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The Effect of Inter-Organisational Collaboration Networks on Climate Knowledge Flows and Communication to Pastoralists in Kenya

Chidiebere Ofoegbu [1,*], Mark George New [1,2] and Kibet Staline [3]

1 African Climate and Development Initiative, University of Cape Town, Rondebosch 7700, South Africa; mark.new@uct.ac.za

2 School of International Development, University of East Anglia, Norwich NR4 7TJ, UK

3 Department of Land Resource Management & Agricultural Technology, University of Nairobi Kenya, Nairobi 00100, Kenya; kibets3k@gmail.com

* Correspondence: ofoegbu.c@gmail.com; Tel.: +27-714-509-439

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Abstract: In Kenya, pastoralists have utilized natural grasslands using practices that often result in overgrazing, low productivity and low income. Such practices have caused environmental problems, which could be exacerbated by climate change. Although knowledge on practices that increase pastoralists' capacity to adapt to climate and environmental challenges is currently available, the adoption rate remains poor. Hence, there is growing interest in understanding how cross-scale inter-organizational collaboration process either facilitates or hinders climate knowledge communications to and uptake by pastoralists. This study used network analysis to identify how inter-organizational collaborations in knowledge production and dissemination shape knowledge flow and communication to pastoralists in Kenya. A knowledge mapping workshop, key informant interviews and questionnaire surveys were used to identify the key organizations involved in the generation, brokering, and dissemination of adaptation knowledge to pastoralists. Two networks of configurations were explored: (i) relations of collaboration in knowledge production and (ii) relations of collaboration in knowledge dissemination. Measure of clustering coefficient, density, core-periphery location, and degree centrality were used to analyze the network structure and cohesion, and its influence on knowledge flow and adoption. Findings revealed a strong integration across the network with research institutes, NGOs (Non-governmental organizations), and CBOs (Community based organizations) identified as among the central actors, based on their degree centrality. Further, we observed a higher density of ties among actors in the knowledge production network than the dissemination network. The lower density of the dissemination network indicates there are not that many activities by key organizations aimed at ensuring that knowledge reaches the users, compared to activities related to knowledge generation. This also results in poor feedback processes from local pastoralists to knowledge generators and brokers. Knowledge transfer and uptake could therefore be enhanced by improving dissemination activities and feedback mechanisms in the dissemination network as a means of capturing pastoralist perspectives on the relevance, reliability, and usability of knowledge for action. Reflection and revision can be used to improve knowledge so that it is more in sync with a pastoralist context.

Keywords: climate change; adaptation; livelihood; pastoralism

1. Introduction

Pastoralism is central to the livelihoods and well-being of millions of rural people, particularly those in the dry arid to semi-arid regions of the world [1]. Pastoralists are faced with many challenges

to their livelihoods and way of life, including climate change, population growth, weak governance, and rangeland loss due to competing activities [2]. At the same time, pastoralists are confronted with the challenge of sustaining the pastoral system, without compromising the environment [3–5]. However, available evidence suggests that pastoralists are employing practices that often result in overgrazing and low productivity, negatively affecting livelihoods and income [4,6–8]. In addition, pastoralism in developing countries is threatened by abandonment of less productive areas and land-use intensification of fertile areas. Despite these non-climatic challenges, climate change has become a dominant topic in the discourse concerning the sustainability of pastoralist systems [9].

Pastoralism can be impacted by climate change through its effects on livestock and livestock systems, primarily via changes in water, heat stress, and feed availability, but also biodiversity and animal health, and conflicts because of competition over dwindling pastures [10–12]. The United Nations Convention on Biological Diversity reported that certain livestock diseases such as trypanosomiasis, could increase in scope and scale due to climate change [13]. These impacts of climate on pastoral livelihoods may amplify other challenges affecting pastoral livelihoods, including competition and violent conflicts among communities due to shrinking grassland, population growth, loss of herding lands to private farms, parks urbanization, and privatization of ownership (tenure) of formerly communal lands [2,14].

Approximately 80 percent of Kenya is arid and semi-arid, with pastoralism and agro-pastoralism being the dominant rural livelihood [10,15–18]. As reported by Silvestri et al. [12], pastoralism contributes over 12% to overall GDP and 47% to agricultural GDP in Kenya. To cope with climate variability and change, pastoralists implement various strategies, including increased livestock sales and movement/migration to distant pastures during drier periods [17]. While these age-old strategies have been used successfully to cope with the shocks imposed by climate variability [14,17,19], climate change is now bringing new challenges that may make these tactics inadequate [20]. A robust and sustainable adaptation response portfolio to effectively and efficiently adapt the pastoral system to climate change will have to encompass multiple dimensions of the pastoral system [21]. This implies that climate risk warning and risk response advisory services informed by weather and climate forecasts will have to be tailored to all stages of decision making in the pastoral sector. These range from operational livestock herding options (that play out on daily to 6-month timescales), to tactical risk management (mostly associated with decisions on livelihood diversification, feedstock sourcing, and livestock sale, playing out at the 6-month to 3-year timescale), and strategic planning and policy decisions that play out at longer timescales, out to several decades in the future [22,23].

In practice, the process of adoption of adaptation knowledge (The phrase adaptation knowledge as used here refers to the assimilation of information on climate risk warning and risk response strategy in policy and actions to address climate change in the pastoral sector.) begins with the sharing of information among the potential users through their social and other networks [3,24]. The relationships between the organizations that are involved in the generation and dissemination of weather and climate forecasts, and their associated warnings and advisory services with respect to pastoralism, are two-way processes shaped and influenced by a multiplicity of factors linked to the collaborations between them in the generation and dissemination of climate information [25]. Thus, enhancing information flow through an inter-organizational network to pastoralists is essential for enhancing pastoralist adaptive capacity to climate change [26]. Inter-organizational networks across scales from national to local provide the avenue through which pastoralists harness knowledge and information on climate risk warning and advisory services [27]. Hence, studies on the exchange and flow of climate risk warning and risk response advisory services need to be focused at understanding the structure and properties of the collaboration network existing between the organizations that are involved in the generation and communication of climate information to pastoralists [28].

Although knowledge on adaptation options to improve the resilience of pastoralist livelihood practices to climate change impacts is available [3,29,30], the adoption rate among pastoralists in Kenya is still low [5]. Additionally, attempts to inform pastoralists, particularly in rural areas on best

available adaptation practices have not yielded satisfactory results [5,15,31]. While there are multiple factors that can influence the adoption of adaptation strategies by pastoralists [12], studies so far have largely focused on pastoralist decision-making processes [20,32]. These studies use pastoralist socioeconomic characteristics to analyze their capacity to harness and adopt adaptation knowledge, and showed wealth and/or financial status play a key role in their capability to adopt climate knowledge both in terms of having access to (radio, TV, mobile phone, etc.) to information, and having the capacity (in terms of financial power) to adopt climate smart strategies [11,33]. These studies have largely neglected the influence of the networks within which pastoralists are located on their access to knowledge.

In this study, we explore how the collaboration between organizations involved in the generation and dissemination of weather and climate information, and their associated climate risk warning and risk response advisory services with respect to pastoralism, influences knowledge flow and communication to pastoralists in Kenya. We explored two network configurations: (i) relations of collaboration in knowledge production and (ii) relations of collaboration in knowledge dissemination. The following research questions were explored:

1. How do existing structural relationships in inter-organizational collaborations either hinder or enhance knowledge flow across scales from national to local?
2. Do inter-organizational collaboration networks promote knowledge exchange with pastoralists? If so, how does knowledge exchange through inter-organizational networks either hinder or enhance pastoralists understanding of climate risks and adaptation?

The rest of the paper is divided into four further sections. Following this first introductory section, the second section discusses the methodological design of the study. The results section presents the findings of the study while the following section discusses the implications of the findings in terms of policy and action for adaptation of pastoral system to climate change impacts. The concluding section summarizes the key message from the study.

