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RESEARCH ARTICLE

Actor roles and networks in agricultural climate services in Ethiopia: a social network analysis

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ABSTRACT
This paper aims to better understand actors involved in the generation, translation, communication and governance of agricultural climate services and their networks in Ethiopia. To achieve these objectives, about 65 actor organizations were selected across seven regions and two city administrations in Ethiopia through a scoping study, extensive literature review, and snowball sampling. Structured questionnaires with closed and open-ended questions were designed to gather relevant information. Results were used to compute network size, density and centrality measures. Our findings show that climate services are regularly communicated to only 10% of the total districts (woredas) on average, with only a third of the actors involved in communicating these services. No single organization or institution plays a dominant role in production, translation, communication or governance of climate services, but a network of organizations and institutions are involved. Major challenges faced by the actors involved in production, translation and delivery of climate services included lack of human and financial resources and weak monitoring and evaluation systems. The paper highlights the importance of strengthening partnerships and networking among actors including monitoring and evaluation systems at all levels to facilitate effective production, translation and dissemination of climate services to farmers.

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Climate services; social network analysis; farmers; agriculture; Ethiopia

Introduction

The agricultural sector remains by far the most important sector in the Ethiopian economy contributing to 35% of the country's gross domestic product and employing 73% of the labour force (CIA, 2019). Because Ethiopia's smallholder agricultural production is predominantly rain-fed (MoA, 2015) with only 5% of the agricultural land being under irrigation (AGRA, 2014), climate variability and change has the potential to significantly reduce Ethiopia's agricultural production (Evangelista, Young, & Burnett, 2013). Effective climate services have the potential to empower institutions and individuals to take anticipatory actions to manage climate-related risks and strengthen resilience against weather extremes and climate variability to effectively mitigate the challenges posed by climate change (Cochrane & Singh, 2017).

For climate services to be interpreted and used in decision making, they need to be developed through strong partnerships between all relevant stakeholders including government ministries, research institutions information providers, implementers and extension service providers, private sector, and farmers (Wilkinson, Budimir, Ahmed, & Ouma, 2015; WMO, 2018). Effective climate services also require governance structures that can facilitate interactions between dispersed institutional and administrative mechanisms (Vaughan, Dessai, & Hewitt, 2018). In addition, strong partnerships and reliable financial resources are vital for the sustainability of these services (Troccoli, 2018). Given the intense competition for scarce public funds in most developing countries in Africa (Perrels, Th, Espejo, Jamin, & Thomalla, 2013; Rogers & Tsirkunov, 2013), decision makers need to be well informed about where to devote time and resources to improve the production and delivery of climate services for societal benefits (Vaughan & Dessai, 2014). Identification of the actors involved in climate services may facilitate targeting and coordination of investments, as investing in the different components of climate services alone or in combination is likely to have quite different costs and benefits. Climate Services Partnership (CSP) describes the various components of climate services as generation, translation, communication and use of climate information services to end users to inform decision making (CSP, 2019). Following this description, the present study provides a working definition of these components of climate services for ease of communication (Table 1).

This study also attempts to better understand the main responsibilities of the various components of agricultural climate services in Ethiopia. Specifically, the study aims to: (i) identify key actors involved in the generation, translation, communication, governance and use of agricultural climate services in Ethiopia across scales (at the national, regional, zonal, woreda[1] and kebele[2] levels); (ii) investigate resources employed to undertake these activities; (iii) describe the network and interaction among actors involved in climate services; and (iv) examine the strongest link through which climate and related

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Table 1. Climate service functions and their definition.

Function	Definition
Generation	The provision of meteorological observations; and derived historical, monitored and forecast information products.
Translation	Converting raw climate information into decision-relevant predictions of impacts, management advisories and decision support tools.
Communication	The delivery of climate information and advisories to end users.
Use	Incorporation of climate information into institutional and individual planning and management decisions.
Governance	Processes and institutional arrangements that support co-production, coordination, monitoring and evaluation, quality control and accountability.

information reaches the farmers. This study is the first attempt that the authors are aware of to categorize organizations in terms of their role in climate services for agriculture in Ethiopia. The study will inform governmental and non-governmental organizations, private sector, and international development partners about the role and significance of actors involved in the different components of agricultural climate services in Ethiopia.

We use the social network analysis (SNA) method to identify the networks of actors, their interactions, and the roles each actor plays in contributing to farmers' use of climate services. A social network involves a set of actors, and relations that hold these actors together (Emirbayer, 1997). SNA has the capacity to derive and measure networks such as the number of links each actor has and network level measures such as network density (Valente, Palinkas, Czaja, Chu, & Brown, 2015). Although there are some applications of SNA in relation to climate change adaptation (e.g. Bharwani et al., 2013; Harman et al., 2016; Jaja, Dawson, & Gaudet, 2017; Preller, Opwonya, & Van der Ploeg, 2010), its use to effectively identifying actors, map their specific roles, interactions and networking in climate services is not well documented in the literature.

Brief history of climate services in Ethiopia

The Ethiopian meteorological unit was first established in 1951 based on the growing demands for meteorological information for safe operation of air transport. It was started as a small meteorological entity within the then Civil Aviation Department of Ethiopia. As the importance of the unit was realized by other economic and social sectors, the National Meteorological Agency (NMA) was officially established in 1980 by proclamation number 201/1980. The main responsibilities of the agency are to: (i) establish and operate a national network of meteorological stations designed across the various climatic regions of Ethiopia; (ii) exchange meteorological data in accordance with international agreements to which Ethiopia is a party; (iii) publish and disseminate through mass media and upon request analyze and interpret meteorological data, meteorological forecasts, advance warnings of adverse weather conditions, advice and educational information; (iv) collect and centrally administer any meteorological data collected by any person in the country, and (v) control air pollution and maintain the natural balance of the air in the country (NMA, 2017).

