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Traditional knowledge and institutions for sustainable climate change adaptation in Ethiopia

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ABSTRACT

Local values, institutions and knowledge have enabled people to understand the happenings and changes in their environment. Local perceptions and knowledge provide a crucial foundation for community-based climate change adaptation measures and natural resource conservation. This paper is specifically focused on the assessment of the opportunities and challenges of traditional knowledge and institutions for community's sustainable climate change adaptation in Ethiopia. We used knowledge products form journal articles, policy documents, working papers, policy briefs, and other gray literature. In addition, two case studies were conducted in central and eastern Ethiopia by interviewing 251 randomly selected households. This helped to determine the state-of-the art for knowledge co-products for community's sustainable climate change adaptation and natural resource management. Regardless of the challenges from global change, cultural erosion and transformation, traditional knowledge still serve as the bases for weather forecasting, agricultural and natural resource management thereby sustain community's livelihoods and landscape resilience against the impacts of climate change and variability. Traditional knowledge and institutions in Ethiopia have maintained landscapes for millennia: Konso cultural landscapes and Gedeo Agroforestry systems are some to mention. The knowledge systems have also contributed for the large diversity of crops and livestock breeds in Ethiopia which play roles in community's climate change adaptation. From this assessment, it can be concluded that both scientific and traditional knowledge have their own gaps and what will be better is the integration of the two to give an additive impact that can foster sustainable development and build livelihood and landscape resilience in times of climate change.

1. Introduction

Ethiopia is a fragile country with geographical setting ranging from −120 to 4600 m. This altitudinal rage has made the country to have different climatic conditions with different degree of vulnerability to climate change impacts. This physical diversity of the country is also accompanied by cultural diversity with more than 80 ethnic groups. Farmers and pastoralists have adopted to lead their livelihood in these fragile and complex environments with the help of their own traditional ways of managing crops, livestock and natural resources. In both agricultural and natural resource management, people use local knowledge to sustain their livelihoods and environments. By the use of indigenous knowledge and practices, people have used different crops varieties to diversify their livelihood options. If one crop type fails due to climate extremes, the other can give an alternative production. Similarly, they have also accustomed to rear different livestock breeds with different potential of resisting drought extreme. Due to their age-old experiences, farmers and pastoralists know what changes were happened in the past, what are the existing current situation and what will happen in the future in their environments. Studies and reports (e.g. IPCC 2007 & 2010; Gyampoh et al., 2009; McLean et al., 2011; Nakashima et al., 2012; Ramos and McLean, 2012; Ford et al., 2016; Magni, 2017) indicated that local knowledge and practices have helped people to adapt climate change impacts and form the foundation for modern adaptations.

In Ethiopia, there are over 80 ethnic groups with their own cultural identities. These ethnic groups have their own ways of traditional knowledge systems on how to manage crops, biodiversity, soil, water and livestock husbandry that enabled them to sustain their livelihoods as well as landscapes for millennia. Indeed, traditional knowledge is also used in weather forecasting thereby help people in making decision in their daily activities. In our context, the terms local, traditional and

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indigenous knowledge are used synonymously. The World Intellectual Property Organization (WIPO-https://www.wipo.int/tk/en/tk/) described traditional knowledge as "*knowledge, know-how, skills and practices that are developed, sustained and passed on from generation to generation within a community, often forming part of its cultural or spiritual identity*." They are specific to a particular environment with a particular community and are dynamic in their nature regardless of the claim that as they were static and inferior (Agrawal, 1995; Ellen and Harris, 1996). Traditional knowledge and practices are, mostly, run through traditional institutions that enabled people to enforce the practices and knowledge into practical application in their daily life (Fig. 1).

The first step in the scientific method is observation. Local people had lived for millennia in their environments by observing all the changes, including climate change, happening in a particular ecosystem. In recognition to this, the Intergovernmental Panel on Climate Change (IPCC), and the Secretariat of the Convention on Biological Diversity (SCBD) have accredited the role of traditional knowledge in sustainable climate change adaptation and sustainable use and conservation of biological diversity (IPCC, 2007, SCBD, 2006). This again, implies that it is unwise to overlook the values of indigenous knowledge and practices when looking into sustainable climate change adaptation and natural resource management initiatives (Chavez and Tauli-Corpuz, 2009; Nakashima et al., 2012). With indication to the role of traditional knowledge and institutions in Ethiopia, it is worthwhile to consider the integration of traditional knowledge with that of scientific knowledge in order to attain sustainable adaptation agonist the impacts of climate change. The objective of this study was, therefore, to showcase the opportunities and challenges of traditional knowledge and institutions for community's sustainable natural resource management and climate change adaptation in Ethiopia.

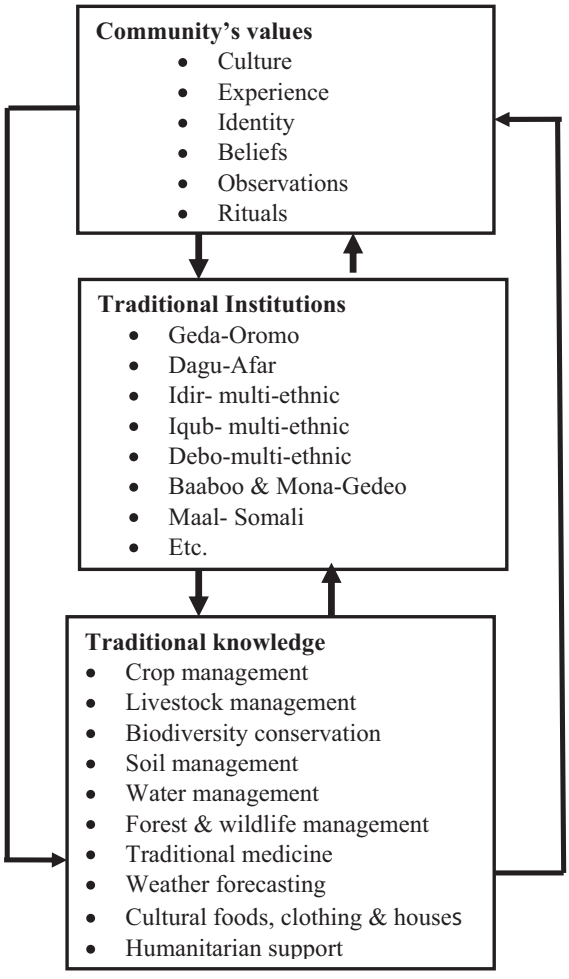

Fig. 1. The interaction between community's values, traditional knowledge and institutions in Ethiopia.