2. Methods

2.1. Study Area and Target Population

The study target groups are pastoralists and organizations that are involved in the generation, brokering, and usage of knowledge on climate risk warning and advisory services with respect to pastoralism in Kenya. To select the organizations with a stake in pastoralism and climate knowledge, we targeted organizations operating at supra-national, national, county and local levels. To select the pastoralist communities for the study we targeted Maasai communities living in Narok County and Laikipia County of Kenya (Figure 1). These two counties were purposefully selected because of their locations in the semi-arid regions of Kenya, where pastoralism is the dominant rural livelihood. The Masai in these counties are, thus, ideal for investigating how the relations of collaboration in knowledge generation and dissemination among the actors in the climate change and pastoral sector either enhance or hinder pastoralist awareness of, and adoption of knowledge on climate risk warning and advisory services.

Laikipia County lies across the Equator between latitude (0°17′ S) and (0°45′ N) and longitude 36°15′ E and 37°20′ E (Figure 1). The county occupies an area of 9500 km^2 forming part of the wider 56,000 Km^2 Ewaso ecosystem stretching from the slopes of Mt. Kenya in the South East to the edge of the Great Rift Valley in the West. The rainfall varies between 750 and 300 mm per year from south to the arid north respectively [34]. The mean annual temperature in Laikipia is estimated at between 16 °C and 26 °C. The variety of land holdings in Laikipia is influenced by the complex history of human settlement and the rainfall gradient. Prior to the arrival of the European settlers in early 1900, nomadic pastoralism was the main economic activity in the county and land was communally owned [33]. At present, the wetter southern parts of the Laikipia are largely occupied by small-scale

farmers, intermediate areas are used by commercial cattle ranchers, while the drier north (the focus of this study) is occupied by Maasai pastoralists [35,36].

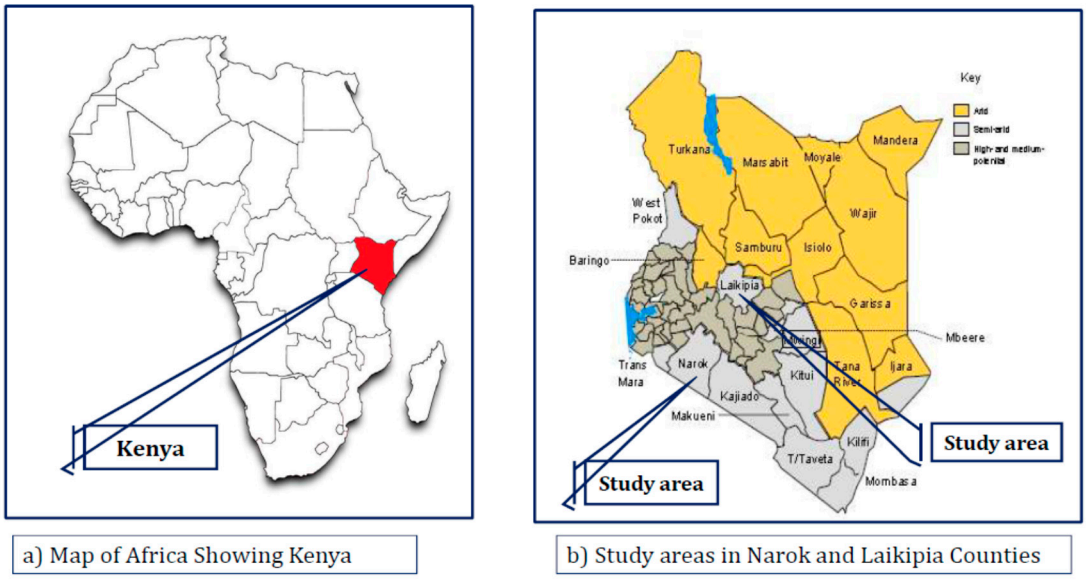

Figure 1. Map of Kenya depicting the Laikipia and Narok counties (Sources: (**a**) [37], (**b**) [38]).

The Narok County is situated in the southwest of Kenya and lies between latitudes 34°45′ E and 36°00′ E and longitudes 0°45′ S and 2°00′ S. Rainfall increases along a gradient from the dry southwest plains (500 mm/year) to wet northern highlands (2000 mm/year), with higher rainfall amounts being realized in higher altitude areas including the hills and escarpments. High human population density in the county is found in the humid, sub-humid and semi-humid zones. These are also the areas associated with high agricultural activities, while the remaining semi-arid lowland portion of the county is occupied by pastoral activities. The seventh wonder of the World—The Maasai Mara Game Reserve is located in Narok County and is associated with a vibrant tourism industry, as well as the presence of several civil societies and conservation organizations.

2.2. Survey Design and Data Collection

We focused our research on organizational collaboration in climate risk related knowledge generation and dissemination, considering individuals and organizations or institutions that are involved in pastoralism and climate change management. Knowledge in the context of this study is focused on information on climate risk warnings and risk response advisory services. Timescales for this knowledge focuses across operational to strategic planning decisions: weather forecasts (days), seasonal forecasts (months), multi-year information (1–5 years), intra-decadal information (5–10 years), and decadal (10 years and above, addressing longer term climate change).

Based on three information sources described below in sequential order of implementation (key informant interviews, a knowledge mapping workshop, and household questionnaire surveys) we triangulated (organizations cited in two or three sources) and defined the key actors in the climate knowledge network in Kenya with respect to pastoralism. This approach is similar to that of Ernstson et al. [39] for defining a whole network (group) boundary using ego-network (individual) level information. The final sample included 20 organizations (Table 1).

Key informant interviews (KIIs) focused on identifying each organization's network of collaborations in the generation and dissemination of climate knowledge, as well as the nature and scale of climate information that the organizations generate, disseminate, or use in their operations. Questions were also asked about the barriers and enablers for knowledge flow and use, and about each organization's background and sphere of operation. This information was arranged in an attribute

matrix that permitted us to categorize organizations in three ways: Organization type, administrative operation level, and role in the knowledge network in terms of (a) generators of knowledge, (b) brokers of knowledge, and (c) users of knowledge. This approach has been used by Cárcamo et al. [40] in their analysis of collaboration and knowledge networks in the management of a coastal marine area in the La Higuera and Freirina communes, Chile.

Table 1. Organizations that participated in the KIIs and/or the Workshop.

Acronym	Organization	Position of Interviewee	Workshop	KII
ALIN	Arid Lands Information Network	Coordinator	✓	✓
CARE	CARE Kenya	Field Officer		✓
CCAFS-CGIAR	Climate Change, Agriculture, and Food Security	Research Scientist		✓
CETRAD	Centre for Training and Integrated research in ASALS Development	Researcher	✓	✓
DRSRS	Department of Resource Surveys and Remote Sensing	Project Manager	✓	
ECAS	The Environmental Capacity and Services	Associate Consultant	✓	✓
FEWSNET	Famine Early Warning Systems Network	Meteorologist		✓
ICCA	The Institute for Climate Change and Adaptation	Director	✓	✓
IDRC	International Development Research Centre	Laboratory Head	✓	
KMD	Kenya Meteorological Department	Assistant Director	✓	✓
KWS	Kenya Wildlife Service	National		
MALF	Ministry of Agriculture Livestock and Fisheries	County Coordinator	✓	✓
NDMA	National Drought Management Authority	County Coordinator	✓	
PDN	Pastoralist Development Network, Kenya	Program Officer	✓	✓
NGO/CBO	Non-governmental Organizations/Community-Based Organizations	Outreach Officer	✓	
NMK	National Museums of Kenya	Research Scientist	✓	✓
ODI-KMT	Kenya Market Trust—ODI project	PRISE Coordinator	✓	✓
Power Hive East Africa	Power Hive East Africa	GIS Specialist	✓	✓
Traditional Institutions	Traditional Organizations	Member		✓
University	University of Nairobi	Lecturer	✓	✓

The KIIs were supplemented with a one-day workshop on knowledge mapping held on the 30th of January 2017 at the International Development Research Centre (IDRC) Regional office in Nairobi, Kenya. The workshop participants included representatives from 15 organizations comprising NGOs, research institutes, universities, government ministries, and donor organizations (Table 1).