According to NMA, there are about 1300 ground weather stations and more than 157 automatic weather stations installed throughout the country. The data collected and managed by the agency cover from one-meter depth into the earth to 30 km into the atmosphere. The agency's major information products include daily weather reports, 10-day weather summaries and 10-day forecasts, monthly weather summaries and forecasts, and seasonal forecasts for the two rainy seasons and the dry season, (locally known as *Bega*). The agency also provides maps showing rainfall received as a percentage of average, potential evapotranspiration, moisture indices, crop water satisfaction, crop water requirement indices and general crop conditions (NMA, 2017). NMA is the main weather and climate data provider in the country, and disseminates weather and climate information products through the government television and radio, workshops, and publications such as agro-meteorology, hydrometeorology and health bulletins.

In 2016, the Federal Agro-met Technical Task Force was established with core institutions such as the Ministry of Agriculture and Natural Resources (MoANR), NMA, Ethiopian Institute of Agricultural Research (EIAR) and Agriculture Transformation Agency (ATA). One of the activities of the task force is to translate NMA's national medium range (10 days and monthly) and long range (seasonal) weather forecasts into agrometeorological advisories. The regional, zonal and woreda level MoANR offices refine these advisories into more location-specific advisories, and communicates these contextualized advisories to the farmers through the MoANR agricultural extension agents, media such as local radio and informal farmer social networks (EPA, 2016; Feleke, 2015). As in many developing countries with centralized extension system, extension agents play a key role in disseminating forecast information across the country in a way that is tailored to farmers' needs (Weiss, Van Crowder, & Bernardi, 2000). Despite the major role the extension agents in Ethiopia play studies show low levels of use of agro-advisory services by farmers in Ethiopia attributed to lack of effective liaison by extension agents between the institutions providing the agro-advisory services and the farming community (e.g. Davis et al., 2010; World Bank, 2015). This is partly attributed to the limited knowledge and skill of extension agents to properly discharge their roles and responsibilities (Belay & Abebaw, 2004). In addition, involvement of extension workers in non-extension activities led to the undermining of their credibility and reputation whereby many people tend to view them as government agents rather than facilitators of agricultural development endeavours (Berhanu & Poulton, 2014). Furthermore, Cochrane (2017) argues that community perspective may influence the adoption of information and technology including climate services.

While NMA has provided weather and climate information for more than three decades (Hellmuth, Moorhead, Thomson, & Williams, 2007), the data and services provided suffer from many shortcomings that are common to many NMSs in Africa. The shortcomings include the number and distribution of stations, data quality, missing observations, and problems with data access and use (Dinku et al., 2014). The coverage is uneven because weather stations are concentrated in cities and towns along major roads and in highland areas of Ethiopia (Gebere, Alamirew, Merkel, & Melesse, 2015), but particularly sparse in the lowland pastoral and agro-pastoral regions. Moreover, in some cases the data is not available for use since it has not been digitized, or do not meet the necessary quality standards

(World Bank, 2015). The data constraint have been partially addressed through a collaborative effort between the NMA of Ethiopia and Columbia University's International Research Institute for Climate and Society (IRI). Availability of historical data has been improved by combining available quality-controlled historical station records with proxy data from satellite remote sensing and climate model reanalysis, to produce spatially and temporally complete data on a roughly 4 km grid – going back more than three decades for precipitation and five decades for temperature (Dinku, Asefa, Hailemariam, & Connor, 2011). Accessibility has also been improved by using a range of derived gridded historical, monitored and forecast information products through NMA's website.

Methodology

Social network analysis

SNA characterizes social relationships as networks of nodes, and the ties that describe their relationships and interactions (Jack, 2010). In this study nodes are the individual or institutional actors within the networks, whereas ties are the relationships (commonalities, social relations, interactions or flows) between the actors (Kosorukoff, 2011). There are two main approaches used to study social networks; these are called sociocentric and egocentric network approaches (Wasserman & Faust, 1994). While the former approach is used to study a whole social network of actors where the boundaries are specified clearly, the latter approach is used to collect data on links or ties between all members of socially or geographically-bounded groups, and has limited inference beyond that group (Borgatti & Halgin, 2011). In this paper, we use the snowball sampling together with egocentric approach, which focuses on the individual actor rather than on the network of actors. Egocentric inference has modest data requirements and is easily adapted to large scale survey research (Butts, 2008). In SNA, there are many metrices or measurements of networks (Valente et al., 2015). This paper focuses on network size, density and centrality measures to analyse the role and influence of actors in a network. Table 2 describes these terminologies and approaches in details.

One limitation of the SNA method is lack of privacy and related ethical issues (Hoppe & Reinelt, 2010). For example, it may be an unpleasant experience for a respondent to disclose the unattractiveness of one's network position so clearly. Therefore, it may be possible that some informants might hesitate to provide information in a truthful manner and hence, careful consideration needs to be given while interpreting the results.

Data and survey locations

The study targeted 65 governmental and non-governmental organizations, research institutes, institute of higher learning and Ethiopia's international development partners across seven regions and two city administrative states. The regions included Oromiya, Amhara, Gambella, Southern Nations and Nationalities Peoples (SNNP), Benishangul-Gumuz, Somali (Jijiga), and Tigray regional states, as well as Dire Dawa and Addis Ababa city administrations.

Table 2. Metrics in social network analysis.

No.	Metric	Description
1	Network size	Total number of all possible relationships which exist among ordered pairs of actors in the network.
2	Network density	The sum of links an actor has with other actors in the network divided by the number of possible links. It indicates whether all actors in a network are reachable by all others.
3	Centrality	It assigns an importance score based purely on the number of links held by actor in a network. It is a measure of the number of links existing in a network.
4	Degree centrality	It counts how many neighbours an actor has. If the network is directed, we have two versions of the measure: in-degree centrality and out-degree centrality.
4.1	In-degree centrality	Also known as access centrality, it is an actor who is a receiver of information.
4.2	Out-degree centrality	Also called activity centrality, it creates opportunities which may facilitate its access to a variety of information from other actors in a network. In short, out-degree centrality is the number of links which leads out of the actor and thus shows the actor who has the beneficial position.
5	Betweenness centrality	Also known as connectivity, bridge and information broker in a network. It measures which actor is more likely to be in communication paths.
6	Eigenvector centrality	A measure of the importance of an actor in a network. It also measures how well a given actor is linked to other well-linked actors in the network.