2. Methodology

Different knowledge products such as journal articles, policy documents, working papers, policy briefs, and other gray literature were reviewed. These have helped us to verify the state-of-the art for knowledge co-products for community's sustainable climate change adaptation as well as the existing and emerging opportunities and challenges in Ethiopia with respect to the use of indigenous and scientific knowledge co-products. In this context, it was emphasized on the characteristics of traditional knowledge, their role in climate change adaptation with specific focus on natural and cultural resources management including landscape, forest, crop and livestock management. It was also given due emphasis on the role of traditional knowledge in weather forecasting and how this information, combined with scientific information, will matters for decision making by pastoralists and agro-pastoralists. Furthermore, assessment was made on traditional institutions from where the traditional knowledge is steam from and how they play a role in climate change adaptation. And, what are the challenges of traditional knowledge and institutions to be applied in climate change adaptation interventions?

In support to the review assessments, two communities (Oromo community in central Ethiopia and Somali community in eastern Ethiopia) were assessed. Communities were selected based on experiences of maintaining and using traditional practices or economies, climate change vulnerable environment and livelihoods. Two hundred and fifty-one household heads, aged 29–75, were randomly selected: 92 for the Oromo community and 159 for the Somali community. Structured questionnaire was developed to conduct household interview. The questionnaire was framed on communities' understanding on climate change and what multi-dimensional indicators (meteorological, lunar cycles and constellations, plant phenology and animals) they accustomed to use for weather forecasting; what traditional strategies are availed to manage natural resources as well as crops and livestock, what traditional institutions and cultural systems are prevailed and the role they played during risks. The questionnaire was translated into native languages (Afan Oromo and Somali) to make more clarity and understanding in the given questions by the interviewees.

Fifteen focus group discussions, five for Oromo community and ten for Somali community, were conducted. Each focus group, with 8–10 members consisting of both men and women, was composed of elders, youth and local leaders who have direct experience in traditional practices including crop and livestock management, natural resource management and weather predictions. The elders have expressed their knowledge on what was happened in the past as compared to the current situation. The youth were included to give us their current observation on what is happening in their environment and how traditional knowledge is transferred from generation to generation.

Key informants were selected based on a snowball method at which one key informant was contacted based on the information given by kebele officials. The officials were advised to select a key informant who is relatively knowledgeable about the community situation, local natural resources, climate conditions, the culture of the community, overall development and the respective changes in these. Then, he/she would inform us the second, the second would tell the third and so forth until a saturation number was reached. In addition, field observations and authors' experiences in different parts of the country were used to extract more information on traditional weather forecasting and resource management strategies of the local communities and the local institutions involved in the traditional knowledge and practices.

3. Results and discussions

3.1. Traditional knowledge and climate change adaptation

Ethiopia is a diverse country both socio-culturally and ecologically. In this assessment, we have come up to pinpoint that there are different traditional knowledge and practices in which communities are experienced in their day-to-day activities. These include, but not limited to, weather forecasting, cultural natural resource management, agroforestry and agricultural management, use of different medicinal plants for veterinary and human medication in different parts of Ethiopia. Developed and transferred through traditional institutions and with potential for influencing policy directions, traditional knowledge and practices have played a fundamental role to build sustainable climate change adaptation and coping strategies which also help to strengthen modern adaptations.

3.1.1. Natural and cultural resource management

Traditional knowledge plays a role in awareness creation in the community to manage their day-to-day activities. They use in risk management during unseasonal rainfall to harvest crops by cooperation like debo; building ecosystem and economic resilience like in the case of the Gedeo agroforestry and Konso houses and terraces (Fig. 2). These management systems have sustained the ecosystem and livelihoods for millennia for the reason that they can, compared to monoculture, reduce soil erosion rates by half and hence increase productivity (e.g. Degefa, 2016; Muchane et al., 2020). These indigenous practices have enabled the communities to build resilience in their livelihoods and ecosystems against the impact of climate change (e.g. Songok et al., 2011).

Traditional houses made of stones by Tigrawai and bamboo houses by Dorze and Sidama communities are playing an important role in moderating the air condition in the home. Likewise, the steles of Axum, the castles of Gondar, the Rock-hewn Churches of Lalibela, Dire Sheck Hussien Mosque, and so forth are all emanated from local knowledge and are sources of tourist attraction in Ethiopia. These cultural resources are contributing to the economy of Ethiopia from tourist attraction and will build the resilience of the community around these resources. The foundations of traditional knowledge were emanated from observation, culture and experiences (Kirsten and Kathy, 2013). Indeed, strengthening the existing local knowledge and institutions with modern ideas will help to build the resilience of communities and ecosystems to maintain sustainability.

