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**Integrating climate in Ugandan health and subsistence food systems: where diverse knowledges meet**

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44 ABSTRACT

45 **Background:** The effects of food insecurity linked to climate change will be exacerbated in subsistence  
46 communities that are dependent upon food systems for their livelihoods and sustenance. Place-and  
47 community-based forms of surveillance are important for growing an equitable evidence base that  
48 integrates climate, food, and health information as well as informs our understanding of how climate  
49 change impacts health through local and Indigenous subsistence food systems.

50 **Methods:** We present a case-study from southwestern Uganda with Batwa and Bakiga subsistence  
51 communities in Kanungu District. We conducted 22 key informant interviews to map what forms of  
52 monitoring and knowledge exist about health and subsistence food systems as they relate to seasonal  
53 variability. A participatory mapping exercise accompanied key informant interviews to identify who holds  
54 knowledge about health and subsistence food systems. Social network theory and analysis methods were  
55 used to explore how information flows between knowledge holders as well as the power and agency that  
56 is involved in knowledge production and exchange processes.

57 **Results:** This research maps existing networks of trusted relationships that are already used for  
58 integrating diverse knowledges, information, and administrative action. Narratives reveal inventories of  
59 ongoing and repeated cycles of observations, interpretations, evaluations, and adjustments that make up  
60 existing health and subsistence food monitoring and response. These networks of local health and  
61 subsistence food systems were not supported by distinct systems of climate and meteorological  
62 information. Our findings demonstrate how integrating surveillance systems is not just about *what* types  
63 of information we monitor, but also *who* and *how* knowledges are connected through existing networks  
64 of monitoring and response.

65 **Conclusion:** Applying conventional approaches to surveillance, without deliberate consideration of the  
66 broader contextual and relational processes, can lead to the re-marginalization of peoples and the  
67 reproduction of inequalities in power between groups of people. We anticipate that our findings can be  
68 used to inform the initiation of a place-based integrated climate-food-health surveillance system in  
69 Kanungu District.

70 **Keywords:** public health surveillance, subsistence food systems, climate change, seasonal variability,  
71 knowledges, participatory knowledge holder mapping, place-based monitoring and response, networks,  
72 Uganda

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79 1. Background

1  
2 80 Climate change impacts human, animal, and environmental health globally (1–5). Extreme climate  
3  
4 81 and weather events are projected to reduce food production, availability, access, and utilization (6–8). As  
5  
6 82 well as impacting the quantity and quality of food, climate change is expected to alter the nutritional  
7  
8 83 composition of food (6). Undernutrition associated with drought and flooding may be one of the most  
9  
10 84 important consequences of climate change with extreme estimates suggesting that up to half the world’s  
11  
12 85 population could face severe food shortages by the end of the century (9). The effects of food insecurity  
13  
14 86 linked to climate change will be exacerbated in areas already vulnerable to risk of hunger and  
15  
16 87 undernourishment (2,7,8). Subsistence communities that are dependent on food systems for their  
17  
18 88 livelihoods and sustenance are expected to experience increased vulnerability (8,10–15).  
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23 89 Climate change impacts on health, caused by changes in local and Indigenous subsistence food  
24  
25 90 systems and food security, are substantial and may exceed other climate-related health impacts (16).  
26  
27 91 However, the impacts of climate change on health include present known risks, as well as future known  
28  
29 92 and unknown risks, and the data we have are limited (9,17). Improving evidence based surveillance  
30  
31 93 methods that capture information about the impacts, exposures, and vulnerabilities of climate change to  
32  
33 94 health will be critical for communities and institutions in adapting a response to climate change (1,18,19).  
34  
35 95 Globally, integrated climate and health surveillance systems are essential for monitoring present and  
36  
37 96 future health effects, as well as guiding public health responses (1,18). Understanding the attributable  
38  
39 97 impact of climate change on specific health outcomes, such as undernutrition, and reducing associated  
40  
41 98 risks of exposure and vulnerability, like food security, requires an approach that prioritizes surveillance  
42  
43 99 across multiple spatial and temporal scales (17). Leveraging existing surveillance systems, that both  
44  
45 100 monitor and use information about the health impacts, exposures, and vulnerabilities to climate change,  
46  
47 101 will be critical in building an integrated evidence-base of both known and unknown, present and future,  
48  
49 102 risks (20,21). The use of information that monitors the impact of interventions or policies to mitigate  
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51 103 these risks will also be vital.  
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104 Existing surveillance systems and conventional epidemiological approaches, however, do not always  
1  
2 105 consider broader contextual, cultural, historical, social and political processes of health inequities, and  
3  
4 106 thus have the tendency to further discriminate against and omit marginalized groups of people (22–26).  
5  
6 107 Place- and community-based forms of monitoring and response are important in underpinning the  
7  
8 108 development of both an integrated as well as equitable evidence base that will inform our understanding  
9  
10 109 of climate-health impacts (27–32). Meaningful engagement of local communities, Indigenous peoples,  
11  
12 110 and experts in this surveillance process not only helps build an evidence base that is equitably diverse and  
13  
14 111 locally meaningful, but also informs the usability of information and connects knowledges<sup>1</sup> into decision-  
15  
16 112 making and action-oriented processes (32–38). Yet place- and community-based forms of surveillance are  
17  
18 113 not uniform, and involve communities and experts in different ways, to different extents, and at different  
19  
20 114 stages (39). The degree of inclusion and leadership plays an important role in determining the extent to  
21  
22 115 which surveillance systems will be locally relevant, contextually-appropriate, sustainable over time, and  
23  
24 116 able to create impact within communities (38,40,41).  
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31 117 A surveillance system includes various stages of monitoring and response: initiation, design,  
32  
33 118 implementation, analysis, dissemination, action, and evaluation. Each stage holds an opportunity for  
34  
35 119 community engagement. A systematic literature review of place-based integrated climate-health  
36  
37 120 surveillance systems globally identified practice gaps in the inclusion of local communities, Indigenous  
38  
39 121 peoples, and diverse knowledges for each of these surveillance stages (32). The potential for greater  
40  
41 122 engagement and leadership in problem definition, tool and indicator development, as well as data  
42  
43 123 ownership and sovereignty in place-based integrated surveillance systems was also highlighted. This  
44  
45 124 paper will focus on improving the practice gap in the initiation stage of surveillance, specifically how local  
46  
47 125 communities, Indigenous peoples, and diverse knowledge holders can, and do, contribute to and/or lead  
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49 126 the definition of meaningful problems, in their own terms. The extent of inclusion and leadership in the  
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57 <sup>1</sup> Knowledge, as a noun, is pluralized throughout the paper to reflect the diversity of knowledge forms and  
58 dimensions embedded in unique systems, networks, and individual holders' experiences (42,103). Knowledge  
59 systems are not always mutually exclusive neither are they distinguishable nor categorizable by consensus (104).  
60 We acknowledge that there is far more diversity and variety than could ever be captured in the networks of  
61 knowledge, monitoring, and response presented here.  
62  
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65

127 initiation stage can inform the subsequent stages of surveillance design and implementation. Particularly  
128 when place-based and Indigenous communities are partners from the inception, we see how decision-  
129 making and procedural processes can be influenced in a way that reflects more than just scientific  
130 practices and ways of knowing (42). Connecting diverse knowledges—technical public health, tacit local,  
131 and Indigenous—through participatory approaches in surveillance systems is both an entry point as well  
132 as a requirement for the just integration of place-based climate-food-health surveillance responses. In  
133 the valuing of diverse worldviews there is opportunity for new epidemiologies and equitable forms of  
134 surveillance that can respond to the impacts of climate change on health via food systems (23).