The workshop focused on organizational mapping, knowledge flow analysis, and knowledge gap analysis paying attention to the nature and scale of knowledge that flows from organization to organization and across scale from national to local level in Kenya. The workshop also enabled gathering of perspectives on barriers and enablers of knowledge flow. In the first session of the workshop institutional maps were created that positioned organizations on a matrix which graphically represented the national climate knowledge network with respect to pastoralism, based on participants' organizational sphere of operations from supra-national, to national, to local level, noting their roles in terms of knowledge generation, brokerage, and usage. This session was followed by a group exercise on knowledge flow analysis, where lines were drawn between organizations to represent existing relationship ties, noting the barriers and enablers of knowledge flow in terms of organizations' characteristics and relationship ties. The final workshop activity identified gaps in knowledge and options for improving the feedback mechanisms in knowledge flow. A similar workshop procedure has been used by Dougill et al. [24] in analyzing knowledge gaps and institutional barriers to the mainstreaming of conservation agriculture in Malawi.

Additionally, to contrast with the results of the network analysis, we conducted a questionnaire survey with pastoralists in Laikipia and Narok to understand their perspectives on the relevance, reliability, and usability of the knowledge they accessed from the knowledge network. The survey includes questions on: (i) where the respondents obtain their information on climate risk warning and advisory services; (ii) who they share the information with; (iii) their perception of the relevance, adequacy, and usability of the information they receive; and (iv) the nature and scale of information received across different timescales, from weather to decadal. Respondents were chosen through a cluster random sampling technique: households in the two counties were divided into two groups, pastoralists and agro-pastoralists (those solely dependent on pastoralism and those having a mixed farming and pastoralism livelihood system). Thirty respondents were then randomly sampled per county from these two groups. The field enumerators were indigenes of Narok and Laikipia, who were also graduate students of the University of Nairobi, with previous survey experience, and good knowledge of pastoralism in the study region. The study was ethically approved by the University of Cape Town Faculty of Science research ethics committee.

2.3. Analysis

The data analysis includes a qualitative analysis of interviews and workshop discussions, quantitative and qualitative analysis of questionnaire records, in addition to a social network analysis (SNA) of the collaborations and knowledge flows. Together these methods provide insights into the case study by combining multiple disciplinary perspectives, as well as inductive and deductive approaches for a more thorough understanding of context and knowledge system dynamics [41].

2.3.1. Organizational Profiles and Characteristics, and Influence on Knowledge Flow

Nominal data from respondent perceptions about their organization roles in the climate knowledge network, relationship strength, influence in the climate knowledge network, and nature/scale of climate knowledge at organization's disposal, perceived effect of organizations' characteristics as either an enabler or barrier for knowledge flow were extracted from workshop records, questionnaire surveys, and KIIs. Descriptive statistics were used to profile the organizations, their sphere of operation, and types of climate adaptation knowledge they generate, disseminate, and/or use in the network. Relations between nominal variables were investigated with contingency tables and likelihood ratio chi-square tests, as recommended by [42,43].

2.3.2. Analysis of the Inter-Organizational Collaboration Network

The main purpose of the network analysis was to examine how the relational structure of the organizations in the network acts as either an enabler or barrier for knowledge flow. Respondent responses were coded as binary variables: the presence or absence of a unidirectional collaboration tie

in the production and dissemination of knowledge in climate adaptation knowledge [1]. Network data were analyzed and visualized using the UCINET 6.0 and NETDRAW 2.0 software Harvard, MA: Analytic Technologies [44]. The network structure was analyzed by calculating the clustering coefficient and core-periphery index. The network cohesion was analyzed using quantitative measures of centrality: density and degree (see Table 2). Network centrality measures were calculated to evaluate the network's power structure and its effect on knowledge flow:

Table 2. Properties used to analyze the network structure and cohesion.

Network Properties Analyzed	Indices	Interpretations
Network Structure	Clustering coefficient	Measures how close together a network is. The clustering coefficient of an actor is the density of its open neighborhood (Borgatti and Everett, 2000).
	Core-periphery	Measures which actors belong in the core and which belong in the periphery of a network.
Network Cohesion	Density	Measures the number of links, as proportion of all possible links present in a network.
	In/out degree centralization (used when direction of ties is taken into account)	Measures the extent to which an actor is holding all the links in the network. An actor with high in-degree centralization can be characterized as prominent, while an actor with high out-degree centralization can be characterized as influential.
	Degree centrality (unidirectional)	Measures the number of links a node has as an indicator of dominance or power over information flow (Vance-Borland and Holley, 2011). Degree centrality is a useful metric to identify organizations that serve as a central source of information for the rest of the network.

3. Results

3.1. Timescales and Types of Information Used in Climate Risk Warning and Advisory Services

The different timescales of weather and climate forecasts and the associated warnings and risk response advisory services are used in different ways by the interviewed organizations for operational, tactical, and strategic decisions. Weather, seasonal, and multi-year (1–5) forecasts are often used to advise pastoralists on their daily livelihood activities, as well as on how to manage extreme events such as fire, drought, and floods. However seasonal and multi-year (1–5) forecasts tend to be mostly used for tactical advice over the medium term that considers issues about feed availability and when to sell livestock, based on variability in climate and market demand. Intra-decadal (5–10) forecasts are used for longer-term strategic decisions on issues related to rangeland management and choice of livestock species to keep. There are no records of any explicit application of decadal or longer forecasts or scenarios in the generation of climate and adaptation knowledge for pastoralists.

As can be inferred from Table 3, operational and tactical decisions are often made by individuals at a household level based on weather and seasonal forecasts. Strategic decisions are often made by organizations operating across scales from local to national, based mainly on seasonal and multi-year (1–5 years) forecasts. Intra-decadal (5–10 years) and decadal forecasts are rarely used. Strategic decisions are made by individuals and institutions at local to regional scales based on climate and other signals over multiple years. Strategic decisions are made by organizations often at county and national level and are based on climate forecasts over multi-years (see Appendix A for the list of organizations that make up both the knowledge production and dissemination networks and their degree centrality measure). At the household level, pastoralists are particularly interested in information/knowledge about feed availability and management of drought. The following statements

from both the workshop and KII illustrate how the different types of decisions are made based on different forecasts:

Example of tactical decision: When there is a forecast for drought for an extended period, we advise pastoralists on when to sell their livestock to avoid loss (**NDMA/NDOC**)

*Example of tactical decision:The seasonal weather forecasts are used to develop likely scenarios with the community and what actions they should take, e.g., if the forecast is depressed rains, the farmers stock feeds for their livestock. If the forecast is excess rains, they prepare for an increased incidence of disease and pests- (**MALF**)*

Example of strategic decision:Because of shrinking rangelands as a result of the drop in average rainfall over the years and competing land use demands, pastoralists are provided with advisory services on how to diversify their livelihood system because the outlook for pastoralism over the next few years is not rosy (**ALIN**).

Table 3. Decision-making options associated with each timescale of weather and climate forecasts.

Types of Decision	Investigated Weather and Climate Forecasts				
	Weather	**Seasonal**	**Multi-Years (1–5 years)**	**Intra-Decadal (5–10 years)**	**Decadal (10+ years)**
Operational	Herding planning				
Tactical		Feed availability warning			
Strategic		Responding to variability in market demand	Livelihood diversification	Land/rangeland management	

Most of the funding for knowledge generation and research for adaptation of the pastoral system to climate change comes from international organizations. The key donor organizations identified in the pastoral adaptation knowledge network include IDRC, CGIAR, GIZ, DFID, IIED, and USAID. The funding often goes to regional bodies such as RCMRD, IGAD, and ICPAC, among others, who then support government ministries and departments such as KMD, NDMA, universities, or NGOs. Some of these regional bodies may also be involved directly in generating climate and weather forecast data for climate risk mapping: such bodies identified include RCMRD, KMD, FEWSNET, and ICPAC. As stated by the representative from the Institute of Climate Change Adaptation, University of Nairobi, *"this funding often comes with a pre-determined research agenda".* This creates a situation where national and local needs may not match with funding agenda. Besides providing climate monitoring and advisory services, KMD and RCMRD are also involved in monitoring vegetation changes using the normalized differential vegetation index (NDVI) data and other tools.