3.1.2. Land management

Many communities in Ethiopia have accustomed to own different landscape management practices. The Konso people, for example, have centuries of accumulated knowledge in managing the landscape sustainably. They accustomed to construct stone terraces and cultural dams combined with agroforestry in such a way that could prevent soil erosion and store rain water to maintain productivity (Mezgebe, 2011). These practices help to build landscape and livelihood sustainability of the community even in extreme cases of climate variability and environmental changes. That is the reason why the Konso community has managed to survive for centuries in marginal and harsh environments. For their marvelous work, they have won the UN prize award in 1995 for being one of the best among fifty communities in the world. Later on, these indigenous talents of Konso community with their role in sustaining landscapes, livelihoods and means of tourist attraction have been given recognition by UNESCO (2012) and registered as World Heritage Site in 2012. The synergies in the landscapes which integrate crop-livestock, multi-cropping and multi-story trees have helped the community in climate change adaptation. For instance, the multipurpose tree, *Moringa stenopetalla*, has been used as food and water purification by Konso people for long before it has been known to be a magic tree throughout Ethiopia for its food, soft drinks, tea indigents and water purification.

The Gedeo agroforestry system is another exemplary local knowledge to mention in sustainable landscape management in Ethiopia. Despite that the Gedeo landscapes are undulating and rugged which are vulnerable to soil erosion and land degradation, the communities have sustained the landscapes for their ecosystem functions and livelihood support for longer periods by averting those risks (Kanshie 2002). The Gedeo communities have adopted two systems of natural resource management-locally named *baabbo* and *mona* (Maru et al., 2019). The first is about retaining or planting native trees on farm for cultural, socio-economic and ecological reasons by which those trees have been given critical care for conservation by the community member. The second is a soil acidity amendment practice by which farmers collect animal manure and other organic inputs in order to improve soil fertility to sustain production and productivity. The old-aged traditional knowledge of agroforestry and soil management practices of the Gedeo communities have build the resilience of the landscapes irrespective of that the Gedeo zone is one of the most densely populated (~1000 persons km^{-2}) areas in Ethiopia SLUF, 2006). The combinations of efficient agronomic and soil management practices and nutrient supply, not only enabled to increase the productivity of crops but also to improve the status of the natural resource base.

Fig. 2. Konso cultural houses (left) and Konso village (right).

Globally, the role of traditional knowledge for climate change adaptation has given due emphasis (Gyampoh et al., 2009, Vinyeta and Lynn, 2013, Leonard et al., 2013, Royer, 2016, Granderson, 2017, Mafongoya and Ajayi, 2017, Makondoa and Thomas, 2018, Nalau et al., 2018, UNU (United Nations University), 2019, Hosen et al., 2020, Huynh et al., 2020, Petzold et al., 2020, Camacho-Villa et al., 2021, Mugambiwa and Makhubele, 2021, Nyadzi et al., 2021a, 2021b). Modern soil and water conservation (SWC) technologies, in one way or another, have been emanated from the improvement or modification of indigenous SWC practices of local communities (CGIAR, 2017). Traditional SWC practices, like those in Fig. 3, are prevalent in different parts of Ethiopia such as in eastern Ethiopia (Mekonnen, 2012), central Ethiopia (Demessie et al., 2000) and northern Ethiopia (Lemma and Haile, 2000). These practices have contributed to climate change resilience in Ethiopia (Kosmowski, 2018; Yohannes, 2018). People in flood prone areas in the low-lying areas of Dire Dawa city, Afar and Somali plains and South Omo lowlands of Ethiopia have accustomed to construct houses with raised plinths to prevent flood waters from entering into their houses or relocate their dwellings to higher grounds during the flooding as a means of coping with the flood (Kitila, 2009). These have helped the communities to build resilience against the impacts of flooding.

3.1.3. Forest management

In south and south west Ethiopia forests are managed by local knowledge systems to sustain livelihood in forest coffee, different spices, honey, bamboo, timber, civet cat, and so on. For instance, the Sheka Forest, which is registered by UNESCO as biosphere reserve in 2012, has been the efforts of long time conservation of the forest by the diverse communities inhabiting in and around the forests. The same is true for Yayu coffee forest biosphere reserve (designated in 2010) in Ilu Aba Bora Zone in Oromia regional State. Borena traditional rangeland management is also local community knowledge to mention that help the pastoralists to sustain the rangeland for centuries and thereby builds the resilience of the community's livelihoods in times of climate change and variability impacts. Traditional knowledge in some cases could also help to guide scientific experiments. For instance, in northern Ethiopia farmers had accustomed to tap *B. papyrifera* trees in two opposite directions- east and west directions only-so as to get better frankincense yield from a particular tree and better wound recovery of a tree (Cherenet et al., 2020).

Traditional knowledge systems are not only important in building resilience of ecosystems and communities but also in introducing new and appropriate technologies into the indigenous decision making systems (Azmeraw, 2006). This concern has been emphasized internationally in the UNFCCC as stated: "…the need for recognition of our traditional knowledge, which we have sustainably used and practiced for generations; and the need to integrate such knowledge in global, national and sub-national efforts. This knowledge is our vital contribution to climate change adaptation and mitigation." In North Shewa, Ethiopia, the local institution called *Gizit* related to the religious value of the church has played important role as effective means of preserving indigenous trees in and around Debrelibanos Monastery. That is, the one who breaks the rules and regulations concerning the monastery's forest management will be penalized by the monastery's administration (Sahilu, 2011). Although there is increasing challenges (*e. g.* Yadav and Mekonnen, 2013), this type of forest management (Fig. 4) is also common in other Orthodox Tewahido churches and Monasteries in Ethiopia where church forests are protected and remained intact even in places where the surrounding landscapes remained bare (Wassie, 2007; Aerts et al., 2016). This in turn helped to build carbon stocks in the church forests both in biomass and soils (Yilma and Derero, 2020). On the other hand, traditional institutions related to traditional beliefs including, but not limited to, rituals and sacred places have also played important role in forest conservation and conflict resolution (Mowo et al., 2013; Muchie and Bayeh, 2015; Mengesha, 2016).