## 135 2. Methods

### 136 2.1. Study Context

137 The Batwa are Indigenous people of the Congo Basin (Uganda, Democratic Republic of the Congo,  
138 Rwanda, Burundi) and the oldest recorded inhabitants of the Great Lakes Region in Central Africa (43). In  
139 1991, the Batwa were evicted from their ancestral land, the Bwindi Impenetrable Forest, in denunciation  
140 of their rights as Indigenous peoples (44). The Bakiga people of southwestern Uganda (and northern  
141 Rwanda) are the fourth largest ethnic group in Uganda, comprising approximately 7% of the population.  
142 Situating our research in Kanungu’s cultural and historical context is vital because it helps us recognize  
143 how underlying issues of land dispossession, acculturation of Indigenous ways of knowing, and ethnic  
144 discrimination may create differences in power, knowledge, and information within communities, and  
145 affect how we conduct place-and community-based research.

146 Kanungu is a district located in the southwestern region of Uganda, sharing its western border with  
147 the Democratic Republic of the Congo (Figure 1). Population estimates for the district were 274,900  
148 people in 2020 (45). Kanungu District has 35 Level 2 health centres (HCII—serve as the interface between  
149 the community and healthcare system, consisting of outpatient clinic facilities, with in-charge nurse), 15  
150 Level 3 health centres (HCIII—comprise basic curative and preventive services, 24 hour maternity,  
151 accident and emergency services, inpatient facilities including minor surgery, with in-charge clinical  
152 officer), and 2 general hospitals with the nearest regional referral hospital in Mbarara (146 km) (46–48).

153 The Ugandan health system is a combination of private and government financed facilities and services.  
1  
2 154 Our study catchment is served by both a private health centre as well as government financed facilities,  
3  
4 155 including those receiving support from NGOs and development partners. Indigenous medicinal  
5  
6 156 knowledge and traditional medicinal knowledge also provide a network of care for communities in this  
7  
8  
9 157 area (49). Our case study is focused in four sub-counties and 10 settlements surrounding the Bwindi  
10  
11 158 Impenetrable National Park. Research sites were selected based on their projected vulnerability to  
12  
13 159 climate-food-health impacts (15,50), as well as ongoing climate change and food security research  
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16 160 partnerships with local communities and Indigenous peoples (51). Many communities living in this region  
17  
18 161 rely on the small-scale farming of agriculture and livestock for their subsistence; both for sustenance and  
19  
20  
21 162 income generation. This dependence means their livelihoods and health are vulnerable to changes in  
22  
23 163 weather and climate.

26 164 Regional climate projections for Africa indicate an increase in average annual temperatures that is  
27  
28 165 likely to exceed 2°C by the end of this century (52). Over this period, the range of warming in East Africa  
29  
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31 166 is likely to be anywhere from 1.7-5.4°C (53). Models of rainfall projections for Uganda indicate an  
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33 167 increase in average rainfall, with changes in rainfall varying dramatically by region and season (March,  
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35 168 April, May and September, October, November) (54,55). Across the continent changes in extreme  
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38 169 weather (both wet and dry) may become more severe (56). These climate projections are regionally  
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40 170 scaled, however, with a lack of localized meteorological information and services (the nearest operational  
41  
42 171 weather station is 47 km away in Kabale) making the ability to provide locally relevant and accurate  
43  
44 172 weather and climate predictions poor. The most likely projections for Kanungu District include: greater  
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46 173 extremes in weather with more variability in seasonal trends; wetter rainy seasons that will be more  
47  
48  
49 174 prone to flooding; hotter and drier dry seasons that will be more prone to droughts. Furthermore, the  
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52 175 security, productivity, and yield of local rain-fed food systems are particularly vulnerable to the mean and  
53  
54 176 variability of temperature and precipitation described (6,54,55,57).

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## 178 2.2. Framework: Applying a case study approach to the initiation of a place-based integrated climate-food- 179 health surveillance system

180 This research draws on ongoing climate-food-health collaborations with Batwa and Bakiga  
181 subsistence communities in Kanungu District of southwestern Uganda and responds to the practice gap of  
182 ethical community engagement and leadership in place-based integrated surveillance initiation. To do  
183 this we used an applied case study approach (58–64). We developed a framework with four components  
184 to inform the research process and contribute to improving place-based integrated surveillance initiation  
185 (Figure 2). Specific questions emerged and were used to guide our investigation of health and  
186 subsistence food systems: what forms of monitoring and knowledge exist; who holds knowledge; how  
187 does information flow; and why might information flow this way? We anticipated that by starting from  
188 the beginning—learning the context in which a place-based surveillance system is initiated, designed,  
189 implemented, and evaluated—would create space for needed ethical engagement, usable information,  
190 and appropriate courses of action in each stage of surveillance.

191 The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)  
192 defines a knowledge system as “a body of propositions that are adhered to, whether formally or  
193 informally, and are routinely used to claim truth” (65). Furthermore, knowledge systems can refer to the  
194 developed and validated understandings, skills, philosophies, and ways of knowing that inform decision-  
195 making about fundamental aspects of life, from day-to-day activities to longer-term actions and  
196 governance (66). Some, like Indigenous knowledge systems, are embodied, relational, placed-based  
197 systems, inseparable from the socio-cultural, political, legal complexes that include language,  
198 classification, resource use practices, social interactions, values, ritual, and spirituality (66–68). Others,  
199 like local knowledge systems, are acquired from experiences, observations, explanatory inference, and  
200 interpretations; they are not necessarily based in wider systems or cultures. Latulippe and Klenk (2020)  
201 highlight the importance of understanding the place-based relations and obligations that give rise to  
202 holistic knowledge systems (68). While Starkey et al. (2017) emphasize the importance of mapping local  
203 knowledges and systems as a key part of understanding community-based surveillance processes (63).  
204 Similarly, Schneider and Lehmann (2016) highlight the need to map knowledge holders and key actors



205 within the community health system, as well as the relationships between them “...as they will shape  
 206 what can be achieved in [and by] communities and will therefore need to be understood and  
 207 engaged”(62).

### 208 2.3 Data Collection and Analyses

209 Table 1 outlines our mixed design, describing the methods of data collection and analyses for each of  
 210 the four conceptual framework components (Figure 2) that were used to define, understand, and  
 211 contextualize place-based integrated climate-food-health surveillance initiation in our case study (59,69–  
 212 71). Key informant interviews were used to collect data about *what* forms of monitoring and knowledge  
 213 exist (formally or informally) about health and subsistence food systems as they relate to seasonal  
 214 variability. In addition to interviews, a participatory mapping exercise was used to identify *who* holds  
 215 knowledge about health and subsistence food systems. Social network analysis was used as a  
 216 methodological approach to explore *how* information flows between knowledge holders as well as the  
 217 power and agency that is involved in knowledge production and exchange processes. We considered the  
 218 intended nature of participatory processes in research more broadly, which attempt to offer ethical,  
 219 adaptive, inclusive, and reflexive methodologies for empowering the holders of multiple and diverse  
 220 knowledges (22,23,72–76). Throughout the entire research processes, a reflexive research journal was  
 221 kept by the lead investigator to reflect on positionality—as non-Indigenous, mostly non-local,  
 222 researchers—and how this may have influenced the process and these findings.

223 **Table 1.** Conceptual framework components and associated research methodologies.