Several organizations operating at national, county, and/or local level were noted to engage in the translation of climate risk information into risk response advisory services for pastoralists. They include NDMA, universities, research institutions, and international NGOs such as Care Kenya. Universities and research institutions are mostly involved in capacity building, climate monitoring, and linking climate risks with socioeconomic and ecological impacts, to the pastoral system. NDMA and NDOC, for example, generate information for early warning systems, livelihood strategies, food prices, nutritional status, and market trends for pastoralists. There are also other organizations, including NGOs that are engaged in brokering of knowledge for capacity building, advisory services, and livelihood sustainability. Identified bodies included ALIN, KMT, private firms, government ministries, and churches. These organizations' activities are focused on translation of climate data into risk warning and advisory services relevant to pastoralism. Similarly, the county governments play strategic roles in the generation of downscaled climate data for climate risk and advisory information at the county level. They work collaboratively with the decentralized offices of the Kenya Meteorological Department at their county to generate downscaled climate data for their county.

3.2. Inter-Organisational Collaboration in Knowledge Production

Out of the 33 organizations in the climate knowledge network that are involved in the production of knowledge on climate risk warning and advisory services, 24 are involved in the production of

weather and seasonal information, and 17 are involved in the production of multi-year information (1–5 years). However, 9 were involved in the generation of intra-decadal (5–10) information, while only research organizations and traditional institutions were identified to be generating decadal climate information. Although we did not interview any representative from the traditional institutions, participants in the workshop reported that traditional institutions base their climate risk information on local/indigenous tacit knowledge accumulated over several generations.

Firstly, we analyzed the core/periphery of the network to understand how embedded different organizations are in the overall network. The core/periphery has a final fitness score of 0.69, showing that about 69% of the actors that make-up the network is situated at the periphery of the network. The core organizations are CETRAD, county government, DRSRS, FEWSNET, KFS, KMD, KWS, local communities, MALF, Media, MICNG, NDMA, NEMA, NGO, research organizations, and traditional institutions. The organizations located in the periphery are ALIN, CARE Kenya, CCAFS, ECAS, ICCA, ICPAC, KALRO, KEMFRI, NDOC, NMK, ODI-KMT, PACJA, Power Hive East Africa, RCMRD, Red Cross, universities, and World Bank. Generally, organizations in the core are able to coordinate their actions, while those in the periphery are not as easily able to do so, due to the loose connection between them. Consequently, organizations in the core are at a structural advantage in exchange relations with organizations in the periphery. The organizations located in the periphery are loosely connected to the network and are less central to the activities of knowledge generation occurring in the network. Nevertheless, the periphery organizations include a mix of donor organizations, international NGOs, governmental agencies, and local NGOs. The location of an organization either in the core or periphery of a network has implication on the rate at which information/activity emanating from such organizations spread through the network. Hence the location of donor organizations and governmental agencies in the periphery of the network can have a negative impact on knowledge generation activities.

The clustering coefficient of the individual organizations in the network showed that most organizations are not maximally connected when their total number of ties is compared to the total number of possible ties (Table 4). For instance, the Kenya Meteorology Department (KMD) which is a key organization in terms of knowledge, out of a possible number of ties has a clustering coefficient of 0.46. This indicates that opportunities for cooperation among the organizations in the production network are yet to be maximized. Similarly, the analysis of the organizations reciprocity (i.e., the number of ties that are reciprocated) showed that apart from the traditional institutions most of the organizations in the production network have a high percentage of reciprocity (Table 4).

Table 4. Clustering coefficient of core actors in the production network.

SN	Organizations	Clustering Coefficient	Total Number of Possible Ties	Reciprocity
1	CETRAD	0.55	351.00	0.67
2	County Gov.	0.49	435.00	0.80
3	DRSRS	0.61	210.00	0.76
4	FEWSNET	0.60	300.00	0.52
5	KFS	0.69	190.00	0.60
6	KMD	0.46	465.00	0.97
7	KWS	0.67	231.00	0.55
8	Local communities	0.45	435.00	0.77
9	MALF	0.62	276.00	0.75
10	Media	0.50	351.00	0.74
11	MICNG	0.65	190.00	0.55
12	NDMA	0.62	231.00	0.59
13	NEMA	0.62	210.00	0.52
14	NGO	0.49	406.00	0.59
15	Research organization	0.62	210.00	0.57
16	Traditional institutions	0.47	378.00	0.29

The knowledge production network (Figure 2) has an overall network density of 0.470 and clustering coefficient of 0.630. This indicates that the production network is dominated by a concentration of a moderate number of organizations. However, based on the degree centrality measure (see Appendix B), we observed that out of the 33 organizations in the production network, KMD, County government, NGOs, and local communities serve as the central actors based on out-degree centrality. KMD, County government, FEWSNET, and local communities serve as the central actors based on in-degree centrality. From this finding, we can infer that activities within the adaptation knowledge production network are centralized around these five actors (KMD, County government, FEWSNET, local communities, and NGOs).

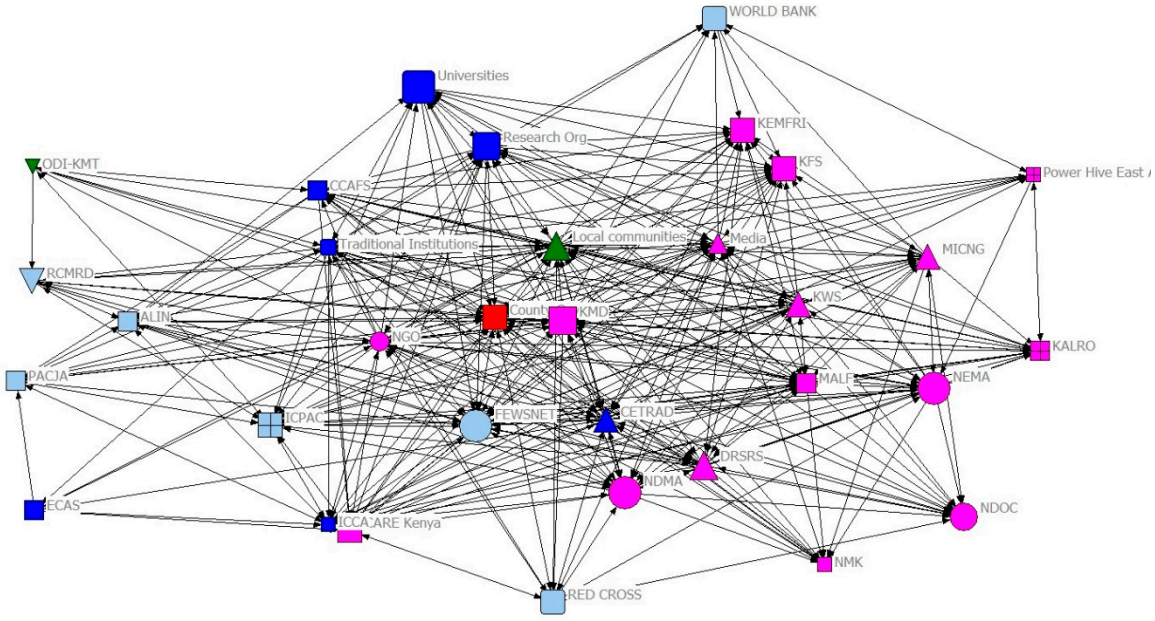

Figure 2. Climate knowledge production network representing collaboration relations among organizations with respect to pastoralism in Kenya. Organizations in the central are the core actors. Nodes were colored based on the administrative operation level of each organization (Light blue: international, Pink: national, Red: County, Blue: Educational and research organization, Green: Local NGOs/CBOs). Node shapes were based on the scale of climate knowledge being produced (weather, seasonal, multi-year 1–5 years, intra-decadal 5–10, and decadal 10+ years), (down triangle: organizations producing all five categories, Box: Organizations producing any four of the categories, up triangle: organization producing any three of the categories, Square: organizations producing only two of the categories, Circle: organizations producing only one of the categories).

3.3. Inter-Organisational Collaboration in Knowledge Dissemination

The core-periphery analysis of the dissemination network showed that the network has core-periphery fit correlation of 0.59. This indicates that about 59% of the actors that make-up the network is situated at the periphery of the network. The actors located in the core of the network are: ALIN, CCAFS, CETRAD, County government, KMD, Local communities, MALF, Media, MENR, NEMA, NGO, and Traditional Institutions. The core actors comprised of government institutions, CBOs, and NGOs. The NGOs and government institutions operate as boundary organizations in the network. Similar to the production network, the clustering coefficient of individual actors in the dissemination network showed that most actors are not maximally connected with respect to the total number of possible ties in the network. The result of the clustering coefficient for the core actors in the dissemination network (Table 5) showed for instance, that local communities have a clustering coefficient of 27% out of a possible total tie of 300.

