. Environ. Sci. Policy 2013, 28, 60–70.
6. Stone, R.C.; Meinke, H. Weather, climate, and farmers: An overview. Meteor. Appl. 2006, 3 (Suppl. 1), 7–20.
7. Oladele, O. Agricultural extension and rural advisory services: Proactiveness or reactiveness on climate change for food security in Africa. Life Sci. J. 2013, 10, 593–597.
8. Ouedraogo, I.; Diouf, N.S.; Ouédraogo, M.; Ndiaye, O.; Zougmoré, R.B. Closing the gap between climate information producers and users: Assessment of needs and uptake in Senegal. Climate 2018, 6, 13.
9. Zongo, B.; Diarra, A.; Barbier, B.; Zorom, M.; Yacouba, H.; Dogot, T. Farmers' perception and willingness to pay for climate information in Burkina Faso. J. Agric. Sci. 2016, 8, 175–187.
10. Tarchiani, V.; Camacho, J.; Coulibaly, H.; Rossi, F.; Stefanski, R. Agrometeorological services for smallholder farmers in West Africa. Adv. Sci. Res. 2018, 15, 15–20.
11. Brasseur, G.P.; Gallardo, L. Climate services: Lessons learned and future prospects. Earth's Future 2016, 4, 79–89.
12. Nesheim, I.; Barkved, L.J.; Bharti, N. What is the role of agro-met information services in farmer decision-making? Uptake and decision-making context among farmers within three case study villages in Maharashtra, India. Agriculture 2017, 7, 70.
13. Coulibaly, Y.J.; Kundhlande, G.; Amosi, N.; Tall, A.; Kaur, H.; Hansen, J. What Climate Services Do Farmers and Pas-Toralists Need in Tanzania? Baseline Study for the GFCS Adaptation Program in Africa; CCAFS Working Paper no. 110; CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS): Copenhagen, Denmark, 2015; Volume 112.
14. Vermeulen, S.J.; Aggarwala, P.K.; Ainslie, A.; Angelone, C.; Campbell, B.M.; Challinor, A.J.; Hansen, J.W.; Ingram, J.S.I.; Jarvis, A.; Kristjanson, P.; et al. Options for support to agriculture and food se-curity under climate change. Environ. Sci. Policy 2012, 15, 136–144.
15. Haig, B.D. Précis of 'an abductive theory of scientific method'. J. Clin. Psychol. 2008, 64, 1019–1022.
16. Ofoegbu, C.; New, M.G.; Staline, K. The effect of inter-organizational collaboration networks on climate knowledge flows and communication to pastoralists in Kenya. Sustainability 2018, 10, 4180.
17. Ziervogel, G.; Johnston, P.; Matthew, M.; Mukheibir, P. Using climate information for supporting climate change adaptation in water resource management in South Africa. Clim. Chang. 2009, 103, 537–554.
18. Kniveton, D.; Visman, E.; Tall, A.; Diop, M.; Ewbank, R.; Njoroge, E.; Pearson, L. Dealing with uncertainty: Inte-grating local and scientific knowledge of the climate and weather. Disasters 2014, 39, S35–S53.
19. Dougill, V.K.; Dixon, A.J.; Stringer, J.L.; Cull, T.L.C. Identifying climate services needs for national planning: Insights from Malawi. Clim. Policy 2017, 17, 189–202.
20. Jones, L.; Harvey, B.; Godfrey-Wood, R. The Changing Role of NGOs in Supporting Climate Services; BRACED Resilience Intel, 4; London Overseas Development Institute: London, UK, 2016.
21. Ongoma, V.; Shilenje, Z.W. The effectiveness of agrometeorological information in the realization of Kenya's Vision 2030; lessons learnt from China. Ital. J. Agrometeorol. 2016, 1, 67–72.

22. Hansen, J.W.; Mason, S.J.; Sun, L.; Tall, A. Review of seasonal climate forecasting for agriculture in Sub-Saharan Africa. Exp. Agric. 2011, 47, 205–240.

23. Nyamwanza, A.M.; New, M. Anticipatory adaptation and the role of decadal climate information in rural African livelihood systems: Lessons from the Mid-Zambezi Valley, Zimbabwe. Int. J. Clim. Change Strateg. Manag. 2015, 8, 236–252.

24. Cooper, P.J.M.; Dimes, J.; Rao, K.P.C.; Shapiro, B.; Shiferaw, B.; Twomlow, S. Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? Agric. Ecosyst. Environ. 2008, 126, 24–35.

25. Dayamba, D.S.; Ky-Dembele, C.; Bayala, J.; Dorward, P.; Clarkson, G.; Sanogo, D.; Mamadou, L.D.; Traoré, I.; Diakité, A.; Nenkam, A.; et al. Assessment of the use of Participatory Integrated Climate Services for Agriculture (PICSA) approach by farmers to manage climate risk in Mali and Senegal. Clim. Serv. 2018, 12, 27–35.

26. Cramer, L. Evaluation of Climate Services Interventions in the GFCS Adaptation Programme for Africa. Part II: Beneficiary Assessment Final Evaluation Summary Report. Statistics for Sustainable Development and Cramer-Njihia Consultants for the World Food Programme and CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). 2017. Available online: https://gfcs.wmo.int/sites/default/files/projects/Global%20Framework%20for%20Climate%20Services%20Adaptation%20Programme%20in %20Building%20Resilience%20in%20Disaster%20Risk%20Management%2C%20Food%20Security%20and%20Health/Final-report_1-Nov-2017-min.pdf (accessed on 6 January 2019).