Framework Component	Data Collection Methods	Data Analysis Methods
What—existing forms of monitoring and knowledge	Key Informant Interviews	Manifest Content Analysis
Who—knowledge holders	Key Informant Interviews	Manifest Content Analysis and Quantification
	Participatory Mapping	
How—information flows and patterns of connectivity	Key Informant Interviews	Descriptive Network Analysis
	Participatory Mapping	
Why—information flows and relationships and dynamics of influence	Key Informant Interviews	Latent Content Analysis

224 **Component: What**

1  
2 225 We conducted 22 key informant interviews to map *what* forms of monitoring exist and knowledges  
3  
4 226 that are held locally (formally or informally) about health and subsistence food systems. Members of the  
5  
6 227 research team (BvB, ST) identified an initial group of potential participants based on their positionality  
7  
8 228 within the local health and/or subsistence food systems. Additional participants were recruited using  
9  
10 229 targeted snowball sampling. The distribution of participants included representation from all (n=10) of  
11  
12 230 the Indigenous subsistence communities and associated sub-counties: Kayonza (n=13), Kanyantorogo  
13  
14 231 (n=5), Nyamirama, and Kirima (n=4) in Kanungu District, Uganda in 2018. Participants were purposively  
15  
16 232 selected to include a range of knowledge holders, from subsistence community members, chairpersons,  
17  
18 233 village health teams, clinical in-charges, and sub-county officials (Table 2). Just over half of those  
19  
20 234 interviewed (n=12) were women. Interviews were conducted by the lead investigator (BvB) and a local  
21  
22 235 researcher (ST) in either Rukiga or English, depending on the participant's preference. Interview topic  
23  
24 236 guides and questions focused on current health and subsistence food systems in terms of the local, often  
25  
26 237 seasonal, activities (MAMJJ, 2018). Participants were also asked to share examples of changes they had  
27  
28 238 experienced, either in this rainy season or over multiple growing seasons, in terms of health (i.e.  
29  
30 239 incidence of disease, severity of symptoms, behaviours, health promotion, associated and perceived risks)  
31  
32 240 and/or food (i.e. subsistence farming activities, times of harvest, yields, supply) (Supplementary Material  
33  
34 241 1). Manifest content analysis of the interview data was performed (70).

42 **Component: Who**

43  
44 243 A participatory mapping exercise accompanied key informant interviews to define *who* holds  
45  
46 244 knowledge about health and food systems. Participatory mapping is a process in which participants  
47  
48 245 created their own visual 'map' of influential and knowledgeable actors engaged in monitoring and  
49  
50 246 responding to health and subsistence food information (77–80). This approach is adapted from  
51  
52 247 participatory research and methodologies, like multi-level stakeholder influence mapping, which are used  
53  
54 248 in the context of climate change adaptation research to help elucidate relationships and power dynamics  
55  
56 249 within and between diverse perspectives of actors and groups (77,80,81).

250 In scoping discussions with members of the research team, drawing from our own local knowledge  
1  
2 251 (ST) and experience (LBF, SL), we compiled a list to begin an initial round of interviews with potential  
3  
4 252 knowledge holders. Interviews with key informants were used to validate the list of knowledge holders.  
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7 253 The list was then used to prompt the participatory mapping exercise. In this exercise, participants were  
8  
9 254 given a blank sheet of paper with labelled x-knowledge and y-influence axes and a series of coloured  
10  
11 255 stickered labels. Some had labels already printed from the first round of potential knowledge holder  
12  
13 256 identification, while others were blank for participants to write their own responses. Throughout the  
14  
15 257 interviews, participants could either confirm, add, or subtract identified knowledge holders to the page.  
16  
17 258 Labels were placed within quadrants according to how knowledgeable and or influential each labelled  
18  
19 259 individual or organization was in their respective monitoring information networks (77,80,82,83).  
20  
21 260 Applying this participatory mapping technique across key informant interviews led to an iterative list of  
22  
23 261 identified key knowledge holders and the number of times they were referenced. The iterative nature of  
24  
25 262 identifying knowledge holders contributed to the analytical rigour of the research process and findings  
26  
27 263 (75). We applied manifest content analysis and quantification of both the interview and participatory  
28  
29 264 mapping data (70). Members of the research team with extensive contextual experience and knowledge  
30  
31 265 also reviewed knowledge holder and information categorizations.  
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### 266 **Component: How and Why**

267 We applied social network theory and analysis methods to map and assess *how* information flows  
38  
39 268 and is connected between knowledge holders. Network analysis is an approach used to characterise the  
40  
41 269 relationships and structures between individual actors and organizations (84–86). Networks are used to  
42  
43 270 visually represent features of the relationships and relational properties between key knowledge holders.  
44  
45 271 A central focus in social network analysis is how individuals are embedded into larger structures; often  
46  
47 272 through their own agency (85). Social network theory and methods have been applied to understand  
48  
49 273 how rural community networks operate and share information to adapt to climate change variability, and  
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51 274 which actors are likely to affect rural climate change adaptation strategies (87).  
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275 We organized the data from the interviews and maps into blocked asymmetric matrices in Microsoft  
1  
2 276 Excel (Supplementary Material 2) and visualized the spreadsheet data using Tableau Desktop (2018) (85).  
3  
4 277 Network data were cleaned. Some identified knowledge holders were grouped together (i.e. district  
5  
6 278 officials were grouped under the district technical planning team; religious leaders were included under  
7  
8 279 local leaders; community drug distributors were grouped with village health teams). We used our  
9  
10 280 network graph (Tableau Desktop) and blocked asymmetric matrices (Microsoft Excel) to identify and  
11  
12 281 assess patterns of reciprocated information flows—the number of times information flows from a  
13  
14 282 knowledge holder (out-degree) and to another knowledge holder (in-degree). Examples of this were  
15  
16 283 educational information during a vaccination campaign, adaptive learning in response to drought, change  
17  
18 284 in the incidence of disease within a community or household. We analyzed the *centrality* of a knowledge  
19  
20 285 holder, as indicated by the size of the node and the number of times information flows both to and from  
21  
22 286 a specific individual (64). We analyzed the *connectivity* of knowledge holders, occurring between  
23  
24 287 groupings of monitored information, knowledge networks, and administrative levels (64). We analyzed  
25  
26 288 reciprocal flows of information within groups (85), and on bridging flows of information between groups  
27  
28 289 (87). The network analysis was further complemented by latent content analysis of interview data to  
29  
30 290 further contextualize the relationships and dynamics influencing *why* information might flow a certain  
31  
32 291 way (70,88). Members of the research team with extensive contextual experience and knowledge also  
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34 292 reviewed matrices and network interpretations.  
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### 293 3. Results

#### 294 3.1 Defining *what* knowledges are already held locally and by *whom*

295 Participants discussed information held by knowledge holders within their respective health and  
46  
47 296 subsistence food systems. Narratives reveal inventories of ongoing and repeated cycles of observations,  
48  
49 297 interpretations, evaluations, and adjustments that make up existing health and subsistence food  
50  
51 298 monitoring and response. This information was about present local, often seasonal, health—holding  
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53 299 clinics, monitoring households, making referrals, conducting outreach—and subsistence activities—  
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55 300 clearing the land, planting, harvesting, and preparing food. Knowledges conveyed were both tacit and  
56  
57 301 technical in nature (89), including an inherent understanding of their roles and responsibilities as holders,  
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1  
2 302 as well as how these activities fit within a wider network. Participants gave examples of both the short-  
3  
4 303 term (present season) and long-term (multiple seasons) changes they were experiencing. Changes  
5  
6 304 observed included the reliability of environmental cues, disruptive and unusual weather events, the  
7  
8 305 associated and perceived risks of those extreme weather events, subsequent behaviours, and subsistence  
9  
10 306 practices. Participants mentioned changes in the crops that they cultivate, for example, cassava and  
11  
12 307 potatoes are more resilient to drought than beans and millet [Key Informants 11, 15,18]. One  
13  
14 308 subsistence community member shared changes about where they cultivate, for example, potatoes are  
15  
16 309 planted lower in the valley if the season is dry and the rains are late [Key Informant 17]. Another  
17  
18 310 participant spoke about changes in the way they cultivate, for example, observing soil decline in some  
19  
20 311 plots of cultivated land [Key Informant 15]. Regardless of their role, many participants held knowledge  
21  
22 312 about experienced changes in the incidence and seasonality of vector-borne and diarrhoeal diseases,  
23  
24 313 including malaria and cholera [Key Informants 1, 3,6, 9, 10.1, 10.2, 14]. One health assistant mentioned  
25  
26 314 behaviours and health promotion activities that needed to occur seasonally, such as deworming and  
27  
28 315 vaccination campaigns in preparation for the rainy season (i.e. March and April; September and October)  
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31 316 [Key Informant 1].  
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36 317 Participatory mapping identified 35 different knowledge holders. Identified individuals represented a  
37  
38 318 diverse range of knowledges and influences including subsistence community members, appointed  
39  
40 319 chairpersons, elected councillors, clinical health professionals, public health outreach personnel, village  
41  
42 320 extension health workers, district officials, administrative chiefs, non-governmental organizations,  
43  
44 321 researchers, as well as educational and religious representatives. Knowledge holders engaged either  
45  
46 322 directly or indirectly with information relating to local health and subsistence food systems. For example,  
47  
48 323 NGOs and development partners were viewed as knowledgeable about subsistence food and farming  
49  
50 324 systems by the training and expertise they provided, while clinical and public health care professionals  
51  
52 325 were recognized as knowledgeable by the point-of-care treatment and preventative outreach they  
53  
54 326 provided. Politically-oriented knowledge holders, such as elected area councillors and administrative  
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56 327 chiefs, engaged indirectly with both health and subsistence information networks. They were considered  
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328 to have influence through their ability to liaise and mobilize those who had knowledge and monitored  
329 information. To define this cohort of knowledge holders we used a flow of categorical attributes: (1) the  
330 monitoring of information they engage in; (2) the knowledge networks that they are embedded in; and  
331 (3) the administrative levels that they operate within (Figure 3). Several community “systems” emerged  
332 throughout participant discussion (i.e. political, council, administrative, religious, traditional, health,  
333 medical, research, agricultural) and were thematically grouped into knowledge networks: western-  
334 scientific, political, administrative, Indigenous, local. The different administrative levels are widely used  
335 classifications in this context.