Sources: Freeman (1978), Bonacich (1987), Wasserman and Faust (1994), Kosorukoff (2011), Valente et al. (2015), Bojovic, Bonzanigo, Giupponi, and Maziotis (2017).

Data were collected on the relationships among actors through scoping study, extensive literature review and snowball sampling during the months of January and February 2018. The study consulted the available potential documents, conducted key informant interview and expert group meeting to identify the 3700 charities and civil society organizations that are found in Ethiopia. Among these organizations, 1600 are working on development and welfare related activities. About 95 organizations are working on environmental issues and related practices. Based on the study objectives, we selected 71 organizations that were directly involved in environmental and climate services related practices. Data was collected from 65 organizations that were willing to give information. A total of 138 interviews were held with officials from the respective actors involved in climate services. When we disaggregate this by region; a total of 95 interviews were conducted in Addis Ababa, 5 in Tigray, 7 in Amhara, 7 in Oromia, 3 in Somali, 5 in Benishangul-Gumuz, 5 in Dire Dawa, 5 in Gambella, and 6 in Southern Nations, Nationalities and Peoples Regional State. All the respondents were representatives that are well-versed with the relevant issues under investigation. As we did for the other regions, we conducted scoping review for the Afar region to identify available research literature in relation with climate information services, but no relevant literature was found that could be a potential source of information. To make sure that the region is included in the study, we sent the questioner through the e-mail address of relevant experts in universities and other relevant offices in the region. Unfortunately, we did not get reply. Finally, we decided to drop out the region. However, the Regional State was identified as destination source of relationships in the social network under consideration by other actors/organizations that were selected as source of ties regarding agricultural climate services. Accordingly, to facilitate our readers' understanding, we resort to append its name as an element of Appendix A – Afar Regional State.

The survey did not target media (such as TV, radio etc.) as a source of information although media play a role in the communication of climate information services. The main reason for excluding media was these organizations did not meet our selection criteria. One of the selection criteria used in this study was to involve only those organizations/institutions that allocate their own budget to carry out activities such as generation, translation and delivery of climate services. In Ethiopia, in most of the cases, media collect advertisement fee for communicating climate information services and hence, not targeted as the point of analysis.

In this study, very few numbers of female representatives of the target organizations were found assigned in managing the issues on agricultural climate services. As is the case in many developing countries, the likely causes of gender disparity in Ethiopia could be related to culture, economy, historical legacies, institutional design, political system and other unknown factors that may need further investigation (Dea, 2016). Given the male dominated nature of our survey, females' views and insights are underrepresented which might imply gender bias in the study.

Figure 1 shows the map of Ethiopia and study locations.

Face-to-face interviews were conducted, based on a structured questionnaire with closed- and open-ended mixed questions. The questionnaire was prepared in English language since all representatives of the actors/organizations who participated in the study were well-educated and experienced experts to meticulously self-administer and properly fill in the responses of all questions in the structured questionnaire. Given that the interview was an in-person meeting with respondents from all regional states, whenever necessary we discussed the questions further to clarify terminologies. However, when studies are conducted at a local level, it is advisable to use the local language to avoid communication barrier and accommodate all the relevant stakeholders.

The interview questions consisted of four main parts. The first part was about respondents' information including type of organization and economic sector they are involved in. The second part focused on climate services, climate change adaptation and mitigation including the human and financial resources allocated to carry out these activities. The third part was about types of climate services communicated, level of communication, responsible body to communicate these services, means, frequency and strength of communication and the way climate services/knowledge was stored/captured. Part four consisted of governance, monitoring, evaluation and bottlenecks in the process of communicating climate services. The major crops grown in these regions include wheat, maize, barley, sorghum, *tef (Eragrostis tef)*, chickpea, sesame, and coffee.

To compute network size and density, out- and in-degree centrality, betweenness and eigenvector centrality measures, we used the University of California at Irvine Network (UCINET) software (Borgatti, Everett, & Freeman, 2002). Mean and frequency scores were used to summarize the empirical observations.

Results and discussion

Characteristics and roles of respondent organizations

Respondents in the organizations sampled were dominated by male (95%) adults, with an average age of 41 years and university level of education. Almost all (94%) were employed full-time by their organizations and their positions included director, researcher, team leader, coordinator, program manager, advisor among others. Most of the respondents had worked with their organizations for an average of eight years, with significant variability on the duration of stay in the specific position they are assigned.

Out of the 65 organizations surveyed, 43 were governmental organizations from different parts of the country; 18 were not-for-profit non-governmental organizations (NGOs),[3] civil society organizations (CSOs) and faith-based organizations (FBOs). Although, there are a number of NGOs operating in the country, the 18 NGOs selected for the analysis were based on our objectives and selection criteria. This might imply that many of the NGOs that are not selected are involved in diversified development activities without focusing/specializing in any one of the climate change related activities. The remaining were international organizations working with the Ethiopian government mostly focusing on agriculture. Almost all the organizations interviewed are involved in agriculture and natural resources management. About 42 of the organizations were engaged in activities that are indirectly related to the generation, translation, communication and governance of climate services. This implies that most organizations are involved in these activities without being given a mandate by the government. About 13 of the organizations are directly engaged in climate services and focus mainly on climate projections, weather forecasting, geospatial analysis, agro-meteorological advisory, and early warning.