3.1.4. Crop and livestock management

Farmers throughout Ethiopia cultivate diversified varieties of crops having different growing periods. They know which variety is better to address their local requirements (Mancini et al., 2017). In central Ethiopia, a single farmer can cultivate potato, maize, peas, barely, wheat, teff, check peas, millet and lentil by allocating small proportion of farmlands from what s/he already holds. In this case, potato help to secure food in the months of June to July, maize spike in August to September, short rotation peas and barely in October to November, and so on. By doing so, a farmer can close food gaps in each month of the year and builds family resilience in food security. Astonishingly, farmers in Gojam, North West Ethiopia, mix three varieties of small millet, locally called *dagusa*, and sow them together on the same plot of land. Type one needs small moisture and short maturing; the second type needs medium moisture and average maturing period; and the third type needs excusive moisture and long maturing period. Look this farmers' genius talent: in times of drought year or excessive rainfall year or mild rainfall year, farmers will not loss production at least from one type of millet variety in each extreme cases.

Intercropping is commonly adopted by farmers in different parts of Ethiopia. A study in Dawro Zone in southern Ethiopia (Waje, 2013), for instance, identified that farmers grow bean, pea, yam, cotton, and sometimes teff in maize or sorghum farms. This arrangement provides soil moisture and fertility maintenance, support to weak crop by strong crop and increase productivity per plot of land. In turn, it helps farmers in reducing risk in times of climate change and variability. That is, if one crop failed due to extreme weather, at least one other crop will give production thereby sustains farmers' livelihoods.

In Ethiopia, pastoralists and agro-pastoralists have accustomed to

Fig. 3. Traditional stone bunds on farms in West Haraghe- Mesela district, east Ethiopia.

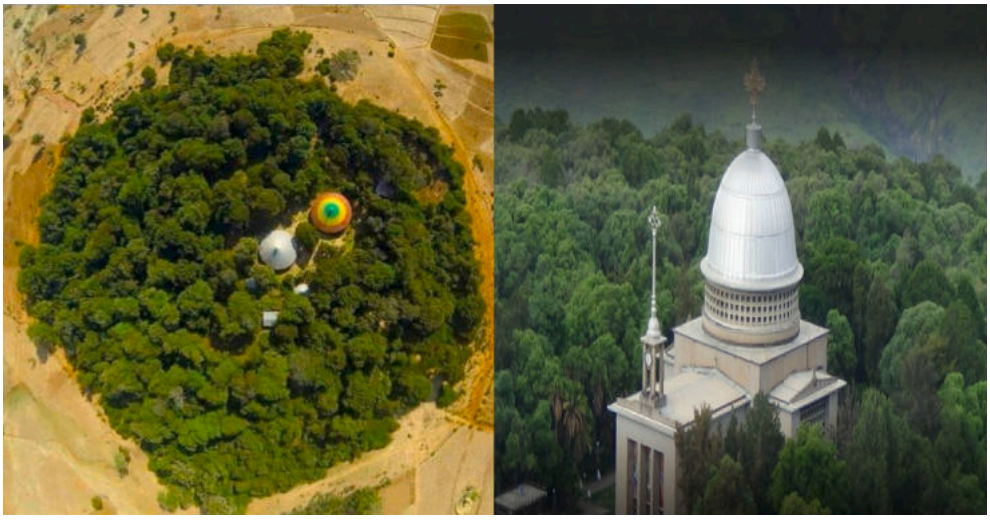

Fig. 4. Examples of Church forests in Ethiopia managed by traditional knowledge.

rear different indigenous breeds of livestock which are selected and preferred for their adaptive traits. The Begait, Borena, Fogera, Hammer, Raya and Harar cattle are among the most known indigenous breed types under indigenous livestock management (Gebru et al., 2017; Assefa and Hailu, 2018; Ayalew et al., 2018; Weldegerima, 2018). The Bonga sheep, Afar and Somali goats are also known indigenous breed types providing quality meat. Pastoralists and agro-pastoralists have their own indigenous methods and knowledge of breeding systems of these breeds. Most of the smallholder farmers are accustomed to use pure breeding management by natural mating of selected bull within their own herd and/or with the neighborhood's herd. These traditional indigenous animal genetic resources management systems have played a role in genetic conservation for centuries. They also use harvesting of feeds and stall feeding for fattening, preserve fodder for their livestock during time of feed shortage (Fig. 5). These traditional knowledge systems are importantly helped agro-pastoralists to cope and adapt the impacts of climate change and variability (Abate, 2016; Gebeyehu et al., 2021).

3.1.5. *Weather forecasting*

Several studies in different parts of Ethiopia had showed that most farmers have perceived the changes in temperature (+) and precipitation (−) by their cognition (Kitila, 2009; Regassa et al., 2010; Amdu et al., 2013; Admasu et al., 2014; Melka et al., 2015; Mekonnen et al., 2017). Communities use different indicators for local weather forecasting (e.g. Ayal et al., 2015; Ayal, 2017; Balehegn et al., 2019). The most commonly used indicators for local weather forecasting includes: (i) astrological-celestial body alignment, movements and sizes; (ii) meteorological-color of the sky, movement of wind, type of cloud, temperature and precipitation conditions; (iii) biotic indicators- plant phenology, animal behavior and body (intestine) conditions.

Studies (e.g. Ayal et al., 2015; Ayal, 2017; Iticha and Husen, 2018) showed that the weather information given to the community by *Urgii Elaltus (*celestial observer for weather forecasting) and *Uchuu (*livestock intestinal reader for weather forecasting) has helped the pastoralists to set actions including, but not limited to, proper rangeland management, prepare feed, move their animals to better place, decrease the number of their livestock and change the times of social celebrities. This in turn helped the herders to build their ecological and livelihood resilience against the impacts of climate change and variability.

3.1.5.1. Climate and weather information. Information matters to respond against the impacts of climate change by setting different adaptation strategies (Gukurume, 2014; Tilahun et al., 2019; Nyadzi et al., 2021a, 2021b). As indicated in Fig. 6, having climate information at hand will help to deal with future uncertainty, setting livelihood strategies, align governance options, resilience building and disaster preparedness options (Zillman, 2009). However, limited climate information and low capacity to use the information have hampered such development interventions in developing countries like Ethiopia (Radeny et al., 2019, Apollo and Mbah 2021, Mbah et al., 2021). In this regard, traditional climate knowledge, which the communities developed for millennia, has been found to be important to provide information to local people to make decision on their day-to-day activities (Nyong et al., 2007).