336 Table 3 breaks down how the attributes map onto each of the different knowledge holders. The  
337 final column indicates the numbers of times a knowledge holder was identified during the participatory  
338 mapping and interview processes. In general, these networks show a density of information diffusion and  
339 knowledge exchange between all members. Knowledge holders identified more frequently were largely  
340 from local knowledge, Indigenous knowledge, and western scientific knowledge networks that operated  
341 across village, parish, and sub-county administrative levels. Knowledge holders operating at the district  
342 level were largely categorized as administrative and scientific knowledge holders, they were not identified  
343 as frequently, with less central and connecting roles. Notably, there was no explicit evidence of climate-  
344 specific information present in these networks.

### 345 **3.2 Understanding *how* information, knowledge holders, and systems are connected**

346 Subsistence community members were identified as central knowledge holders in these networks  
347 and notably where information about health and subsistence food systems converge. These were  
348 members of subsistence-based farming communities, reliant on each other for generating and sharing  
349 knowledge about agricultural cycles and practices. The community chairpersons, local, and religious  
350 leaders were all seen as trusted and influential representatives situated at both the village and parish  
351 levels of administration. Leaders formed a critical connection between the community and local  
352 councillors, as well as development and research partners. They also served on different boards and  
353 committee meetings. While a lot of information came from outside of the community (i.e. NGOs, local

1 354 area councillors, health assistants, etc.), important information still came from ancestral knowledge and  
2 355 tradition. Traditional herbalists were identified as knowledge holders for information relating to health.  
3  
4 356 The Bataka, a self-organized, social welfare group devised by the community, was also identified in the  
5  
6 357 network. This group meets regularly, face-to-face, to organize collective financing, loans, health  
7  
8 358 insurance, and other activities based on identified need such as funerals and emergency transport to the  
9  
10 359 nearest health facility.  
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14 360 Local councillors (LC) were identified as influential knowledge holders, engaged in decision-making  
15  
16 361 processes from the village (LC1) to the district (LC5). These were elected representatives, who facilitated  
17  
18 362 political links with the village, parish, sub-county, and district administrative levels of knowledge holders  
19  
20 363 and systems. NGOs and development partners refer to independent organizations with programmes  
21  
22 364 broadly focused in areas of development. Despite being classified as knowledge holders by numerous  
23  
24 365 participants, however, they did not play a central role in the matrix depicted (i.e. there were fewer  
25  
26 366 number of lines connecting these nodes). Most participants did not make a distinction between different  
27  
28 367 NGOs and development partners, or their respective programmes, operating within food and health  
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30 368 information systems (Table 3).  
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36 369 The Bwindi Community Hospital, a private health care facility in Kanungu, was also considered a  
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38 370 central point for monitoring and responding to health information. The hospital has the resources to  
39  
40 371 extend some outreach services directly into the communities through community nurses, health  
41  
42 372 extension workers, and outreach teams. The health assistant (HA) was identified as playing a critical role  
43  
44 373 to connect the spaces between clinic-based and community-based health monitoring and response  
45  
46 374 across different levels of government administration. HAs are public health professionals concerned with  
47  
48 375 health promotion and outreach. While situated at the sub-county level, they are also seen as  
49  
50 376 'fieldworkers' in the village, for example, making seasonal household visits to monitor sanitation practices  
51  
52 377 or deworming and vaccination coverage. The in-charge referred to the nurse or clinical officer 'in-charge'  
53  
54 378 of the health centre (II or III). Their clinical training and responsibility identified them as knowledgeable  
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56 379 about information relating to health management and treatment. They engage in monitoring and  
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1 380 response at both the parish and district levels. This includes using clinical records and data to make  
2 381 clinical observations and decisions, as well as receiving written referrals from the community. Village  
3  
4 382 health teams (VHT) were considered active community monitors and observers nested within Indigenous  
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6 383 knowledge, local knowledge, and western scientific knowledges networks. Typically, they are members of  
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8  
9 384 the community themselves, appointed to carry out household visits, make written hospital referrals, and  
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11 385 ongoing follow-up care. While mainly focussed at the village level, they connect through the VHT  
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13 386 coordinator and link facilitator to feed health-related information into monitoring and response  
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15 387 mechanisms such as the technical planning team meetings at the district level.  
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19 388 The district technical planning team (DTPT) consists of the chief administrative officer and sub-county  
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21 389 chief, with expert representatives and officials in health (health inspector), environment (natural resource  
22  
23 390 officer), agriculture (agricultural officer), social welfare (community development officer), wildlife  
24  
25 391 (Uganda Wildlife Authority), security (police officer), finances (chief financial officer), and education  
26  
27 392 (teacher representative). Together they are seen to provide a channel for monitoring information,  
28  
29 393 relating directly and indirectly to local health and food systems, to flow into decision-making and  
30  
31 394 response processes. Reports are taken directly from the village, parish, and sub-county and brought into  
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33 395 deliberation at these meetings. Similarly, decisions are implemented by key representatives directly into  
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35 396 sub-county, parish, and village administration and practice.  
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41 397 Figure 4 represents a subset of this network to elucidate the dynamics detailed above between how  
42  
43 398 information, knowledge holders, and networks are connected. The centrality of the community members  
44  
45 399 is observed with numerous flows of information to and from. We note the connectivity of the health  
46  
47 400 assistant, the diversity of information they engaged with, across village, parish, and sub-county levels of  
48  
49 401 administration. The LC is distinguished by being the only member identified from the parish  
50  
51 402 administrative level (4a) and political knowledge system (4b). Finally, the VHT's unique position is made  
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53 403 apparent by their bridging of diverse networks of Indigenous knowledge, local knowledge, and western  
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55 404 scientific knowledge.  
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### 406 3.3 Contextualizing the connectivity of systems and networks

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2 407 Those in political or administrative positions, such as local councillors, chiefs, chairpersons, were  
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4 408 recognized by most informants as being key to monitoring information networks, having the ability to  
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6 409 liaise and mobilize across information networks [Key Informants 1, 6, 7, 9]. As one clinical officer  
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9 410 explained,

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12 411 *If you want something to come out properly, then the political structure backed by administrative*  
13 412 *structures, then things can be, what, be pushed... because these political leaders, once they give*  
14 413 *voice, once involved everything is implemented...the political system helps the community own*  
15 414 *it...but once we leave [the political leaders] behind [sighs] then we are lost completely [Key*  
16 415 *Informant 6].*

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19 416 This same informant also identified four systems of stakeholders (health, political, administrative, and  
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21 417 religious), suggesting that by combining these systems and stakeholders meant that “whatever you  
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23 418 wanted can be implemented”. Local area councillors (LC1, LC2, LC3) were recognized as influential and  
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25 419 authoritative individuals that can link between administrative levels (1-village, 2-parish, 3-sub-county). As  
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28 420 two VHTs suggested, “they have the authority to command” [Key Informant 10.1, 10.2]. Regarding the  
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30 421 communication channels and mobilization within these information networks numerous participants  
31  
32 422 considered “the LC system [to be] very helpful” [Key Informant 2, 4, 7,9, 10.1, 10.2]. Community leaders,  
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34 423 such as designated chairpersons and elected councillors, provide links for subsistence communities to  
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37 424 political and health networks [Key Informant 16].