Table 5. Clustering coefficient of core actors in the dissemination network.

SN	Organisations	Clustering Coefficient	Total Number of Possible Ties	Reciprocity
1	ALIN	0.49	66.00	0.42
2	CCAFS	0.41	153.00	0.11
3	CETRAD	0.25	325.00	0.15
4	County gov.	0.42	153.00	0.33
5	KMD	0.34	231.00	0.50
6	Local communities	0.27	300.00	0.64
7	MALF	0.43	120.00	0.44
8	Media	0.43	105.00	0.27
9	MENR	0.43	91.00	0.21
10	NEMA	0.58	66.00	0.42
11	NGO	0.42	78.00	0.31
12	Traditional institutions	0.30	231.00	0.55

Out of the 28 organizations in the knowledge dissemination network, CETRAD, local communities, and traditional institutions serve as the central sources of information based on out-degree centrality (see Appendix C). Local communities, traditional institutions, and county government serve as the central source of information based on in-degree centralization. Thus, activities within the adaptation knowledge dissemination network are centralized around these four actors. The pastoralist adaptation knowledge dissemination network (Figure 3) has an overall network density of 0.302 and clustering coefficient of 0.508, which are lower than those in the production network.

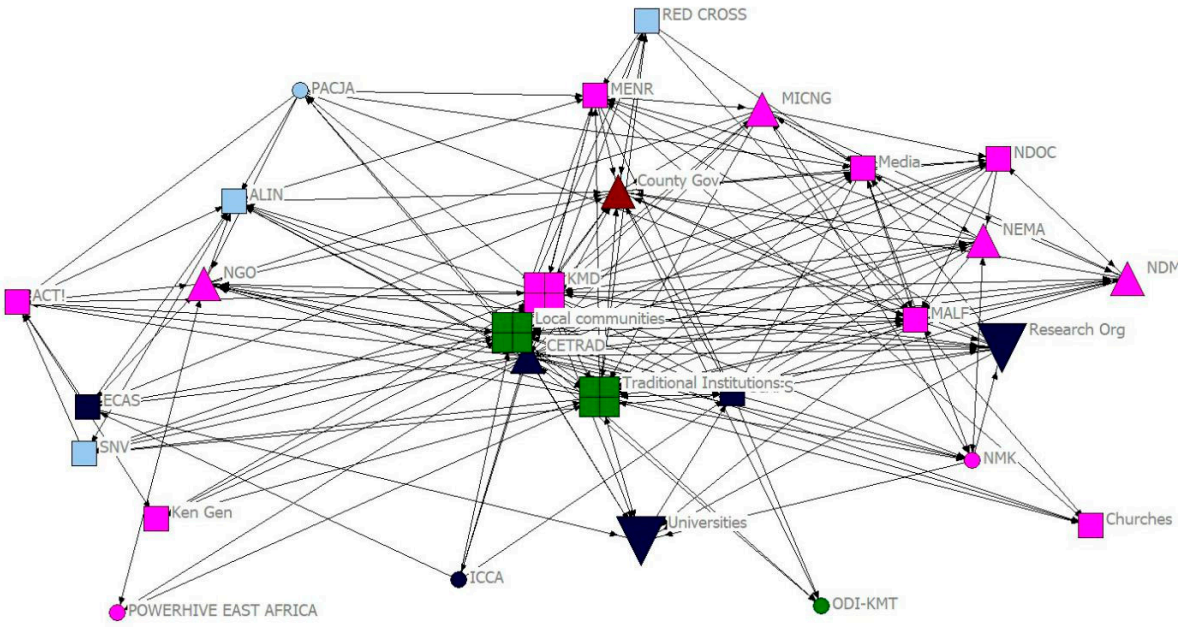

Figure 3. Climate knowledge dissemination network representing collaboration relations among organizations with respect to pastoralism in Kenya. Nodes were colored based on the administrative operation level of each organization (Light blue: International, Pink: National, Orange: County, Navy blue: Educational and research organization, Green: Local NGOs/CBOs). Node shapes were based on scale of climate knowledge being disseminated (weather, seasonal, multi-year 1–5 years, intra-decadal 5–10, and decadal 10+ years), (Down triangle: organizations disseminating all five categories, Box: Organizations disseminating any four of the categories, up triangle: organization disseminating any three of the categories, Square: organizations disseminating weather and seasonal categories, circle: Organizations disseminating only one of the five categories).

3.4. Access to Information by Pastoralist Communities

We sort the opinion of pastoralists in Kenya concerning the adaptation knowledge they currently harnessed for their livelihood practices. The sources mentioned by the pastoralists were in broad agreement with those organizations identified during the knowledge mapping workshop and KII interviews. The bulk of information disseminated to pastoralists on climate risks is based on weather and seasonal forecasts with little or nothing happening on the dissemination of information on long-term forecasts (Figure 4): 21% and 39% of respondents from Laikipia, and 78% and 61% of respondents in Narok indicated that they received climate risk warning on weather and seasonal timescales, respectively. The chi-square test for the dissemination of climate risk warning information based on these two categories of forecasts (Weather and seasonal) was significant ($p = 0.001$), indicating that dissemination of climate risk warning is much more improved in Narok than in Laikipia. Nevertheless, there are pastoralists in the communities who do not seem to be receiving information on climate risk warning with respect to the pastoral system. These groups of pastoralists who do not receive information on climate risk and risk response strategy are represented as "no response" in Figure 4.

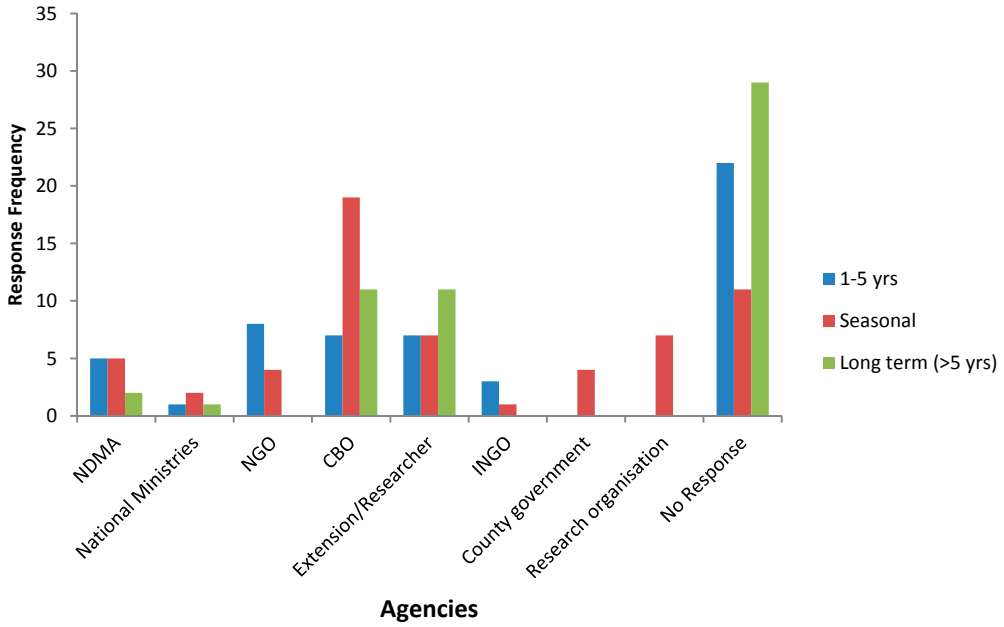

Figure 4. Pastoralists source of information on climate risk warning.

Furthermore, we explored with the pastoralists where they source information on advisory services for their pastoral livelihood strategy. Government agencies (National ministries) and CBOs appear to dominate the knowledge dissemination on advisory services (Figure 5). Nevertheless, in spite of the ongoing effort, there are still many pastoralists in the community who are not getting information on advisory services.