With regard to activities, less than one-third of the organizations generate climate information products that include: general climate information, daily and three days weather forecast, decadal and monthly medium range weather forecast, mid-season and seasonal long-range weather forecasts and early warning and risk reduction (Table 3). Many of the organizations reported being involved in the translation and communication of climate information generated by the above-mentioned organizations. About 63% of the organizations were engaged in aspects of climate service governance, monitoring and evaluation. Only a few organizations were engaged in research and knowledge generation related to climate services. Universities and research institutions were involved in more than one component of climate services.

Organizations also reported challenges related to human and financial resources that were in short supply. In particular inadequate financial resource was a major concern for most of the actors as it hampers investment on capacity building for staff, purchase of high capacity computers, software, and other infrastructure. Many organizations stated that high staff turnover – a proxy for institutional instability – is an obstacle to effective implementation of their climate services related activities. Organizational bottlenecks that considerably hindered effective communication of climate services are presented in Figure 2.

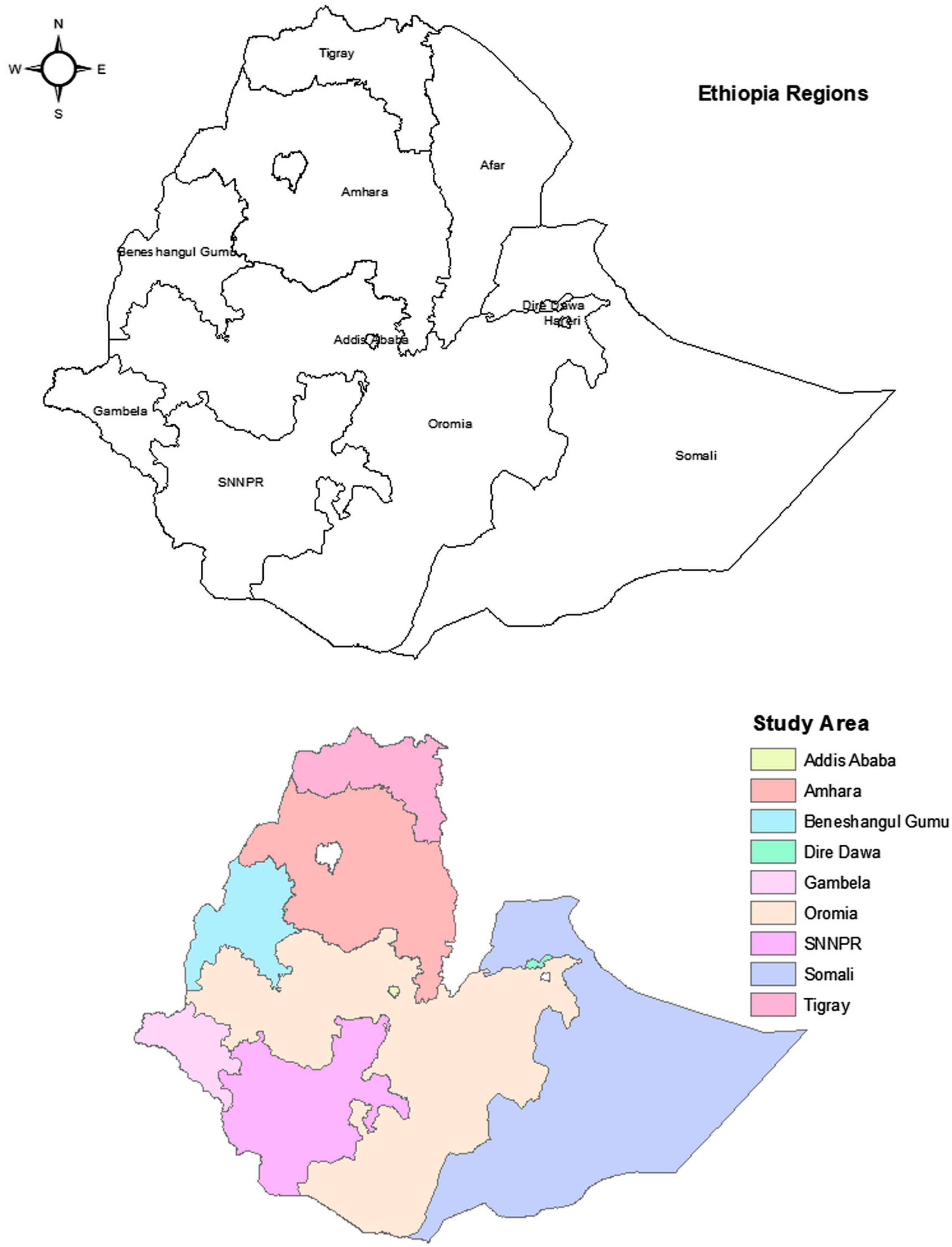

Figure 1. Map of Ethiopia and study locations.

Communication of climate services within and across organizations

We assessed communication within the organizations regarding climate services. Out of the 65 organizations, 60% had both vertical[4] and horizontal[5] types of communication within their organizations. Again, a similar percentage of the organizations reported having both vertical and horizontal types of communication with other organizations. The study furthermore investigated the frequency of communication among actors in the network regarding climate services. About two-thirds of them had connectivity on a quarterly basis. Organizations were asked if they knew about the likelihood or possibility of communication between other organizations that are their stakeholders. The results are mixed with more than half of the respondents stating that there could be possibility of relationships among them while the remaining respondents argued that there might not at all be communication between one another. Whenever there were gaps in terms of providing all the necessary climate services in the context of a particular

Table 3. Organizations involved in various components of climate services.