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41 425 Information flows within and between neighbouring Batwa and Bakiga subsistence communities were  
42  
43 426 identified as a key pathway for adaptive learning and sharing information about food, farming, as well as  
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45 427 resulting changes in subsistence practices [Key Informants 11, 12, 14, 15, 16, 19, 20]. For example,  
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48 428 drought and resulting challenges with food security and farming adjustments experienced in one  
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50 429 subsistence community were also raised by a member of a neighbouring community that was concerned  
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52 430 about potential threats to their water security [Key Informant 14].

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55 431 VHTs were identified as active community monitors and observers. They described how they were  
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57 432 “responsible for knowing every household in their catchment area” [Key Informants 10.1, 10.2]. Here,  
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59 433 information flows between households and health centres to identify health issues, deliver and receive

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434 care, educate, and promote health-related behaviours. Rather than relying on individual households to  
435 initiate information flows, focal persons (with a supported level of training and expertise) are identified  
436 from within the community to take on the responsibilities of actively monitoring households. VHTs are  
437 trusted representatives that link necessary health information to, and from, communities.

438 At the community level, several platforms exist for facilitating information flow within health and  
439 subsistence food networks. An interesting example of an existing community information-sharing  
440 channel is the Bataka—a community-led social welfare group. For both Batwa and Bakiga communities,  
441 these groups “have power at the community level” by helping subsistence communities organize  
442 collective financing, loans, and insurance themselves [Key Informants 8.1, 8.2, 13, 15, 15, 17, 20]. Several  
443 informants considered intergenerational knowledge transfer as a useful mechanism of information flow.  
444 Examples of this included teachings and transfers of herbal and medicinal knowledge, how to ‘dig’, when  
445 to plant, when to harvest, and observations of long-term seasonal and environmental cues [Key  
446 Informant 11, 15, 17, 19, 20]. Another example of a community information-sharing platform was  
447 through religious leaders and groups, “because they have a good platform to *give* information” ... “to  
448 preach the gospel of environmental health and sanitation... and the followers listen to them” [Key  
449 Informants 1, 2, 3, 6, 8.1, 8.2, 13]. The radio was also considered a channel for facilitating information-  
450 sharing with community members from weather forecasts, agricultural updates, health promotion, and  
451 outreach [Key Informants 10.1, 10.2, 11, 15, 18]. It is an established platform used to “teach the whole of  
452 Kanungu” [Key Informants 10.1, 10.2]. Face-to-face meetings are also used as channel for sharing and  
453 processing information. From the Technical Planning Team Meetings held at the District, to quarterly  
454 meetings in the communities mobilized through VHTs, Coordinators, and HAs. VHTs explained how, in  
455 the event of a localized outbreak identified by presentations to the health centre, they would trace  
456 symptoms back into the communities to initiate primary and secondary treatment plans [Key Informant  
457 10.1, 10.2].

458 While there was no explicit evidence (or perhaps recognition) of ‘Climate Information Holders’, it was  
459 still a category that appeared inherently in local health and subsistence food information systems. At this

1  
2 461 level of local experience, the easiest way to talk about and understand climate is in terms of weather.  
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5 462 There was no mention of local, regional, or nationally recognized climate and weather affiliated  
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7 463 organizations. It seemed that knowledge about climate and seasonal change was not recognized (either  
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9 464 formally or informally) in the same manners as other knowledge about health and food, for example, in  
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11 465 the way that people had control over it or could 'hold' it. One key informant mentioned that while they  
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13 466 may rely on information from other knowledge holders, both inside and outside of their immediate  
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15 467 networks, they cannot blame people when this information is wrong since the weather has been so  
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17 468 unpredictable [Key Informant 11]. For example, when unexpected amounts and/or duration of rain spoil  
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19 469 the crops, disrupt the harvest, and lower the yields. Or similarly, when a delayed onset of rain, or  
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21 470 prolonged period of drought, prevents the crops from germinating and people cannot cultivate enough  
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23 471 food for the season. Informants stated that people would often plant in accordance with seasonal  
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25 472 timeframes that they have learned and have been passed down for generations. It was also disclosed  
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27 473 that no adjustments to these timeframes were being made, even despite the weather being so  
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29 474 unpredictable, "we just leave it up to God" [Key Informant 13]. For knowledge holders, particularly health  
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31 475 affiliated knowledge holders, climate-related information was considered in relation to seasonality (i.e.  
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33 476 how malaria incidences increase in the rainy season), or simply environmental determinants of health (i.e.  
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35 477 water, sanitation, and hygiene), and not across longer temporal frames of seasonal variability and change.  
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#### 41 477 **4. Discussion**

42 478 This research maps existing networks of trusted relationships already used for integrating diverse  
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44 479 knowledges, information, and administrative action. As researchers and public health practitioners, we  
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46 480 tend to focus on the implementation stage of surveillance as being an easy entry point for opening the  
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48 481 process up to others (28,32,41,90). In this way, we allow for extractive approaches in practice that  
49  
50 482 disregard alternative, and sometimes divergent, ways of knowing embedded in diverse (non-western  
51  
52 483 scientific) knowledge systems (33,40). Applying conventional approaches to surveillance in this way,  
53  
54 484 without deliberate consideration of the broader contextual, cultural, historical, social and political  
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56 485 processes, can lead to the re-marginalization of peoples and the reproduction of inequalities in power  
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58 486 between groups of people (22–24). We present some of the core insights that have emerged from this  
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1 487 case study and how this work moves to fill the practice gap of meaningfully engaging local communities,  
2 488 Indigenous peoples, and diverse knowledge holders to drive equitable and integrated surveillance  
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4 489 initiation. We anticipate that our findings can be used to inform the initiation stage of a place-based  
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6 490 integrated climate-food-health surveillance system, both in Kanungu District, Uganda, and other local  
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9 491 contexts rich in a diversity of knowledges as well as existing forms of monitoring and response.  
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#### 11 492 **4.1. Information Needs**

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14 493 The networks of local health and subsistence food systems that we investigated were not supported  
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16 494 by distinct systems of climate and meteorological information. The diversity of perspectives within the  
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19 495 networks we investigated, however, means there will be a difference in climate and meteorological  
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21 496 information needs (35). This includes differences in how information is evaluated and used to make  
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23 497 decisions. For example, take the perspective of a public health professional deciding to conduct  
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26 498 community health promotion activities, or a clinical health professional managing referrals at a health  
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28 499 centre, or a smallholder farmer deciding when to plant their crops. While different knowledge holders  
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31 500 may engage in different information and knowledge networks, regardless of whether they are a health  
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33 501 practitioner or subsistence farmer, there is a need for specific information about the risks of climate  
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35 502 change, how they are changing, and adjustable action pathways for reducing those risks (9). Ebi and  
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38 503 colleagues suggest initiating surveillance systems that not only monitor and respond to the impacts of  
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40 504 climate change in standard health outcomes, but also consider indicators for vulnerability, exposures,  
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42 505 health system resilience, adaptive learning, and knowledge management (17). How the definitions and  
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44 506 measures of climate-related surveillance thresholds and indicators are chosen will impact the knowledge  
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47 507 holders and networks engaged in this process as well as the ensuing surveillance response (22,74). An  
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50 508 important part of developing a just place-based climate-food-health integrated surveillance system, one  
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52 509 that precipitates action, will be to determine what is considered accurate, relevant, and reliable climate-  
53  
54 510 related information in accordance with the diversity of knowledge holders represented (35). Integrating  
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57 511 climate information will affect the structure, content, and context of existing health and subsistence food  
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59 512 surveillance response in terms of what, who, how, and why (Figure 2). *How* we build on existing  
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1 513 relationships to produce new forms of knowledge and provide needed climate-weather information in  
2 514 community systems is a key way forward; with the possible added-value of this information depending on  
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4 515 how equitably new knowledge forms converge, or diverge, to create positive synergies with existing  
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6 516 knowledges (35). This will also apply if we are to understand *how* the monitoring of information and  
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9 517 knowledge networks are changing relationally in response to climatic and environmental changes.  
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## 11 518 **4.2. Knowledge Bridges**