In addition, we examined the frequency of times that pastoralists have contact with the knowledge provider in their locality in order to determine the strength of such relationship. We found that 53% of respondents in Laikipia and 50% in Narok have contact with knowledge providers in their locality every few months. However, 33% of respondents in Laikipia and 50% in Narok reported that they have contact once a year with the knowledge providers in their locality.

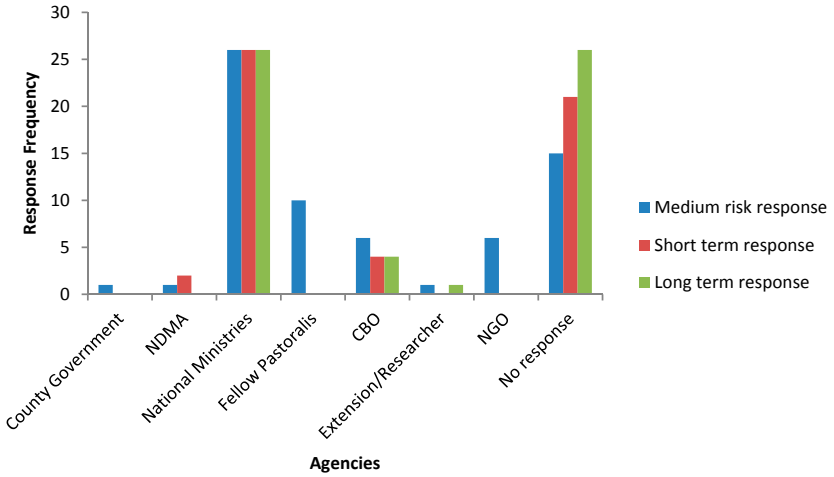

Figure 5. Pastoralists' source of information on risk response advisory services.

4. Discussion

4.1. Nature and Scale of Generated and Disseminated Knowledge

The generation and dissemination of relevant knowledge to tackle the impacts of climate risk are essential for resilient sustainable development. However, this idea is challenged by low capacity and/or poor access to best practices in the development field in most developing countries [45]. This is particularly critical for developing countries in the arid and semi-arid regions where the impacts of climate variability and change present substantial environmental and development challenges. In this study, it was observed that funding for knowledge generation is dominated by international donor organizations, often driven by international agendas. The poor involvement of national organizations in the funding of knowledge generation activities is a great concern that has also been observed in many developing countries [46]. To improve the chances for the generation of knowledge that is compatible with prioritized key national challenges in respect to adaptation of pastoral systems to climate change, it is important that the Kenyan government should increase its funding for research activities and also align more with donor organizations in ensuring that local/national priorities are at the forefront agenda of externally funded activities.

Although gaps sometimes exist in knowledge generation activities in terms of differences between agenda of internationally funded knowledge generation projects and prioritized key national challenges, collaborations between donor organizations and national knowledge production and dissemination organizations have helped in bridging this gap. In this study, collaborations between knowledge generating organizations (e.g., KMD) and boundary organizations (e.g., MALF) have helped in improving the relevance and acceptability of knowledge generated and disseminated to pastoralists, consequently helping to bridge the gap between organizations' (donors and knowledge generating organizations) and pastoralists' perceived and actual knowledge need. Similar trends have been reported by [47] where collaborations between climate-forecast producers and agriculture officials resulted in enhancing two-way transfer of knowledge—the technical knowledge of the producers and the practical, contextualized knowledge of the users in the agriculture sector. Indeed, inter-organizational collaboration has the potential to increase the legitimacy and credibility of knowledge generation and dissemination activities.

Similarly, the study showed that the translation of climate data into climate risk, impact maps, advisory services, and risk response strategies with respect to pastoral systems is mostly done by regional and national organizations. The implication is that most of the knowledge generation occurs at the national scale; however, the practice of a devolved system of governance in the country and the involvement of county governments in knowledge generation have greatly facilitated downscaling and customization of knowledge on climate risk, impact, and response advisory services relevant for

local use. Decentralization of governance has also been cited as an enabler of the generation of local scale knowledge on climate risk and risk warning, as well as advisory services in many developing countries [48,49].

In the case of pastoral systems in Kenya, knowledge of climate risk, impact, and advisory services are mostly generated from data on weather and seasonal forecast timescales. Intra-decadal and decadal data are rarely used in risk mapping and advisory services. The notion often put forward by most of the organizations involved in knowledge generation and dissemination is that decadal and multi-year information are not needed for climate risk mapping and advisory service generation for the pastoral system [30,50]. The implication is that advisory services and risk mapping disseminated to pastoralists are focused on short-term adaptation strategies. This implication means that livelihood planning and activities of the pastoralists are geared towards immediate needs with no plan for long-term strategies that are essential in ensuring the long-term sustainability of their production systems.

The nature and characteristics of the organizations in the network can have an impact on knowledge flow, as connections across scales are vital for addressing mismatches between the generation and dissemination of relevant knowledge to pastoralists [39]. In this study, the involvement of governmental organizations both at national and county level in knowledge generation and dissemination was observed to serve as an enabler of knowledge flow. In the same vein, the location of governmental organizations as central actors in the network enhanced the generation and dissemination of new adaptation knowledge. This observation is supported by the findings of [51], where they reported that multi-scalar collaborative networks can overcome a resistance to novelty and innovation through the circulation of new ideas and strategies.

There is high reciprocity between most of the primary organizations responsible for knowledge generation. However, in the dissemination network, with the exception of KMD, traditional institutions and local communities sit at the core of the network, but the majority has low reciprocity. This finding implies that many of the core organizations in the dissemination network are not engaging in a two-way flow of information, which can constitute a significant barrier to the flow of relevant knowledge to pastoralists in Kenya. The knowledge flow between these organizations is vital for the translation of adaptation knowledge into appropriate action in the pastoral system.

While donor organizations may not be engaged in knowledge production, they have great influence over the nature and type of knowledge generated. It is possible therefore that funding agendas of these organizations do not match with national priority needs with respect to adaptation of the pastoral system to climate change. Close collaboration between donor organizations and core organizations in the network is essential for setting the base for generation of relevant knowledge for the adaptation of the pastoral system.

4.2. Effect of Inter-Organisational Networks on Knowledge Flow

This study has provided important insights into the structure and properties of knowledge production and dissemination networks with respect to pastoral systems in Kenya. The production network showed high density, reciprocity, and clustering coefficient values. This finding implies the existence of a high flow of collaborative and exchange relations among the different actors that make up the network. The dissemination network, on the other hand, showed much less cohesion, with low values for centralization and density, indicating weak collaborative and exchange relations among the different actors in the network. As noted elsewhere, networks with low density are associated with the disadvantages of higher transaction costs with respect to exchange and cooperation, and low capacity for collective action [26,44,48,52]. This might be the reason for some of the current challenges (e.g., low rate of knowledge dissemination and dissemination of knowledge that do not sufficiently cover all climate change challenges) associated with knowledge dissemination to pastoralists at the local level in Kenya. Managing the challenge of poor collaboration in the dissemination network may require incentivizing organizations in the core of the network to get involved in knowledge dissemination activities. As noted by [53,54], improving relations among actors in the core of a network

can help maximize efficiency. This notion is supported by [55], where they reported that adoption of new innovations generally tends to trickle-down from highly interconnected core actors to more loosely connected peripheral actors.