Studies (e.g. Moeletsi et al., 2013; Kolawole et al., 2014; Roudier

Fig. 5. Traditional practices of fodder preservation by agro-pastoralists in Ethiopia (by doing so like this, the fodder will be aerated, not rotted, not affected by termite and stays long).

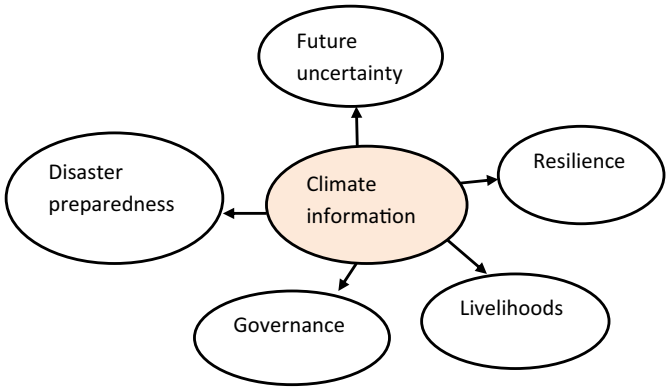

Fig. 6. Access and usage of climatic information matters for climate change adaptation.

et al., 2014) described that the ability of farmers and pastoralists to anticipate climate and environmental changes and make adjustment on their practices will enable them to build resilient livelihoods during climate change shocks. The use of a combination of traditional knowledge and meteorological information adds the advantage of resilience building and sustain their livelihoods (Roudier et al., 2014; Mapfumo et al., 2015; Gbangou et al., 2021).

3.2. Knowledge co-production for climate change adaptation

Armitage et al. (2011) defined knowledge co-production as "the collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems oriented understanding of the problem." In no doubt, climate change adaptation requires new technologies. However, this is not by ignoring the indigenous knowledge systems which played a great role in local specific climate change adaptation in countries like Ethiopia. This is also acknowledged at the global level (Raygorodetsky, 2011; Mafongoya and Ajayi, 2017). It is not difficult to imagine how the knowledge co-production from scientific and indigenous knowledge could play a double role in climate change adaptation. Studies showed that agricultural practices that have been resulted from the knowledge co-production were found to be more superior in building resilience to droughts and floods (Gyampoh et al., 2009, Alexander et al., 2011, Kasali, 2011, Gómez-Baggethun et al. 2013).

The role indigenous knowledge systems played and will continue to play to location specific sustainable climate change adaptation has been usually forgotten or ignored including in the basics of the first two IPCC reports (IPCC (Intergovernmental Panel on Climate Change), 2001). Integration of the knowledge systems could avoid maladaptation (Kasali, 2011; Admasie, 2014) or misconception (Mekonnen et al., 2017) from the use of new technology or information by farmers. The interweaving of the two knowledge systems could provide a better understanding and information on climate and weather forecasting (Irumva et al., 2021). This in turn enables sustainable adaptation against the impacts of climate change and variability (Fig. 7). However, in Ethiopia, the dearth of effective linkages between indigenous and scientific knowledge not only hinder sustainable agricultural development but also agricultural research and extension systems (Kebede, 2010).

Ellen and Haris (2000) described that scientific knowledge is considered as open, methodical, objective and highly dependent on an enthusiastic center of wisdom and intelligence, and takes the notion of modernity. In the same token, traditional knowledge is considered as closed, static, unintellectual, narrow-minded, primitive and emotional, and has given the perception of backwardness and savage. However, studies (e.g. Yemataw et al., 2016; Magni, 2017) have accredited the importance of indigenous knowledge systems for sustainable development. Agrawal (1995) had also described that indigenous knowledge

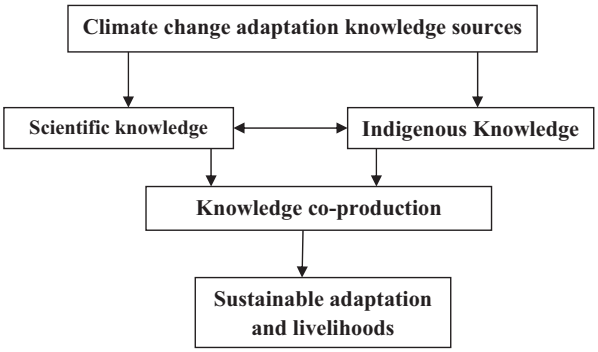

Fig. 7. Knowledge co-production for sustainable climate change adaptation.

has allowed the integration of people and nature for millennia by presenting a shift away from the concern with centralized, technically oriented solutions that have failed to change the life prospects of smallholder farmers.

Gearheard et al. (2010) have described that traditional knowledge owners use multiple environmental and social factors including, but not limited to, patterns of precipitation, speed and direction of winds, animal behavior, temperature variability, ritual deeds and star constellations to make decisions. Indeed, scientists will make decision based on the extrapolation from a narrow data set of a range of climate variables. Regardless of the differences in the use of parameters, the integration of the two knowledge systems is found to be crucial for better understanding and decision making on climate change adaptations (Patt and Gwata, 2002; Nakashima et al., 2012; Chanza, 2014; Mapfumo et al., 2015).

3.3. Traditional institutions and climate change adaptation

Traditional knowledge and institutions are interlinked to each other. Communities pass their traditional knowledge through traditional institutions to act on such knowledge to maintain their interests, rules and regulations and natural resources management. For instance, the Geda System is one of the traditional institutions in the Oromo community by which the knowledge of natural resource management will be enforced through the rules and regulations of this system (Edossa et al., 2007; OXFAM, 2013). Similarly, the *adda* traditional administration system in the Afar community uses weather forecasting system called *Edos* for climate related information and *Daguu* for other communication network to make decisions (Balehegn et al., 2019). Traditional institutions are less bureaucratic, more democratic and egalitarian and use local languages that have built their wide acceptance by their communities.