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14 519 In the valuing of diverse worldviews there is opportunity to create new epidemiologies and equitable  
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16 520 forms of surveillance that can respond to the impacts of climate change on health through food systems  
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19 521 (23). Knowledge co-production has also been used as a lens to illustrate the relational processes that link  
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21 522 communication pathways (in our case reciprocal information flows) and knowledge systems with adaptive  
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23  
24 523 forms of learning and decision making (91). Equally, the relational bridges of information and knowledges  
25  
26 524 identified within our networks are important for facilitating iterative decision making and adaptive  
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29 525 learning in local health and subsistence food systems given the context of changing and inequitable  
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31 526 vulnerabilities, exposures, and hazards associated with climate change (9,17). Using the number and  
32  
33 527 reciprocity of relational processes in a network as a proxy to determine the efficiency of knowledge  
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35  
36 528 transfer and information diffusion (92), we suggest that most of the transfer and diffusion is happening  
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38 529 within and between Indigenous, local, and western scientific knowledge networks, as well as village,  
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41 530 parish, and sub-county administrative levels. In contrast, the reciprocal diffusion and exchange from, and  
42  
43 531 to, district levels and administrative systems was less apparent. Furthermore, we found that identifying  
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45 532 the flows of information between groups in our network allowed us to see the specific knowledge holders  
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47  
48 533 responsible for bridging between more than one knowledge network (n=9) and between more than one  
49  
50 534 administration level (n=11) (Table 3). For example, there were only two knowledge holders, VHT  
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52 535 coordinator and sub-county chief, who bridged both administration levels and knowledge networks.  
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54  
55 536 Perhaps a focus on these weaker bridging points could help improve adaptive forms of knowledge  
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57 537 transfer and information diffusion necessary for monitoring and responding to changes in local health and  
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59 538 subsistence food systems (87,93).  
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### 539 4.3. Knowledge Brokers

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2 540 If a bridge is a method by which information is diffused or knowledge is transferred between groups  
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4 541 (87), then *who* is positioned to bridge that information and knowledge is also important for initiating  
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6 542 equitable and integrated surveillance systems. From the identification of influential knowledge holders  
7  
8 543 within these systems, we found that not all knowledge holders needed to be directly associated with  
9  
10 544 health and subsistence food information to be identified in the network (n=11) (Table 3). This highlights  
11  
12 545 that there may be an important distinction between those who bridge networks through power and  
13  
14 546 influence, and those who bridge networks through knowledge and expertise. A knowledge broker is not  
15  
16 547 necessarily the expert who is the most knowledgeable, however, they can be well situated to connect the  
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18 548 people who are (94). For example, politically-oriented knowledge holders, such as elected area  
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20 549 councillors and administrative chiefs, were noted for their ability to liaise with and mobilize people, not  
21  
22 550 necessarily for the technical knowledge and capacity they had in health and subsistence food systems.  
23  
24 551 We can apply a similar rationale, based on how knowledge holders were identified, to determine  
25  
26 552 “proxies” for what is needed when establishing new network connections that broker the production and  
27  
28 553 use of climate and meteorological information (95). Having trusted intermediary knowledge brokers will  
29  
30 554 be an important part of integrating a climate-food-health surveillance system.  
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### 38 4.4. Positioning Knowledges and Power

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40 556 The relationships within knowledge systems shape the flows of knowledge, information, credibility,  
41  
42 557 and power within those systems (96). We reflect on how numerous participants with various  
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44 558 characteristics (Table 2), all outside the political system (Table 3), viewed those within the political system  
45  
46 559 as having the power to influence decisions that concerned them. Furthermore, while all identified  
47  
48 560 knowledge holders were considered “knowledgeable” in ways, some were referenced as having “more”  
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50 561 knowledge (i.e. VHT coordinators or link facilitators compared to VHTs; a clinical officer or health assistant  
51  
52 562 with many years of experience and education). However, experience alone was not a determining factor  
53  
54 563 for being considered “more” knowledgeable, with many subsistence community members and  
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56 564 chairpersons having decades of experience and intergenerational knowledge. Formal education and  
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58 565 training might also be criteria that influence how knowledgeable a person was considered, as well as their  
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566 access to knowledge systems and use of information. We note how highly dispersed knowledge can be at  
567 the local level, with different knowledge holders having access to different forms of information and  
568 knowledge. For example, the role that ethnicity has in accessing knowledge systems and monitoring  
569 information networks (both existing and potential). Those identified as having influential connecting roles  
570 were non-Indigenous knowledge holders. This must be a consideration in the future integration of a  
571 place-based surveillance system in a context whereby power can influence access to new forms of  
572 knowledge and information within communities. In this same context, land dispossession, lacking  
573 reparations, forced relocation, and shifting from forest-based to agriculture-based livelihoods inflict  
574 barriers to Indigenous knowledge transmission and generation. Therefore, sharing examples of  
575 Indigenous leadership and relationships in knowledge networks, such as connectedness of the Bataka,  
576 neighbouring settlements, and VHTs, becomes pertinent for informing research processes as well as  
577 future monitoring and response efforts. We cannot separate the research of existing knowledge  
578 networks from the politics that (re)produce inequalities of power between groups of people (68). Local  
579 hierarchies in health and subsistence food systems became apparent throughout the research process.  
580 For example, how any essential information needed to pass through the appropriate channels (i.e. DHT,  
581 DTPT), by specific persons or gatekeepers (i.e. VHT coordinators, HAs, LCs) to enact a community  
582 response. There is a risk that we as researchers engaged in place- and community-based research need to  
583 be aware of, which is that our methods reemphasize pre-existing inequalities and power dynamics,  
584 consolidating the position of people and gatekeepers within local hierarchies. Particularly when the  
585 diffusion of information and production of knowledge is so deeply rooted in power and influence.  
586 Discerning where influence is, and how power is distributed, within knowledge production processes will  
587 help to understand the context, and constraints, in which knowledges are being produced (91) and will be  
588 another critical part in the initiation of a place-based integrated surveillance system.

#### 589 **4.5. Next Steps**

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590 The surveillance of complex and uncertain interactions, like the impacts of climate change on health  
591 through food systems, requires us to disrupt our existing methods of inquiry and create space for multiple

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592 knowledge systems and diverse knowledge holders to produce new forms of knowledge (68,91,97–100).  
593 Effectively monitoring and responding to the impacts of climate change on health through subsistence  
594 food systems also means engaging across sectors and disciplines, like agriculture and meteorology, whose  
595 policies and programmes may also affect human health (1,9). While there may be limited climate change  
596 adaptation action planned in the Ugandan health sector, a focus on improving access to climate and  
597 weather information may be happening in other sectors, like agriculture, the benefits of which could be  
598 extended into health information and knowledge networks through partnerships (21,101). Brokering and  
599 bridging between agencies (like health, hydrological, and meteorological services) and communities (like  
600 the ones mapped here) can strengthen networks and help connect information and resources across  
601 sectors and disciplines (9,87,93). In the context of Kanungu District, potential collaborating bodies could  
602 be the national meteorological association (UNMA), or the Intergovernmental Authority on Development  
603 Climate Predictions and Applications Centre (ICPAC), or the Greater Horn of Africa Climate Outlook Forum  
604 (*GHACOF*). These organizations produce information on a range of scales from climate predictions, to  
605 seasonal forecasts, and daily weather forecasts. Bridging can also occur across different knowledge  
606 systems and cultural complexes to help establish long-term collaborative partnerships between  
607 knowledge holders in different groups (42). For example, VHTs, members of the local community with  
608 training in community health, can help bridge understanding and access between households and  
609 providers. Financing this bridging is another consideration for initiating and maintaining a place-based  
610 integrated climate-food-health surveillance system where health facilities and services, both government  
611 and private, struggle to finance targeted outreach services that extend into communities (102).