The difference in the number of organizations involved in the production versus the dissemination networks is at least partly the result of some of the organizations limiting their activities to either production or dissemination. The higher number of organizations in the production network can also be explained by the greater funding and general attention being paid to knowledge generation without commensurate effort being made towards ensuring that generated knowledge is communicated to relevant audiences [30,56]. Nevertheless, both the knowledge production and knowledge dissemination networks showed a high level of integration with government agencies, NGOs, research institutions, and traditional institutions occupying central positions. This finding indicates that these organizations are increasingly gaining power and influence in the generation and dissemination of adaptation knowledge with respect to pastoralism in Kenya. This will have a positive influence in ensuring that the views of minorities and marginal organizations are addressed in knowledge generation and dissemination

While organizational diversity within the network greatly facilitates the generation of knowledge that addresses the complex challenge of pastoral system adaptation to climate change [57], it is the structure which underlies the relation among the diverse organizations in the network that mainly influences the knowledge flow and adoption in adaptation action, particularly at local level pastoralists [39]. The high centrality of a few key organizations and low clustering coefficients of some of them shows that power asymmetries and fragmentation of knowledge flow are evident and could potentially be constraining generation and dissemination of relevant adaptation knowledge to pastoralists. These organizations with the highest centrality in the production network (KMD, County government, FEWSNET, local communities, and NGOs), and the dissemination network (Local communities, traditional institutions, and county government), serve as the main sources of knowledge on adaptation of the pastoral system to climate change in Kenya. This statement means that these organizations have more influence over information flows and are highly likely to become opinion leaders in the network [57]. How these organizations utilize their favorable position within the network will have an impact on governance outcomes of the pastoral system [48]. As reported by [26], "if individuals occupying influential positions in the social networks are unaware of the need for, or unwilling to engage in, a collective action they may end up, deliberately or not, blocking initiatives by others". Most of the government agencies that are involved in pastoral knowledge support activities are not direct producers of knowledge, but they achieve relevant positions in the knowledge network, indicating a potential role as bridging actors, connecting producers and consumers of knowledge [40].

The presence of the traditional institutions and county government as central actors in the dissemination network is not surprising given their jurisdictional roles in planning and regulating adaptation-related actions at the local level in Kenya. The KMD and FEWSNET, not surprisingly, serve as an important source of knowledge on climate risk and risk response with respect to pastoralism; however, their poor and moderate clustering coefficients, respectively, imply that the knowledge they generate may not be communicated to the respective target audiences as efficiently and effectively as possible. Furthermore, their poor connections also have implications for feedback from pastoralists, which may negatively affect their reflective collective learning efforts for improving the reliability, relevance, and suitability of knowledge generated and disseminated to them. The high centrality of NGOs in knowledge production could also have a negative impact of knowledge generation given the fact that most of these NGOs are local and highly volatile in terms of continuity of funding for their existence and functioning. The lack of centrality of pastoralist CBOs in the network suggests that pastoral associations are not yet playing a meaningful role in the generation and dissemination of adaptation knowledge in Kenya. Strengthening the capacity of pastoral associations is thus needed to improve engagement of pastoralists in knowledge generation and dissemination activities. As reported by [58] in their work on the governance of water resources, the introduction and capacitation of water

user associations have helped to better link otherwise disconnected stakeholders at the local level, to higher levels of governance.

The observed centrality of NGOs, county government, and local communities in the knowledge generation and dissemination network has a potential for promoting efficient feedback from local to national level, while enhancing the opportunity for revision and reflection to ensure that generated and disseminated knowledge are in conformity with the user context. However, attaining this potential will require that the issue of volatility associated with most local NGOs operating in the area must be addressed. Most of the local NGOs are challenged with the issue of sustainable funding for the continuity of their activities. Similarly, though traditional authorities are currently involved in scenario planning and development of knowledge on climate risk warning and advisory services for their local constituency, such involvement is currently very limited in scope. Their inclusion is limited in its current form of application. Currently, traditional authorities' inclusion is limited to collaboration with governmental agencies in the prediction of future/scenario of climate risk impact and risk response strategy using local indigenous knowledge. The critical issue of the local perspective of generated scientific knowledge, in terms of its suitability, relevance, and reliance with respects to the people's context is often overlooked. Thus, investigation on modalities for involving traditional institutions in adaptation knowledge to address issues of suitability, relevance, and reliance of generated knowledge is needed.

4.3. Effect of Inter-Organisational Networks on Pastoralist Awareness of Climate Change

Based on the surveys in Narok and Laikipia, we observed that the bulk of the information pastoralists receive are based on weather and seasonal data. This is consistent with what was reported by organizations active in the pastoral climate knowledge network. The survey confirmed that long-term and decadal adaptation forecasts are rarely generated and communicated to pastoralists despite their relevance for anticipatory and long-term adaptation. A similar trend has been observed by [59] where they found that the climate knowledge of greatest interest to pastoralists concerns the onset of the rains.

There are two possible explanations for the poor use of intra-decadal and decadal data in the generation of knowledge on climate risk warning and advisory services. The first could be because of the socioeconomic status of the pastoralists, most of whom are poor and lack capacity for long-term planning for livelihood strategies and are, therefore, concerned about how to navigate through their immediate needs. This makes them only interested in knowledge for managing immediate challenges. The second reason could be as a result of supply and demand factors. Given the fact that pastoralists are mostly interested in short-term knowledge on climate risk warning and advisory services, organizations operating in the pastoralist adaptation knowledge network tend to focus on supplying or satisfying such need. As observed by [59], pastoralists who have adopted highly flexible production systems have less need for long-lead information. Such have adopted a livelihood strategy built around flexibility in production, primarily through migration in response to spatio-temporal variation in range conditions [60]. The onus is therefore on organizations operating in the pastoralists' network to find a means of convincing the pastoralist to begin to incorporate long-term knowledge in their livelihood strategy/plan as a way of enhancing the sustainability of their livelihood, while enhancing their capacity to escape the 'poverty trap'.

It is also important to note that some respondents reported that they do not receive adaptation knowledge 12%, 23%, and 28% with respect to seasonal, annual to mid-term (1–5 years), and long-term (5 years and beyond) respectively. This also is a confirmation of the findings of the influence of the properties and structure of the knowledge dissemination network on knowledge flow, where we observed that low reciprocity, density, and centrality of the network is negatively affecting knowledge flow. This explains why some pastoralists are not receiving adaptation knowledge.

The location of pastoralists (local communities) in the core of the knowledge dissemination network indicates that pastoralist communities should be the center of all actions. However, there is

a mismatch between the perception of the pastoralists and organizations operating the network on the relevance and suitability of generated knowledge. When pastoralists were asked to indicate the type of knowledge that they wish to receive, that they currently do not receive, nearly all the needs reflected information the organizations operating in the network claim to be currently providing. This mismatch could, therefore, be as a result of the nature or channel through which knowledge is disseminated to pastoralists. As reported by [60], climate risk information is sometimes disseminated to pastoralists without corresponding advice on how to cope with the forecasted climatic condition. When knowledge is disseminated in such manner, most of the recipients are generally not able to act on the received knowledge. Additionally, given the observed poor reciprocity and density in the dissemination network, we can infer that poor collaboration among organizations in the dissemination network, and a low feedback connection between the organizations and pastoralists are negatively impacting knowledge dissemination. Thus, knowledge dissemination to pastoralists seems to communicate adaptation knowledge that is not relevant to a particular pastoralist, even though the required knowledge by such pastoralists is available. In such circumstances, the exact knowledge needed by a pastoralist tends to be unknown to the disseminating organization. When this mismatch is probed further, in terms of the average frequency of meeting between pastoralists and knowledge providers, we confirm that there is a low average frequency of meeting/contact between pastoralists and knowledge disseminating organizations. A similar trend was observed by [60–62], where they reported that most pastoralists have seasonal contact with knowledge disseminating agency.

There is room for improving connections between actors and improve feedback mechanisms. This finding is illustrated by the clustering coefficient of organizations in the dissemination network. The KMD, for example, is a core organization in the network, yet its clustering coefficient is a mere 0.459. Improving the ties/connection between organizations in the network will improve opportunity for a feedback process between organizations in the network and help to ensure that knowledge generated is highly suitable to the needs of pastoralists [24].

5. Conclusions

Although pastoralists, particularly those in the arid and semi-arid regions, have past experience and success in coping with climate variability and extreme weather events, there are concerns that these coping strategies could be less effective in handling the accelerated pace of climate change-induced extreme weather events. This concern, coupled with the emerging evidence that the rate of adoption of knowledge on climate adaptation by pastoralists is far lower than the rate of knowledge generation, is stimulating interest on how to enhance knowledge communication to and adoption by pastoralists.

The government of Kenya, in its National Climate Change Response Strategy, highlights the importance of effective and efficient communication of adaptation knowledge between producers, brokers, and pastoralists in ensuring the effective adaptation of pastoralists [63]. However, the success of such processes depends on understanding the structure and properties of the pastoral adaptation knowledge network. The analysis of the structure and properties of pastoralist social-knowledge network is thus a rational research approach to uncover patterns by which pastoralists harness knowledge on climate risks and adaptation practices and factors shaping their adoption of such knowledge. The result from this study has shed some light on the organizational structures affecting knowledge generation and dissemination in the Kenyan pastoral adaptation network.