For sustainable development to happen, formal institutions will be important but not sufficient in themselves unless integrated with informal ones (Sikor et al., 2010). Traditional institutions not only played a role in natural resource management and conflict resolution but also make a basis for the development of modern institutions (Mengesha, 2016; Bekele et al., 2020). There are several traditional and cultural institutions in Ethiopia which have important role in climate change adaptation. However, these institutions have given little consideration and emphasis. Some of them forbids cutting of trees and used as conflict resolution during resource sharing such as water in the arid and semi-arid areas. Since most traditional institutions are linked to spirituality (e.g. Geda and Wagas systems in the Oromo and Gamo communities respectively), they help to manage natural resource conservation such as forests, soil, water and rangelands due to spiritual respects. Religious institutions such as the Ethiopian Orthodox Church has accustomed to conserve, maintain and plant trees inside the church compound and surrounding landscapes. This is an area to learn lessons on how to sustainably manage Ethiopian degraded landscapes.

When one is at risk of family member loss or livestock loss, there are financial supporting institutions. Moreover, communities could form working groups (e.g. *Debo* as in Mowo et al., 2013*)* to accomplish work during farm cultivation and sowing, crop harvesting, especially during unseasonal rainfall to save crops from damage, house construction when one want to construct new house or in case once own house might be burnt by accidental fire or damaged by flooding.

3.3.1. Financial institutions

Informal financial institutions have important role to build community's resilience during shocks and are the basis for developing microfinance institutions in Ethiopia (Bouman, 1977; Mequanent, 1996; Mackie et al., 2015). In most parts of Ethiopia, there are two commonly known traditional financial institutions. The first is *iddir* with the function of: (i) organize burial ceremonies when death happened on a family or close relatives of a member; (ii) pays some amount of money to the *iddir* member who lost family member by death; (iii) assist a member when accidentally become sick and ill-health or loss livestock or damage on house due to fire or flood or strong wind; and (iv) coordinate *iddir* member and non-members for local development works such as school maintenance, spring development and fencing, and so forth.

The second is *iqub,* a form of rotating fund, in which a certain number of people have been organized into *iqub* members. Each member agrees to contribute some amount of money based on the members' financial capacity. Then, the money collected at the start up of the *iqub* from all members will be given to the first member with first lottery draw. The second time, the collected money will be given for a member with second lottery draw and it will continues with similar procedure until the last member with last chance of lottery draw obtains the final collected money. After all members, get their chances, the round will continues similarly or discontinued with the agreement of the members.

3.3.2. Share stock-raising

Farmers are used to build their livelihood resilience by share stock-raising. A type of share stock-raising is '*ribi*' at which a livestock owner gives female livestock (sheep, cow and goat) to a livestock keeper, who has sufficient grazing lands and who can properly manage the livestock. Then, when the livestock give offspring and grown up, the offspring will be sold and the cash income is equally shared among the two. While the livestock keeper takes the milk and manure independently. The livestock that are given to the livestock keeper remain the assets of the livestock owner and s/he can take them to her/his own home after one or more offspring sharing with the livestock keeper but not before the first offspring sharing (Mowo et al., 2013). The other share stock-raising is *'agaji'* at which a livestock owner gives cattle (mostly oxen) during the rainy season, when there is no plough service by the oxen, to the livestock keeper, who has sufficient grazing lands, and pays an agreed amount of money for that. When the rainy season has passed, the livestock owner will turn back the ox or oxen to her/his home to use the oxen for threshing and plough power services during the dry seasons.

3.3.3. Sharecropping

In central Ethiopia, there are two most commonly used sharecropping types (Mowo et al., 2013). The first is a 50 to 50 share, locally named *Yekul* (meaning equal). This is a relationship between two farmers by which one has farm lands but not oxen and the other has oxen but limited farm lands. The farm holder contributes the land and the cultivator contributes labor and oxen for plough and threshing. Both contribute equal seed amount for sowing. Finally, they share the produce equally. The agreement is mutual but not binding and can stay 2–3 years. The farm land remained for the holder and s/he can take over when builds assets (oxen) and can cultivate by her/his own. The second type of sharecropping is a 25 to 75 share, locally named *Siso* (meaning a third). This is a relationship between two farmers by which one has farm lands but not oxen and the other has oxen but limited farm lands. In this case, the farm holder contributes only the land and the cultivator contributes seeds, labor and oxen for plough and threshing. The agreements and holding rights are similar to that in *yekul*. However, in *Siso,* the land holder takes 25% of the produce and the cultivator takes 75%. These relationships, particularly the *siso*, are declining nowadays due to the increasing value of land.

3.4. Case studies: Central and eastern Ethiopia

The case study in central Ethiopia showed that 85% of the respondents use indigenous rainfall prediction for decision making in their agricultural activities. Focus group discussants and key informants briefed that indigenous rainfall prediction had been used for long to adjust their cropping calendar with the shift of rainfall, chose which crop to cultivate, manage water and range resources, mange livestock and cultivate diversified crops (Table 1). In their traditional knowledge of rainfall prediction, local communities, especially those who have the expertise, have used indicators such as wind direction and speed, rainbow occurrence, moon and star position, water and sky colors, and cloud types which converge to the indicators used by formal science.

In Eastern Ethiopia case study, the pastoralists and agro-pastoralists have traditionally accustomed to practice water harvesting (93%), fodder reservation for harsh times (68%) and livelihood diversification (52%) for adaptation strategies against the impacts of climate change and variability. In addition, the communities have traditional institutions that enabled them to share resources during harsh times: *Irmaansi, maal, rai, keyd* and *dhowrto* are among the main traditional institutions in Somali communities by which people share livestock, labor, credit and milk products in difficult times such as extreme droughts.