#### 48 612 **4.6. Study Limitations**

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613 The data collection for this case study was conducted over a period of 3 months and may not be well  
614 positioned to account for changes in networks over time. The analyses presented here are still  
615 representations of real, changing, and complex systems. Since networks are dynamic, much of what we  
616 investigate in this type of analyses is trying to understand how individuals are embedded within larger  
617 structures (85,88). Some flows of information may change depending on the individual occupying the



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618 position. This is particularly the case for more formally derived administrative or political positions and  
619 fixed-terms positions in which there might be high turn-over rates. We tried to account for some level of  
620 variation by including data sources from different sub-counties within the district. However, we  
621 recognize that similar analyses conducted over longer periods of time can provide deeper, more  
622 contextualized, understandings of network dynamics (92).

623 We also consider the bias inherent in the iterative snowball identification method and recruitment  
624 process of key informants. Using the support of other key informants has the potential to skew the  
625 composition of representation that reflects both the researchers' positionalities and key informants'  
626 subjective definitions of *who* is considered a focal group or individual, as well as bias the understanding of  
627 power and inequalities between groups (77,80). We observed that some knowledge holders had fewer  
628 reciprocal relationships (i.e. teachers, traditional healers, researchers). This may have been shaped by  
629 the perspective of our key informants and the experience they used to define these knowledge holders.  
630 Alternatively, the knowledge holders with the highest number of reciprocal relationships (i.e. subsistence  
631 community members, chairpersons, health assistant) were often roles occupied by key informants  
632 themselves.

## 633 5. Conclusion

634 Integrating place-based climate-food-health surveillance systems is not just about *what* types of  
635 information we monitor, but also *how* and *who* connects it through existing information monitoring and  
636 knowledge networks. Our findings emphasized the need to understand the unique contributions of  
637 diverse knowledge systems and holders as we prepare for and manage climate-food-health problems and  
638 impact pathways that are both evidence-based and locally relevant. Understanding existing network  
639 dynamics, boundaries, and interactions are an important part of the process in initiating and designing  
640 the integration of usable climate-food-health surveillance systems. A deep contextualized and relational  
641 understanding of existing community health and subsistence food systems will enable us to recognize  
642 existing and potential opportunities for bridging diverse knowledges and equitably integrating the  
643 information necessary for monitoring and responding to the impacts of climate change.

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## 6. List of Abbreviations

DHT—District Health Team

DTPT—Technical Planning Team

GHACOF—Greater Horn of Africa Climate Outlook Forum

HA—Health Assistant

HCII—Level 2 Health Centre

HCIII—Level 3 Health Centre

ICPAC—Intergovernmental Authority on Development Climate Predictions and Applications Centre

IPBES—Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

LC—Local Councillor

LC1—Level 1 Village Local Councillor

LC2—Level 2 Parish Local Councillor

LC3—Level 3 Sub-County Local Councillor

LC5—Level 5 District Local Councillor

MAMJJ—March, April, May, June, July

NGO—Non-Governmental Organization

VHT—Village Health Team

## 7. Declarations

### Ethics approval and consent to participate

This study was submitted to and approved by the Business, Environment, and Social Sciences (AREA) Faculty Research Ethics Committee, University of Leeds, United Kingdom, and the Makerere School of Social Sciences (MAKSS) Research Ethics Committee, Makerere University, Uganda. Written informed consent for data collection and publication was given by all participants. Identifying features were removed from the original data and not specified in reporting to respect participant confidentiality. For

1 example, an informant's role and sub-county were not linked to protect and prevent the reverse

2 identification of an individual.

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5 **Consent for publication**

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8 Not applicable.

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11 **Availability of data and material**

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14 The dataset supporting the conclusions of this article is included within the article and its additional files.

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17 **Competing interests**

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20 The authors declare that they have no competing interests.

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36 role in the study design; in the collection, analysis, and interpretation of data; in the writing of the  
37  
38 manuscript; or in the decision to submit for publication.

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41 **Authors' contributions**

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43  
44 Conceptualization, BvB; Data curation, BvB; Formal analysis, BvB; Funding acquisition, BvB, LBF, SL, DN,  
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46 SLH; Investigation, BvB, ST; Methodology, BvB; Project administration, BvB, ST; Supervision, LBF, RK, HE;  
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48 Visualization, BvB, LBF, SLH; Writing – original draft, BvB, LBF; Writing – review & editing, BvB, LBF, RK, SL,  
49  
50 DN, HE, SLH. All authors have read and approved the final manuscript.

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4 strengthen the manuscript.  
5

#### 6 Authors' information

7  
8 The authors of this paper are informed by diverse interdisciplinary backgrounds—global public health,  
9 epidemiology, geography, ethnography. While each are informed by different geographic and  
10 institutional contexts—academic, government, community—they share commonalities in place-and  
11 community-based research methodologies that seek to address greater societal challenges.  
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## 21 Figure Legends

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**Figure 1 a.** Map of Uganda with Kanungu District. By © OpenStreetMap contributors, Jarry1250, NordNordWest/Wikipedia. Available under [CC-BY-SA-3.0](https://creativecommons.org/licenses/by-sa/3.0/).

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**Figure 1 b.** Enlarged map of study area showing the case study sites of Indigenous subsistence communities ● as well as local health and administrative facilities ● in relation to the shaded area of Bwindi Impenetrable National Park.

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**Figure 2.** Four components used to inform the surveillance initiation and problem definition in a place-based integrated climate-food-health surveillance systems.

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**Figure 3.** Flow of categorical attributes used to define knowledge holders.

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**Figure 4a.** Grouped network of select identified knowledge holders and reciprocated information flows by administrative level.

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**Figure 4b.** Grouped network of select identified knowledge holders and reciprocated information flows by knowledge network.

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In both Figure 4a and 4b we have selected a subset of the most influential knowledge holders to visualize these network dynamics. These figures depict reciprocated monitored information flows—whereby the same set of knowledge holders send and received information from each other. The figure also shows centrality—the size of the node and the number of times information flows to and from them. We show the connectivity of knowledge holders within and between different groupings of monitored information, administrative levels, and knowledge networks.

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<b>Monitoring Information</b>	<b>Administrative Level</b>		<b>Knowledge Network</b>	
Health —————	Village	●	Indigenous	●
			Local	●
Subsistence Food - - - - -	Parish	●	Western Scientific	●
Health + Food —————	Sub-county	●	Administrative	●
Indirect —————	District	●	Political	●

**Table 2.** Key Informant Characteristics.

\*Numbering indicates instances where two key informants participated in one interview: 8.1, 8.2 and 10.1, 10.2