No.	Activity	Type of organization	%
1	Generation	Federal and regional meteorological offices, universities, NGOs	28
2	Translation	Universities, research institutes, federal and regional agricultural and meteorological offices, NGOs, FBOs, CSOs	57
3	Communication	Federal and regional agricultural offices, research institutes, NGOs, FBOs, CSOs	65
4	Governance (transparency, monitoring, evaluation)	Federal and regional agricultural offices, research institutes	63
5	Research, knowledge generation	Universities, research institutes	17

actor in the network, there may be a need for a practice of referrals to other potential actors. Referral is the official act of directing an actor to a different institutions, organizations or professionals often more knowledgeable about a particular subject matter (Apel, Yom-Tov, & Tennenholtz, 2018). In this study, the practice of referrals is particularly important since the actors in agricultural climate services were not involved in all of the functions of climate services. NMA, for example, is mandated to generate and translate climate services in different parts of the country. Accordingly, when organizations under the auspices of MoANR or MoWIE needed such information, the responsible people in these ministries may officially refer the requesting subordinate organizations to NMA offices in different parts of the country. The study thus attempted to assess the practice of referrals among these organizations and results indicate that 43% of the actors practiced referrals usually on a quarterly basis. The study furthermore examined perception of actors to other organizations' expertise related to climate services in the network. The result shows that majority of the actors perceived that other interacting organizations have expertise as good as the respective organizations while some of the responding actors viewed the other actors' expertise as either satisfactory or poor.

Types and usefulness of climate services

Weather and climate information shared frequently among organizations includes real-time weather information (daily rainfall, temperature, etc.), agro-meteorological advisories, decadal, monthly and seasonal forecasts, localized early warnings.

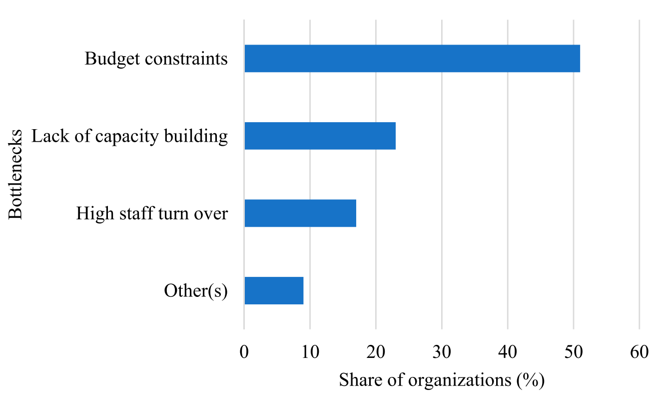

Figure 2. Organizational bottlenecks in the production and dissemination of climate services.

Regarding the usefulness of climate services, almost all actors (95%) reported that the climate services communicated were useful. When examining the way in which climate services were captured and stored among sample actors in the network, all reported that they used a combination of softcopy and printed copies as the main means of capturing and storing knowledge on climate services. Actors also revealed that means of transferring knowledge include stakeholders' meetings, agro-meteorological conferences, capacity building interventions, mass media communications, field demonstrations, and quarterly and annual reports.

On average climate services were regularly communicated to 76 woredas in the country, which is 10% of the total woredas (770) (Table 4). This huge variation in the communication of climate services was justified by respondents as remoteness of many woredas particularly in the Oromia and SNNP regional states which in turn has resulted in lack of access to technology, infrastructure and trained manpower to deliver the services. Respondents explained that, in some cases, climate services that reached the woreda level fail to reach the local level (kebele and village) because of a lack of prioritization of information communication by woreda experts. Weak linkages between research and extension in the country (Davis et al., 2010; Leta, Kelboro, Stellmacher, & Hornidge, 2017) could be another potential reason that may have resulted in lack of awareness of the benefits of climate services in boosting agricultural productivity which some studies confirmed using different methodologies (e.g. Amegnaglo, Anaman, Mensah-Bonsu, Onumah, & Gero, 2017; Ouédraogo et al., 2018; Roudier, Alhassane, Baron, Louvet, & Sultan, 2016). In addition, lack of knowledge, in communicating climate services in culturally-informed and user-friendly approaches might have also influenced the dissemination of these services. A third of the actors asserted that the communication of climate services reaches kebele and village level based on the regular monitoring and evaluation reports received by actors. The communication gap mentioned by respondents was also shared by a presentation by the Deputy General of NMA which pointed out that the agency lacks sufficient skilled personnel and technology to effectively communicate between the agency's head office and branch offices, and called for support from the international development partners for institutional strengthening and infrastructure modernization. Table 4 shows the different levels of communications of climate services in Ethiopia.

Governance of climate services

There are practices of governance of climate services within actor organizations. These practices encompass climate services

Table 4. Share of organizations and their level of communication of climate services.

No.	Level of communication	Share of organizations (%)
1	National	15.4
2	Regional	12.3
3	Zonal	7.7
4	Woreda/district	23.1
5	Farmers training centre (FTC)	6.1
6	Kebele	12.3
7	Village	23.1

governance structure, policy related to climate services, transparency, accountability and monitoring and evaluation systems. The various types of monitoring systems undertaken by the organizations include performance-based indicators, participatory monitoring system, monthly and quarterly monitoring activities and progress reports. This indicated that there were no common indicators to monitor progress. Similarly, in the evaluation system there was no dominant activity which can be considered as indicator. Only a few respondents revealed that they used result, indicator and performance-based evaluation system in addition to impact assessment, and review meeting and field visit.

Indicating the exact share of resource involved to undertake climate services governance practices may not be straightforward, but monitoring and evaluation reports may give rough estimate of the amount of resource committed for these practices.

SNA metrics

Network size and density

The maximum number of possible connections an organization has in this study was 64. The mean of the network was 6.2, which indicated the mean strength of ties across all possible ties (ignoring self-ties). As the data collected for this purpose was binary (i.e. 0 or 1), the computed mean score implied that 62% of all those possible ties which were expected to be linked among those actors under consideration were present (i.e. the density of the network). Though the network density was 62% which appeared to be the presence of relatively dense relationships among the actors, the pair of actors linked was found to be located far from each other in net-draw visualization and representation of them in the network.