The observed mean annual rainfall for the period 1987–2016 from NMA data in kebrebeya district has shown a decreasing trend with a change of 0.315 mm per annum. This was vaildated with the tradtional knowledge of the communities that only 26% of the respondents were agreed that the frequency of rainfall (average of long-rain and short-rain seasons) before 30 years (1987) was less than a day per week. Indeed,

Table 1
Traditional weather forecast indicators and adaptive responses by farmers.

Phenomenon/indicators	Indication	Adaptive responses
Red sky at sunrise	Rain is expected	Start to cultivate land
Temperature of the day become hotter	It is going to rain soon	Stay at home, move livestock to tree shades
'Harbu' tree started to flushing leaves	Coming of rainfall in a few days	Start to cultivate land
Color of lake become black	It will be good season	Plan to do more agricultural activities
Rain started on *woman's fortune* day	It will be good season	
Rain started on *horse's 'fortune* day	It will rain erratically	Plan to store grain to next season and use some available irrigations
Rain started on *elephant's fortune* day	Heavy rain is expected	Plan to prepare for flood diversion and control
Rain started on the *bull's fortune* day	Drought is expected	Prepare grass for livestock and store grain for next season, harvest water
Children unusually cry for food	The coming season will be bad	Pray God to liberation
Bulls capering in the field	Rain to come soon	Land preparation when it is during May or crop harvesting when it is during November
Hyenas screaming in low tone		
Roaming of red ants around home		
Bee migration to lowland	Better rainfall at lowland	Hang up beehives on trees and prepare farm land
Change in the direction of cloud movements from normal	Expectation of the absence of rainfall (i.e. drought)	Store fodder for livestock and grain for humans for the coming drought year

the percent of respondents that were agreed with this frequency of rainfall has increased to 69% for the year 2016. In addition, 89% of the respondents were agreed the incrase of temprature in 2016 as compared to the 1987 (the observed data shows 0.049 °C increase per annum for the max temperature) and 99% of them agreed for the decrease of the amount of rainfall. Focus group discussants and key informants highlighted that the communities in Kebrebeya and Ararso districts of Somali National Regional State have accustomed to classify their own seasonal calendar based on traditional knowledge thereby they plan and decide their herd and crop management practices accordingly (Tables 2 & 3).

3.5. Limitations of scientific and indigenous knowledge

Despite the limitation in the provision of climate information service in developing countries like Ethiopia, the acceptance and use of the service is hampered by lack of proper data, weak coordination, coarse projections and weak delivery to the users. When this has been combined with lack of awareness, data inaccessibility, limited capacity on the use of climate information for decision making, by the users, it exacerbates the poor uptake and utilization of the service provided (UNECA 2017). In addition, the climate services provided from the meteorological agencies are not location specific, unreliable and untimely, not easily understandable to non-professionals and do not showcase the opportunities and challenges specifically. As a result, they might not effectively address the vulnerability of the communities to the impacts of the changes in climate extremes. Due to these inefficiencies, people will inclined to use their own traditional knowledge of weather forecasting and prediction by using biological and physical indicators which they have mastered them for millennia (Makwara, 2013).

Although the pastoralists and agro-pastoralists are almost dependent on their knowledge of traditional rainfall prediction to make decisions, there are potential limitations on traditional knowledge of weather predictions. The constraints are criticism from religious people, lack of trust by young generation that inclined to modernization, the degradation of biotic indicators due to changes in climate and environmental degradation as well as absence of documentation. Desalegn et al. (2015) has noted that there is disagreement between religious followers and local weather forecasters by which the former believes only in God. The other challenges in local knowledge are lack of documentation, population dynamics, development of technology and civilization (Mapara, 2009) and the change in environment and climate that leads to change in the biological indicators used by local weather forecasters (Mafongoya and Ajayi, 2017) that create doubts on the reliability of traditional knowledge. The main challenges to traditional knowledge in Ethiopia include:

- *Climate variability*-unpredictability of the weather condition from time to time due to global climate change, biotic indicators have been disappearing and/or shifting their phenology from the usual time accustomed by forecasters.
- *Modernization and education*-unacceptability by the youth and marginalization of local traditional institutions from development plans and interventions (Tessera, 2006). There is more inclination toward scientific knowledge and information. There have been wrong perceptions of considering traditional knowledge as static, simple, incomplete, unscientific and unverifiable while the opposites are true for all these considerations (Magni, 2017). Because of these wrong perceptions, most researchers have failed to attempt a

Table 3
Local indicators of good or bad season by Somali communities, Eastern Ethiopia.

Livestock related indicators
- When livestock become skinny while good pasture, highly infested by pests (tick and lice) and disease outbreak, it is an indicator of an upcoming drought.
- When cattle refused to go back to home; refuse to obey to follow the directions of the herd man and run away in different directions; stertorouses when sleeping at night; drink more water and stay long at the water resource, it is a sign of bad season while doing the reverse, a good season is coming.
- When camels change their behavior and move here and there, do not browse and do not hear normally, it depicts a bad season to come. When camels give more milk than cows, the coming season will be bad.

Insect and reptile related indicators
- When black ants move forth and back forming one root from their hole, it indicates the coming of bad season while they make more than four routes from their holes, it indicates the coming of a good season.
- When termite problems (e.g. damage on crops) and their population increases, it indicates the coming season will be bad.
- When tortoise become prevalent in the area or snake population and biting increases, it indicates the coming season will be good and rainy.

Vegetation related indicators
- When invasive plants appear more abundant and occupy large areas; death and/or reduction in the number of some plants and others may grow with thorny and small levels, and fodder plants decreased, it indicates the coming season will be bad. The opposites of the above indicate good season.

Ecological and physical indicators
- When soil erosion by wind become prevalent with dust storms; poor pasture, drying of water points, soil compacted and crusted, the formation of sand sheets and dunes by frequent sand storm, symbolizes drought for the coming season.