The application of SNA as a diagnostic tool in this study has provided two main contributions: (1) the description of the structure and properties of the knowledge production and dissemination network in Kenya, and (2) the influence of the network structure and properties on knowledge flow, noting the barriers and enablers. While the knowledge production network showed high density and cohesion, the knowledge dissemination network showed less density and cohesion. The production network indicated the existence of a high rate of collaborative and exchange relations among different organizations in the network, while the dissemination network indicated the existence of a low rate of collaborative and exchange relations among the different organizations. Some disadvantages that

could be attributed to low-density cohesion in the dissemination network include low capacity for collective action, dissemination of non-relevant knowledge, and duplication of activities. The location of local pastoralist communities and county government in the core of the knowledge dissemination network signifies that county government is playing a significant role in the generation of locally relevant knowledge and that the pastoralist is at least in the center of all actions. This insight can inform future participatory extension approaches targeting pastoral system adaptation to climate change.

In addition, findings from the study showed that inter-organizational collaboration has influence on the perceived relevancy, credibility, and acceptability of knowledge communicated through the adaptation knowledge network to pastoralists. Similarly, organizations' position in the adaptation knowledge network (core or periphery) has impact on the efficiency and effectiveness of their role in the generation and dissemination of climate knowledge to pastoralists. However, this study did not investigate the factors that either facilitates or hinders organizations' collaboration capability. Such factors will ultimately influence organizations' positions in the adaptation knowledge network which will in turn affect their role in the network. Further research is needed in this regard as a way of unearthing modalities for increasing the centralization of the pastoral adaptation network thereby improving its efficiency in the communication of relevant knowledge to pastoralists in a timely manner.

Author Contributions: The conceptualization of the study was done by C.O. and M.N. The design of the methodology was done by all three authors. Project administration was done by C.O. and M.N. Formal Analysis and investigation was done by C.O. and K.S. Writing review and editing was done by all three authors. Funding was acquired by M.N. Lastly, validation and visualisation was done by all three authors.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A.

Table A1. Names of organizations that made up both the production and dissemination network.

Acronyms	Name of Organization
ACT!	Act Change Transform
ALIN	Arid Lands Information Network
CARE Kenya	CARE Kenya
CCAFS	Climate Change, Agriculture, and Food Security
CETRAD	Centre for Training and Integrated research in ASALS Development
CGIAR	Consultative Group on International Agricultural Research
Churches	Churches
County Gov.	County Government
DFID	Department for International Development
DRSRS	Department of Resource Surveys and Remote Sensing
ECAS	The Environmental Capacity and Services
FEWSNET	Famine Early Warning Systems Network
GIZ	German Agency for International Cooperation
IGAD	Intergovernmental Authority on Development
ICCA	The Institute for Climate Change and Adaptation
ICPAC	IGAD Climate Prediction and Application Centre
IDRC	International Development Research Centre
IIED	International Institute for Environment and Development
KALRO	Kenya Agricultural & Livestock Research Organization
KEMFRI	Kenya Marine &Fisheries Research Institute
Ken Gen	Kenya Electricity Generating Company
KFS	Kenya Forest Service
KMD	Kenya Meteorological Department
KWS	Kenya Wildlife Service

Table A1. *Cont.*

Local communities	Local communities
MALF	Ministry of Agriculture Livestock and Fisheries
Media	Media
MENR	Ministry of Environment and Natural Resources
MICNG	Ministry of Information, Communications and Technology
NDMA	National Drought Management Authority
NDOC	National Disaster Operations Centre
NEMA	National Environment Management Authority
NGO	Non-governmental organizations/community-based organization
NMK	National Museums of Kenya
ODI-KMT	Kenya Market Trust – ODI project
PACJA	Pan Africa Climate Justice Alliance
Power Hive East Africa	Power Hive East Africa
RCMRD	Regional Centre for Mapping of Resources for Development
RED CROSS	RED CROSS Kenya
Research Org	Research Institutes
SNV	SNV Kenya
Traditional Institutions	Traditional Organizations
Universities	
USAID	United States Agency for International Development
WORLD BANK	

Appendix B.

Table A2. In/Out degree centrality measures of organizations in the production network.

Degree	**Measures**				
		1	**2**	**3**	**4**
		Outdeg	**Indeg**	**nOutdeg**	**nIndeg**
1	ALIN	13.000	12.000	0.406	0.375
2	CARE Kenya	11.000	14.000	0.344	0.438
3	CCAFS	13.000	12.000	0.406	0.375
4	CETRAD	25.000	20.000	0.781	0.625
5	County Gov	27.000	27.000	0.844	0.844
6	DRSRS	18.000	19.000	0.563	0.594
7	ECAS	4.000	4.000	0.125	0.125
8	FEWSNET	15.000	23.000	0.469	0.719
9	ICCA	9.000	15.000	0.281	0.469
10	ICPAC	10.000	19.000	0.313	0.594
11	KALRO	12.000	13.000	0.375	0.406
12	KEMFRI	9.000	18.000	0.281	0.563
13	KFS	14.000	18.000	0.438	0.563
14	KMD	31.000	30.000	0.969	0.938
15	KWS	21.000	13.000	0.656	0.406
16	Local communities	29.000	24.000	0.906	0.750
17	MALF	21.000	21.000	0.656	0.656
18	Media	24.000	23.000	0.750	0.719
19	MICNG	18.000	13.000	0.563	0.406
20	NDMA	18.000	17.000	0.563	0.531
21	NDOC	7.000	13.000	0.219	0.406
22	NEMA	19.000	13.000	0.594	0.406
23	NGO	29.000	17.000	0.906	0.531
24	NMK	7.000	12.000	0.219	0.375
25	ODI-KMT	6.000	6.000	0.188	0.188
26	PACJA	7.000	11.000	0.219	0.344
27	Power Hive East Africa	4.000	8.000	0.125	0.250
28	RCMRD	7.000	9.000	0.219	0.281
29	RED CROSS	9.000	7.000	0.281	0.219
30	Research Org	20.000	13.000	0.625	0.406
31	Traditional Institutions	22.000	14.000	0.688	0.438
32	Universities	13.000	11.000	0.406	0.344
33	WORLD BANK	4.000	7.000	0.125	0.219

Appendix C.

Table A3. In/Out degree centrality of actors in the dissemination network.

Degree	Measures				
		1	2	3	4
		Outdeg	Indeg	nOutdeg	nIndeg
1	ACT!	5.000	9.000	0.185	0.333
2	ALIN	6.000	11.000	0.222	0.407
3	CCAFS	3.000	17.000	0.111	0.630
4	CETRAD	26.000	4.000	0.963	0.148
5	Churches	2.000	4.000	0.074	0.148
6	County Gov	7.000	17.000	0.259	0.630
7	ECAS	5.000	5.000	0.185	0.185
8	ICCA	4.000	1.000	0.148	0.037
9	Ken Gen	3.000	4.000	0.111	0.148
10	KMD	19.000	14.000	0.704	0.519
11	Local communities	22.000	19.000	0.815	0.704
12	MALF	10.000	13.000	0.370	0.481
13	Media	9.000	10.000	0.333	0.370
14	MENR	7.000	10.000	0.259	0.370
15	MICNG	9.000	6.000	0.333	0.222
16	NDMA	7.000	7.000	0.259	0.259
17	NDOC	9.000	6.000	0.333	0.222
18	NEMA	9.000	8.000	0.333	0.296
19	NGO	7.000	10.000	0.259	0.370
20	NMK	5.000	7.000	0.185	0.259
21	ODI-KMT	3.000	4.000	0.111	0.148
22	PACJA	8.000	2.000	0.296	0.074
23	POWERHIVE EAST AFRICA	2.000	3.000	0.074	0.111
24	RED CROSS	6.000	3.000	0.222	0.111
25	Research Org	8.000	6.000	0.296	0.222
26	SNV	4.000	5.000	0.148	0.185
27	Traditional Institutions	19.000	15.000	0.704	0.556
28	Universities	4.000	8.000	0.148	0.296

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