This may suggest that all possible links among the actors were not embedded in the network, implying the network was not well-connected or it was incomplete. This can be interpreted as an indication for low level of interactions among the actors, and a slow speed of climate services communication. Most actors in this network and even those in prominent positions along the network were using long pathways to interact in the climate services knowledge sharing process. This result demonstrated that when climate services dissemination was handled by few actors in the network, both the flow of resources in the network and the network growth became limited.

Out-degree centrality (activity)

The Ethio Wetlands and Natural Resources Association (EWNRA) had the greatest out-degree centrality of 0.12, followed by the Ethiopian Policy Study and Research Centre (EPSRC), and NMA with equal out-degree value of 0.08, MoANR with the value of 0.07, and the Ethiopian Development Research Institute (EDRI) with a value of out-degree centrality 0.06. Here EWNRA might be regarded as the most influential actor in the network in terms of its ability to communicate climate services directly with other actors across the network. However, it might matter to whom this actor is sending the climate services in the existing network, which the measure of out-degree centrality does not consider.

In-degree centrality (access)

NMA (0.95), MoANR (0.94), ATA (0.79), and Bureau of Agriculture and Natural Resource of Amhara Region (AR-BoANR) (0.78) had relatively the maximum in-degree of points. In climate services network, it is to be noted that those actors who have received climate services from many sources are powerful, but they could also suffer from information overload. Information overload may refer to a situation where actors with relatively the highest in-degree centrality (also known as access centrality), would have access to those actors receiving information on climate services from the prestigious ones within the network. In so doing, the two prestigious actors in this particular network may have received a huge amount of information from those actors that are information receivers. Consequently, such two ways interaction might put those prestigious actors in this network at stake of information overload. NMA, MoANR, ATA and even AR-BoANR were the highest receivers of climate services because of their position in the network as key and influential actors.

Betweenness centrality (connectivity)

Betweenness centrality measure views the actor in the network as being in a favoured position to the extent that the actor falls on the shortest paths between other pairs of actors in the network (Cunningham, Jacobs, Measham, Harman, & Cvitanovic, 2017). In other words, the more the actors in the network depend on one actor to make connections or links with other actors, the more this particular actor has power. NMA had the highest betweenness centrality of 0.13. Accordingly, this agency could serve as the intermediary or connectivity to all other actors in the network under discussion. NMA has emerged as an actor playing a relevant role in communicating with other actors involved in the survey and setting up communication of climate services also with those that do not have reciprocal interactions. In the final analysis, EWNRA emerged as the determinant actor for activity related to climate services communication, while NMA has emerged as an actor for climate information access and connectivity with other actors in the network. Consequently, EWNRA and NMA may be referred to as the outstanding actors in terms of activity, access and connectivity of climate services in the network under discussion. Table 5 presents actors in-degree and out-degree measures and betweenness centrality scores.

Eigenvector centrality

The eigenvector approach is an effort to find the most central actors, that is, those actors with the smallest farness from others in the network. Higher eigenvector scores indicate that actors are more central to the main pattern of distances among all the actors, but lower values indicate that actors are more peripheral than others in the network. Our result indicated that out of those organizations that participated in this study, the EWNRA was found to have the strongest link with an eigenvalue of 0.60 which helped this actor to establish links with 29 other actors. This indicates that EWNRA was the most central actor with the smallest farness from others in the network. The second strongest link was established by the Development and Inter-Church Aid Commission (DICAC) of the Ethiopian Orthodox Church (EOC). The MoANR scored the third

Table 5. Actors in-degree and out-degree measures and betweenness centrality scores.

No.	Actor	In-degree centrality value	Actor	Out-degree centrality value	Actor	Betweenness centrality scores
1.	NMA	0.95	EWNRA	0.12	ATA	0.03
2.	MoANR	0.94	EPSRC	0.08	NMA	0.13
3.	ATA	0.79	NMA	0.08	MoANR	0.08
4.	AR BoANR	0.78	MoANR	0.07	MoWIE	0.06
5.	FAO	0.77	EDRI	0.06	MoEFCC	0.06

strongest link in the network of actors while Famine Early Warning Systems Network (FEWS NET) and Arba Minch University were the fourth and fifth strongest links respectively. The first eigenvalue was found to be considerably larger than the second eigenvalue with the ratio of 1.39:1. This means that the first dominant pattern is 1.39 times more important than the second, and so on. Generally, this score indicates that this actor is more central to the main pattern of distances among all the actors, while the lower values indicate that actors are more peripheral in the network. Table 6 shows all the five top strongest links and their eigenvalue among actors involved in the generation, translation, communication and governance of climate services in the country. Appendix A displays all the links the five strongest links have established with other organizations. Appendix B shows network visualization of actors involved in climate services in Ethiopia. It also illustrates how dense or sparse the links among these actors, their centrality degree, in-degree centrality, out-degree centrality, betweenness centrality and eigenvector centrality of the strongest links created among the sample actors. The square shape in the network visualization shows organizations that perform one or more of the generation, translation, communication and governance of climate services, while the circle shape depicts organizations that are involved in any one of these four activities.

Conclusion

This study attempted to better understand the actors involved in the generation, translation, communication and governance of climate services; investigate resources utilized to undertake these activities; assess the interactions among actors regarding sharing of climate services, and identify the strongest links through which climate services reach end users in Ethiopia. To achieve these objectives, 65 actor organizations were identified and selected through a scoping study, extensive literature reviews, and snowball sampling technique. Structured questionnaires, with closed and open-ended and mixed questions, were designed to gather information. The UCINET software was used to compute network size and density, out-degree centrality, in-degree centrality, betweenness centrality, and eigenvector centrality measures. Mean and frequency scores were used to summarize empirical observations.

Table 6. The five strongest links among actors.