27. Weichselgartner, J.; Kasperson, R. Barriers in the science-policy-practice interface: Toward a knowledge-action-system in global environmental change research. Glob. Environ. Chang. 2010, 20, 266–277.

28. Waiswa, M.; Mulamba, P.; Isabirye, P. Climate information for food security: Responding to user’s climate information needs. In Climate Prediction and Agriculture: Advances and Challenge; Sivakumar, M.V.K., Hansen, J., Eds.; Springer: Berlin/Heidelberg, Germany, 2007; pp. 225–248.

29. Nadine, A.; Fanny, H.; Ousmane, N.; Armando, M.; Carlos, M.; Guy, F. Climate smart services: Case studies in Senegal, Burkina, and Colombia. In Climate Smart Agriculture-Global Science Conference; CIRAD: Montpeiller, France, 2015; p. 113. Available online: http://csa2015.cirad.fr/var/csa2015/storage/fckeditor/file/L3%20Towards%20Climate-smart%20Solutions(1).pdf (accessed on 18 December 2018).

30. Mwaniki, F.; Gichuki, C.; Mwangi, M.; Mburia, P.; Wandago, B.O. Addressing challenges in communicating adaptation practices to smallholder farmers in Kenya through a radio intervention. J. Agric. Environ. Int. Dev. 2017, 111, 279–322.

31. Roudier, P.; Muller, B.; D’Aquino, P.; Roncoli, C.; Soumaré, M.; Batté, L.; Sultan, B. The role of climate forecasts in smallholder agriculture: Lessons from participatory research in two communities in Senegal. Clim. Risk Manag. 2014, 2, 42–55.

32. Kruk, M.C.; Parker, B.; Marra, J.J.; Werner, K.; Heim, R. Engaging with users of climate information and the coproduction of knowledge. Weather Clim. Soc. 2017, 9, 839–849.

33. Aker, J.C. Dial “A” for agriculture: A review of information and communication technologies for agricultural extension in developing countries. Agric. Econ. 2011, 42, 631–647.

34. Machingura, F.; Nyamwanza, A.; Hulme, D.; Stewart, E. Climate information services, integrated knowledge systems and the 2030 Agenda for Sustainable Development. Sustain. Earth 2018, 1, 1.

35. Kanno, H.; Sakurai, T.; Shinjo, H.; Miyazaki, H.; Ishimoto, Y.; Saeki, T.; Umetsu, C.; Sokotela, S.; Chiboola, M. Indigenous climate information and modern meteorological records in Sinazongwe district, Southern Province, Zambia. Jpn. Agric. Res. Q. 2013, 47, 191–201.

36. Nyamwanza, A.M.; New, M.; Fujisawa, M.; Johnston, P.; Hajat, A. Contributions of decadal climate information in agriculture and food systems in east and southern Africa. Clim. Chang. 2017, 143, 115–128.

37. Makondo, C.C.; Thomas, D.S.G. Climate change adaptation: Linking indigenous knowledge with western science for effective adaptation. Environ. Sci. Policy 2018, 88, 83–91.

38. Buizer, J.; Jacobs, K.; Cash, D. Making short-term climate forecasts useful: Linking science and action. Proc. Natl. Acad. Sci. USA 2016, 113, 4597–4602.

39. Vaughan, C.; Dessai, S. Climate services for society: Origins, institutional arrangements, and design elements for an evaluation framework. WIREs Clim. Chang. 2014, 5, 587–603.

40. Kadi, M.; Njau, L.N.; Mwikya, J.; Kamga, A. The State of Climate Information Services for Agriculture and Food Security in East African Countries; Working Paper No. 5; Climate Change, Agriculture and Food Security (CCAFS): Copenhagen, Denmark, 2011; Available online: www.ccafs.cgiar.org (accessed on 9 December 2018).

41. Best, A.; Holmes, B. Systems thinking, knowledge and action: Towards better models and methods. Evid. Policy J. Res. Debate Pract. 2010, 6, 145–159.

42. Naaba, F.Z.; Abubakari, Z.; Ahmed, A. The role of climate services in agricultural productivity in Ghana: The perspectives of farmers and institutions. Clim. Serv. 2019, 13, 24–32.

43. Kalafatis, S.E.; Lemos, M.C.; Lo, Y.-J.; Frank, K.A. Increasing information usability for climate adaptation: The role of knowledge networks and communities of practice. Glob. Environ. Chang. 2015, 32, 30–39.

44. Sivakumar, M.V.K.; Motha, R.P. Managing Weather and Climate Risks in Agriculture Summary and Recommendations. In Managing Weather and Climate Risks in Agriculture; Sivakumar, M.V.K., Motha, R.P., Eds.; Springer: Berlin, Heidelberg, 2007.
45. Ziervogel, G.; Zermoglio, F. Climate change scenarios and the development of adaptation strategies in Africa: Challenges and opportunities. Clim. Res. 2009, 40, 133–146.
46. Never, B. Regional Power Shifts and Climate Knowledge Systems: South Africa as a Climate Power? Working Paper No. 125; German Institute of Global and Area Studies: Hamburg, Germany, 2010; p. 311.
47. Sivakumar, M. Climate prediction and agriculture: Current status and future challenges. Clim. Res. 2006, 33, 3–17.
48. Rasmussen, L.V.; Mertz, O.; Rasmussen, K.; Nieto, H. Improving how meteorological information is used by pastoralists through adequate communication tools. J. Arid. Environ. 2015, 121, 52–58.
49. Mittal, S.; Hariharan, V.K. Mobile-based climate services impact on farmers risk management ability in India. Clim. Risk Manag. 2018, 22, 42–51.