Astronomical Indicators
- The rise of new moon whereby its crescent is directed to the north (left) indicates drought prevalence.
- When crescent moon tilts to right, it symbolizes the coming season is hoped to bring good rains.
- When the star locally called *Zikual* appears long in the sky for about 2 years or locally named *Zura* star observed for more than two months in the sky and seen from east direction, it indicates the coming season will be bad and drought will occur.
- When *Zura* star is observed in the sky for long time and rotates from west direction or locally named *Duay* star is observed in the sky in west direction, it indicates the coming of good season or rain.

Birds related Indicators
- When *Humoya* (black bird) songs between mid-night and dawn or *Esankuye* bird produces sharp sounds during the night, it indicates a sign of a good rain season
- When certain birds fly very high in the sky, it indicates drought, while when they fly low, it indicates the coming of the rains.

Table 2
Local seasonal calender and the narration of the seasons by Somali Communities.

Kebrebeya district	**Season**	**Dry *Jilaal***		***Gu (long rain season)***							**Dry *Jilaal***		
				***Diraa* rainy**		***Hagaa* dry**		***Karan* rainy**					
	Months	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	Rainfall												
Ararso district	**Season**	**Dry *Jilaal***			***Gu***			***Hagaa dry***			***Deyr (short rain)***		
	Rainfall												

Local season	**Local narrations /characterizations**
Dry *Jilaal*	High temperature, water shortage, drying of trees leaves, sand dune, decreased livestock production and livestock stay more in shading, clear sky and cracking of soils
Rainy *Gu* (*Diraa* and *Karan*)	High temperature at the beginning of the April, rainy, clouds cover the sky and very cold at nights and high winds
Dry *Hagaa*	Too windy that reduces pasture productivity, animal weight reduced, outbreak of diseases, and skin of livestock infected by pests
Deyr	High temperature, unpredictable clouds and rains, and the communities are uncertain on the coming or absence of rainfall

practical and insightful combination of these knowledge sources into their studies (Vadigi, 2016).

- *Religious*–consideration as evil spirit by religious leaders and expansion of Christianity in areas where traditional weather forecasting are more accustomed, for example in Borena Oromo community in southern Ethiopia.
- *Data record*-lack of documentation of traditional knowledge will lead to a gradual disappearance of the knowledge before it is passed to the next generation.
- *Cultural erosion and life style transformation*-domination and expansion of the western culture in Ethiopia has resulted the consideration of those traditional knowledge and practices as backward and contrary to modern science. The dynamic changes in the local indicators and ways of life have also a role in cultural transformation. For instance, the Nyangatom community in southwest Ethiopia has replaced their leather skirts to cotton. In addition, seasonal celebrities have been changed from normal due to changes in the timing of natural indicators and they have accepted the transformation and adjust their seasonal calendar and livelihood strategies accordingly to adapt the changes (McLean, 2012; Lumborg et al., 2021). The gradual shifts in ways of life away from nomadic herding toward settled agriculture in a recent time (as the focus group discussants in Eastern Ethiopia case study foretold), has shifted the traditional rangeland management practices to agricultural practices that are new to the community. This in turn leads to the conversion of rangelands to crop cultivation. Indeed, this has negatively affected resource management and leads to their depletion that allows unusual human mobility. In addition, regardless of providing useful highlights of prediction, indicators used to predict weather and/or climate by traditional knowledge are insufficient to provide detail hazard warnings.

4. Conclusion

In developing countries like Ethiopia, where modern technologies are still immature, traditional knowledge systems and institutions will help a lot in agricultural and natural resource management decision making. Local forecasts focus on the distribution of rainfall regardless of its quantity that is rather the basis for formal weather forecasting. They deal with weather conditions related to farmers' day-to-day activities which may not be touched by scientific forecasts.

Based on their experiences and narrations, local people have developed their own adaptation strategies against climate change and variability. However, this has been challenged by more rapid and complex global change. Although indigenous knowledge is important in climate prediction, agricultural and natural resource management, there still remain some challenges to consider. Challenges to traditional knowledge include rejection by the youth because of modernization; consideration as evil sprit in religious perspective; perceived incompatibility with western science; absence of documentation (oral transformation); considered as backward and hindrance to modernization; and confidentiality to tell the information by the owner. This recalls the need of disseminating scientific information to reduce the risk of climate change impacts on local people.

Scientific knowledge is also not free of significant gaps where local knowledge plays important role in aligning strategies of climate change adaptation by the local communities. Since local knowledge is accustomed by people in their day-to-day livelihood activities and their observation in their life time, they acknowledge focusing on it than the scientific information. Therefore, the integration of the two knowledge systems could strengthen the success of farmers and pastoralists in the decision of farm and natural resource management. This integration has an additive impact to foster sustainable development and build resilience in times of climate change.

Traditional knowledge and practices are interrelated with traditional institutions as formal science are interrelated to formal institutions such as universities, research centers, meteorological agency, etc. In this regard, knowledge co-production could help to build community support and trust so as to make sustainable climate change adaptation options. Indeed, good policy environment and appropriate institutional arrangements are inevitable for sustainable knowledge co-production for better climate change adaptation. In doing so: (i) policy makers and development planners should integrate traditional knowledge, practices, skills, institutions and social mechanisms as part of the sustainable development planning; (ii) choice on future adaptation strategies should acknowledge existing and age-old traditional knowledge systems of a given community as the lessons learnt from this assessment show that exclusion of these systems has facilitated social-ecological vulnerability of rural communities; (iii) understanding and integrating traditional knowledge systems into the formal planning systems has a multiplier effect on other government interventions such as through facilitation of technology adoption and/or absorption, building trust among differentiated societal groups and between people and government, enhancing rural-urban linkages, and minimizing transaction costs, among others.

Declaration of Competing Interest

The authors declare that as there is no conflict of interest.

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