No.	Rank	Actor	Eigenvalue	Number of actors in the strongest link
1	First	EWNRA	0.60	29
2	Second	EOC-DICAC	0.43	27
3	Third	MoANR	0.28	12
4	Fourth	FEWS-NET	0.21	10
5	Fifth	Arba Minch University	0.17	7

The main actors involved in these activities are governmental, non-governmental, civil society, faith-based organizations and international partners of the Ethiopian government who are mostly engaged in the agricultural sector. Few of the actors have duties and responsibilities directly related to climate services, while majority were involved in these activities without being given a mandate by the government. In addition, most of the staff has expertise indirectly relevant to climate services. Many more actors were involved in climate service translation and communication than generation and governance of these services. Climate services were communicated regularly to 76 woredas on average. Only a third of the actors were involved in communicating these services to end users. Almost all actors rated the climate services communicated to the end users (smallholder farmers) to be useful. However, this study noted that it would have been better to investigate the usefulness of the services from the perspective of the end users. The results also indicate a low level of interaction among actors, and a slow speed of climate services dissemination in the network of actors. Most actors in the network use long pathways to interact in the climate services knowledge sharing process. No single organization plays a significant role across the production, translation, communication and governance functions of climate services. A network of organizations and institutions were involved in the process. The strongest link identified in the network began at the EWNRA, and it was composed of 29 other actors through which climate services reach end-users. For most of the actors involved in climate services, both human and financial resources were scarce, particularly inadequacy of financial resource was major concern since it hampered investment on staff capacity building, purchase of high capacity computers and other infrastructure. High staff turnover, which was used as a proxy for lack of institutional stability was stated by many organizations as problematic to properly undertake their climate services related activities. Furthermore, weak and non-uniform monitoring and evaluation system was the existing trend among actors which made the follow-up system difficult.

The study highlights the importance of strengthening partnership and networking among actors through policy, monitoring and evaluation system at all levels to facilitate smooth and effective delivery of climate services to farmers. Allocating sufficient budget to build the capacity of those actors who play key role in networking and communicating climate services to end users, which this study identified as ‘the strongest links’, would empower them to maintain effective and sustainable communication of these services. In addition to capacity building, institutional strengthening and infrastructure modernization would contribute to successful production and delivery of the services. Strengthening the link between research and extension would inform officials to realize the benefits of climate services to agricultural productivity and encourage them to promote and facilitate the dissemination of climate services to more woredas.

Most of all, integrating climate services as main duties and responsibilities of organizations can help prioritize budget allocation and engagement of experts with relevant background.

This study suggests further research using mixed research methods of social network analyses to explore at a broader scale the role each actor plays in these activities at various agro-ecological zones. Finally, the main challenge encountered while conducting this research was reluctance of organizations to provide information. Due to the unwillingness of some organizations to disclose their activities related to climate services, the list of organizations used for the analysis was not exhaustive. Some of those who provided information took a considerable amount of time to complete and return the questionnaires.

Notes

1. Woreda refers an administrative unit equivalent to district.
2. Kebele refers to the smallest administrative unit in Ethiopia.
3. The breakdown for the participants from not-for-profit non-governmental organizations was 12 NGOs, 2 CSOs and 4 FBOs.
4. Communication between different levels of organizational hierarchy e.g. between superior and subordinates.
5. Communication between professionals, divisions, departments, or functional units within the same level of organizational hierarchy and/or in the same government administrative units.

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Appendices

Appendix A: The links the five strongest links have established with other organizations

Rank	Actor name	Eigenvalue
First	Ethio – Wetlands Natural Resources Association (EWNRA)	.60
	Afar National Regional State Bureau of Agriculture and Natural Resource (Afar – BoANR)	.13
	Afar National Regional State Bureau of Water, Irrigation and Energy (Afar – BoWIE)	.08
	Addis Ababa City Government Bureau of Agriculture and Natural Resource (Addis Ababa – BoANR)	.12
	Addis Ababa City Government Bureau of Water, Irrigation and Energy (Addis Ababa – BoWIE)	.08
	Amhara National Regional State Bureau of Agriculture and Natural Resource (AR – BoANR)	.21
	Amhara National Regional State Bureau of Water, Irrigation and Energy (AR – BoWIE)	.15
	Benishangul-Gumuz National Regional State Bureau of Agriculture and Natural Resource (BSG – BoANR)	.17
	Benishangul-Gumuz National Regional State Bureau of Water, Irrigation and Energy (BSG – BoWIE)	.14
	Dire Dawa City Administration Bureau of Agriculture and Natural Resource (DD – BoANR)	.15
	Dire Dawa City Administration Bureau of Water, Irrigation and Energy (DD – BoWIE)	.14
	Ethiopia Somali National Regional State Bureau of Agriculture and Natural Resource (ES – BoANR)	.11
	Addis Ababa University, Horn of Africa Regional Environment Centre and Network (AAU – HoA – REC & N)	.08
	Ethiopia Somali National Regional State Bureau of Water, Irrigation and Energy (ES – BoWIE)	.08
	Ethiopian Universities (ETH-Units)	.01
	Forum for Environment (FfE)	.00
	Gambella National Regional State Bureau of Agriculture and Natural Resource (G – BoANR)	.19
	Gambella National Regional State Bureau of Water, Irrigation and Energy (G – BoWIE)	.14
	Harari National Regional Bureau of Agriculture and Natural Resource (H – BoANR)	.11
	Harari National Regional Bureau of Water, Irrigation and Energy (H – BoWIE)	.08
	Ministry of Agriculture and Livestock Resources (MoANR)	.39
	Ministry of Water, Irrigation and Electricity (MoWIE)	.20
	National Meteorological Agency (NMA)	.33
	Oromia National Regional State Bureau of Agriculture and Natural Resource (O – BoAN)	.18
	Oromia National Regional State Bureau of Water, Irrigation and Energy (O – BoWIE)	.14
	Southern Nations, Nationalities and Peoples' National Regional State Bureau of Agriculture and Natural Resosurce (SNNP – BoANR)	.22
	Southern Nations, Nationalities and Peoples' National Regional State Bureau of Water, Irrigation and Energy (SNNP – BoWIE)	.16
	Tigray National Regional State Bureau of Agriculture and Natural Resource (T – BoANR)	.19
	Tigray National Regional State Bureau of Water, Irrigation and Energy (T – BoWIE)	.14
	Water, Sanitation and Hygiene Programme in Ethiopia (WASH – Ethiopia)	.08
Second	Ethiopian Orthodox Church – Development and Inter-Church Aid Commission (EOC – DICAC)	.43
	Amhara National Regional State Bureau of Agriculture and Natural Resource (AR – BoANR)	.17
	Amhara National Regional State Bureau of Water, Irrigation and Energy (AR – BoWIE)	.15
	Amhara National Regional State Disaster, Risk Mitigation, Food Security and Coordination Commission (AR – DRMFSCC)	.05
	Benishangul-Gumuz National Regional State Disaster, Risk Mitigation, Food Security and Coordination Agency (BSG – DRMFSCA)	.05
	Benishangul-Gumuz National Regional State Bureau of Agriculture and Natural Resource (BSG – BoANR)	.17
	Benishangul-Gumuz National Regional State Bureau of Water, Irrigation and Energy (BSG – BoWIE)	.14
	Dire Dawa City Administration Bureau of Agriculture and Natural Resource (DD – BoANR)	.15
	Dire Dawa City Administration Bureau of Environment, Forest and Climate Change (DD – BoEFCC)	.06
	Dire Dawa City Administration Bureau of Water, Irrigation and Energy (DD – BoWIE)	.14
	Dire Dawa City Administration Disaster, Risk Mitigation Office (DD – DRMO)	.05
	Ethiopian Climate-Smart Network – Climate Change (ECSN – CC)	.05
	Ethiopian Environmental and Forest Research Institute (EEFRI)	.08
	Gambella National Regional State Bureau of Agriculture and Natural Resource (G – BoANR)	.19
	Gambella National Regional State Meteorological Office (G – MO)	.05
	Gambella National Regional Bureau of Agriculture and Natural Resource – Climate Resilient Green Economy Directorate (G – BoAECRGD)	.05
	Gambella National Regional State Bureau of Water, Irrigation and Energy (G – BoWIE)	.14
	Oromia National Regional State Bureau of Agriculture and Natural Resource (O – BoANR)	.18
	Oromia National Regional State Bureau of Water, Irrigation and Energy (O – BoWIE)	.14
	Oromia National Regional State Disaster, Risk Mitigation, and Food Security Coordination Directorate (O – DRMFSCD)	.07
	Regional Biogas Projects (REG – Biogas Projects)	.05
	Southern Nations, Nationalities and Peoples' National Regional State Bureau of Agriculture and Natural Resource (SNNP – BoANR)	.22
	Southern Nations, Nationalities and Peoples' National Regional State Bureau of Water, Irrigation and Energy (SNNP – BoWIE)	.16
	Southern Nations, Nationalities and Peoples' National Regional State Disaster, Risk Mitigation and Food Security Coordination Office (SNNP – DRMFSCO)	.08
	Southern Nations, Nationalities and Peoples' National Regional State – Crop Production and Protection Directorate (SNNP – BoANR – CPPD)	.05
	Tigray National Regional State Bureau of Agriculture and Natural Resource (T – BoANR)	.19
	Tigray National Regional State Bureau of Water, Irrigation and Energy (T – BoWIE)	.14

(*Continued*)

Continued.

Rank	Actor name	Eigenvalue
	Tigray National Regional State Early Warning Directorate (T – EWD)	.06
Third	Ministry of agriculture and Natural Resource (MoANR)	.28
	Afar National Regional State Bureau of Agriculture and Natural Resource (Afar – BoANR)	.13
	Addis Ababa City Government Bureau of Agriculture and Natural Resource (AA – BoANR)	.12
	Amhara National Regional State Bureau of Agriculture and Natural Resource (AR – BoANR)	.21
	Agricultural Transformation Agency (ATA)	.09
	Benishangul-Gumuz National Regional State Bureau of Agriculture and Natural Resource (BSG – BoANR)	.00
	Ethiopia Somali National Regional State Bureau of Agriculture and Natural Resource (ES – BoANR)	.11
	Gambella National Regional State Bureau of Agriculture and Natural Resource (G – BoANR)	.02
	Harari National Regional Bureau of Agriculture and Natural Resource (H – BoANR)	.11
	National Meteorological Agency (NMA)	.03
	Oromia National Regional State Bureau of Agriculture and Natural Resource (O – BoANR)	.05
	Southern Nations, Nationalities and Peoples' National Regional State Bureau of Agriculture and Natural Resource (SNNP – BoANR)	.08
	Tigray National Regional State Bureau of Agriculture and Natural Resource (T – BoANR)	.19
Fourth	Food Security and Early Warning Network (FEWS-NET)	.21
	(Local) community members in Ethiopia	.13
	Donors	.12
	Federal National Disaster and Risk Mitigation Commission (FNDRM – Commission)	.12
	(Local)woreda administration offices in Ethiopia	.12
	Ministry of Agriculture and Livestock Resources (MoANR)	.28
	Ministry of Health (MoH)	.02
	Ministry of Water, Irrigation and Electricity (MoWIE)	.20
	National Meteorological Agency (NMA)	.17
	National Oceanic and Atmospheric Administration of United States (NoAA)	.02
	United States Geological Survey (USGS)	.02
Fifth	Arba Minch University (Arbaminch – Uni)	.17
	(Local) community members in Arba Minch Administrative Zone of SNNP National Regional State	.13
	Donors	.12
	Federal National Disaster and Risk Mitigation Commission (FNDRM – Commission)	.12
	Ethiopian Research and Development Centres (ETH – RDCs)	.06
	(Local) woreda admin offices in SNNP National Regional State	.12
	Ministry of Agriculture and Livestock Resources (MoANR)	.28
	National Meteorological Agency (NMA)	.17

Appendix B: Network visualization of actors involved in climate services in Ethiopia