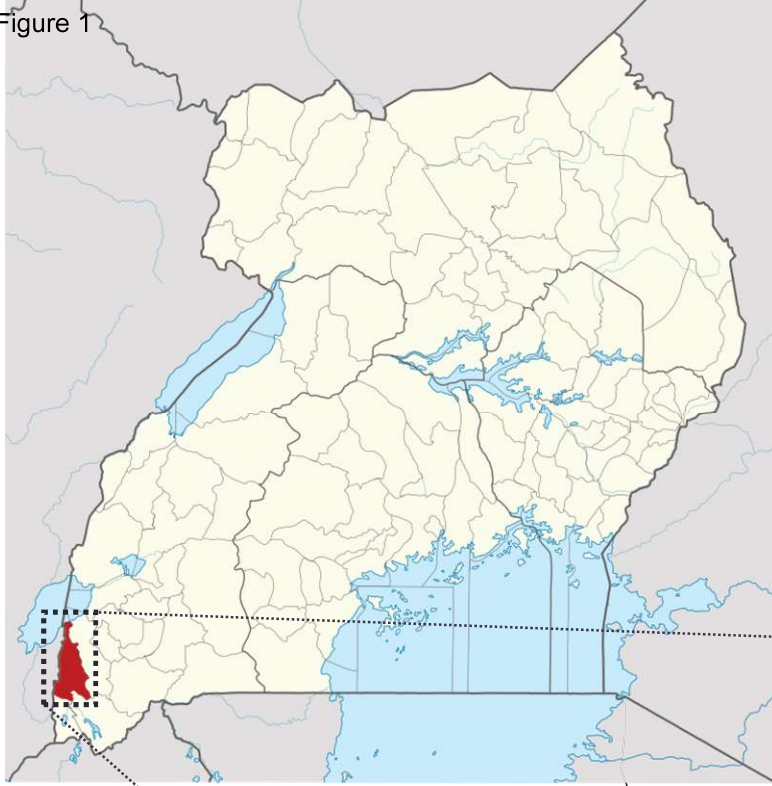
No.	Role	Gender	Ethnicity	Informant for Mapping Health Network	Informant for Mapping Subsistence Food Network
1	Health Assistant	Male	Bakiga	✘	✘
2	Community Development Officer (HCI)	Male	Bakiga		
3	Chief Medical Officer (In-Charge)	Male	Bakiga	✘	
4	Village Health Team	Female	Bakiga	✘	
5	Village Health Team	Female	Bakiga	✘	
6	Clinical Officer (In-Charge)	Male	Bakiga	✘	✘
7	Health Assistance	Female	Bakiga	✘	
8.1	Village Health Team	Female	Bakiga	✘	✘
8.2	Village Health Team Link Facilitator	Male	Bakiga	✘	✘
9	Health Assistant	Male	Bakiga	✘	
10.1	Village Health Team	Female	Bakiga	✘	
10.2	Village Health Team Coordinator	Male	Bakiga	✘	
11	Subsistence Community Member/ Village Health Team	Female	Batwa	✘	✘
12	Indigenous Chairperson	Male	Batwa	✘	✘
13	Subsistence Community Member	Female	Batwa	✘	✘
14	Subsistence Community Member	Female	Batwa	✘	✘
15	Indigenous Chairperson	Male	Batwa	✘	✘
16	Subsistence Community Member	Female	Batwa	✘	✘
17	Subsistence Community Member	Female	Batwa	✘	✘
18	Subsistence Community Member	Female	Batwa		✘
19	Subsistence Community Member	Female	Batwa		✘
20	Subsistence Community Member	Male	Batwa	✘	✘

**Table 3.** Identified knowledge holders of local health and subsistence food systems

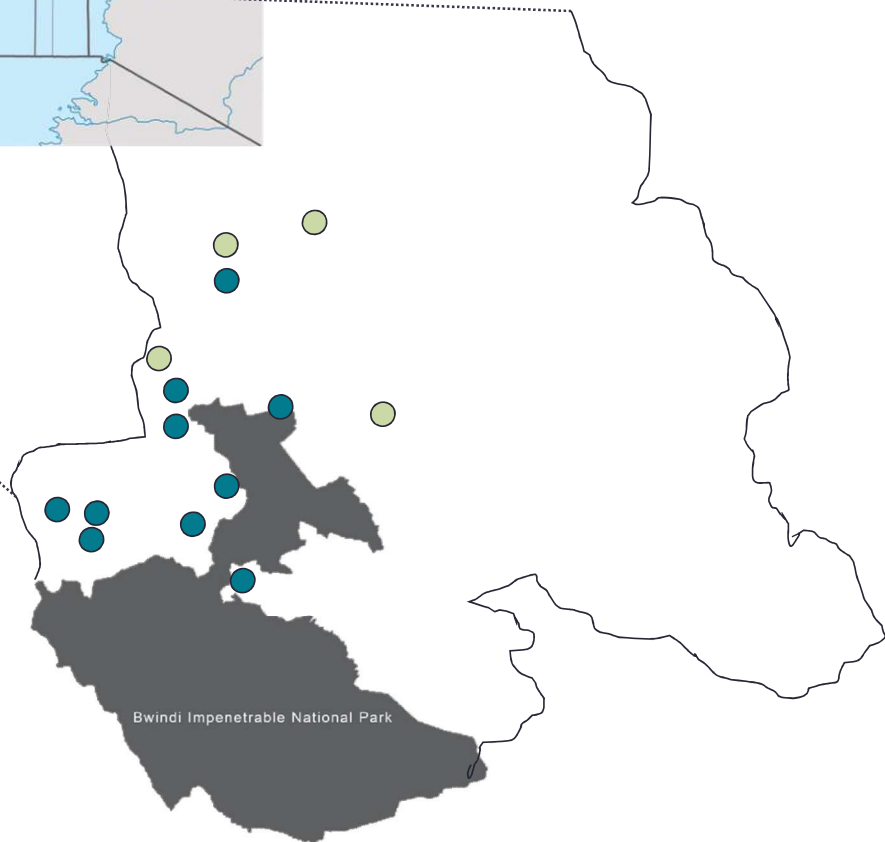
Knowledge Holder	Monitoring Information	Knowledge Network	Administrative Level	No. Times Identified
Local Councillor (LC1)	Indirect			17
NGOs Development Partner				16
In-Charge (HC II/III)				16
Chairperson / Community Leader				13
Village Health Team (VHT)				13
Community Hospital				11
Indigenous Community Member (Batwa)				11
Health Assistant				10
Community Outreach Team				9
VHT Coordinator / Health Link Facilitator				9
Local Councillor (LC5) MPs / Lawyers	Indirect			8
Local Councillor (LC2)	Indirect			8
Community Development Officer	Indirect			8
Sub-County Chief	Indirect			8
Local Councillor (LC3)	Indirect			8
District Health Team (Officer and Inspector)				7
Parish Chief	Indirect			7
Local Community Member (Bakiga)				7
Religious Leader				7
Police Security Officer	Indirect			6
Bataka				6
Chief Administrative Officer	Indirect			5
Researcher				5
Teacher / School Rep				5
District Veterinary Officer				4
District Natural Resource Officer				4
Chief Financial Officer	Indirect			4
District Agricultural Officer				4
Uganda Wildlife Authority	Indirect			4
Ancestor				4
Traditional Herbalist				3

**Legend for Table 3**

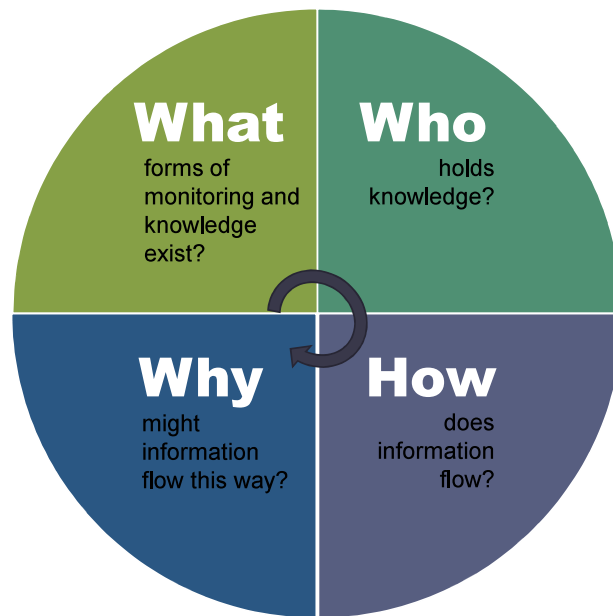
Health	
Subsistence Food	
Indigenous	
Local	
Western Scientific	
Political	
Administrative	
Village	
Parish	
Sub-County	
District	



**Figure 1 a.** Map of Uganda with Kanungu District. By © OpenStreetMap contributors, Jarry1250, NordNordWest/Wikipedia. Available under [CC-BY-SA-3.0](#).



**Figure 1 b.** Enlarged map of study area showing the case study sites of Indigenous subsistence communities as well as local health and administrative facilities in relation to the shaded area of Bwindi Impenetrable National Park.

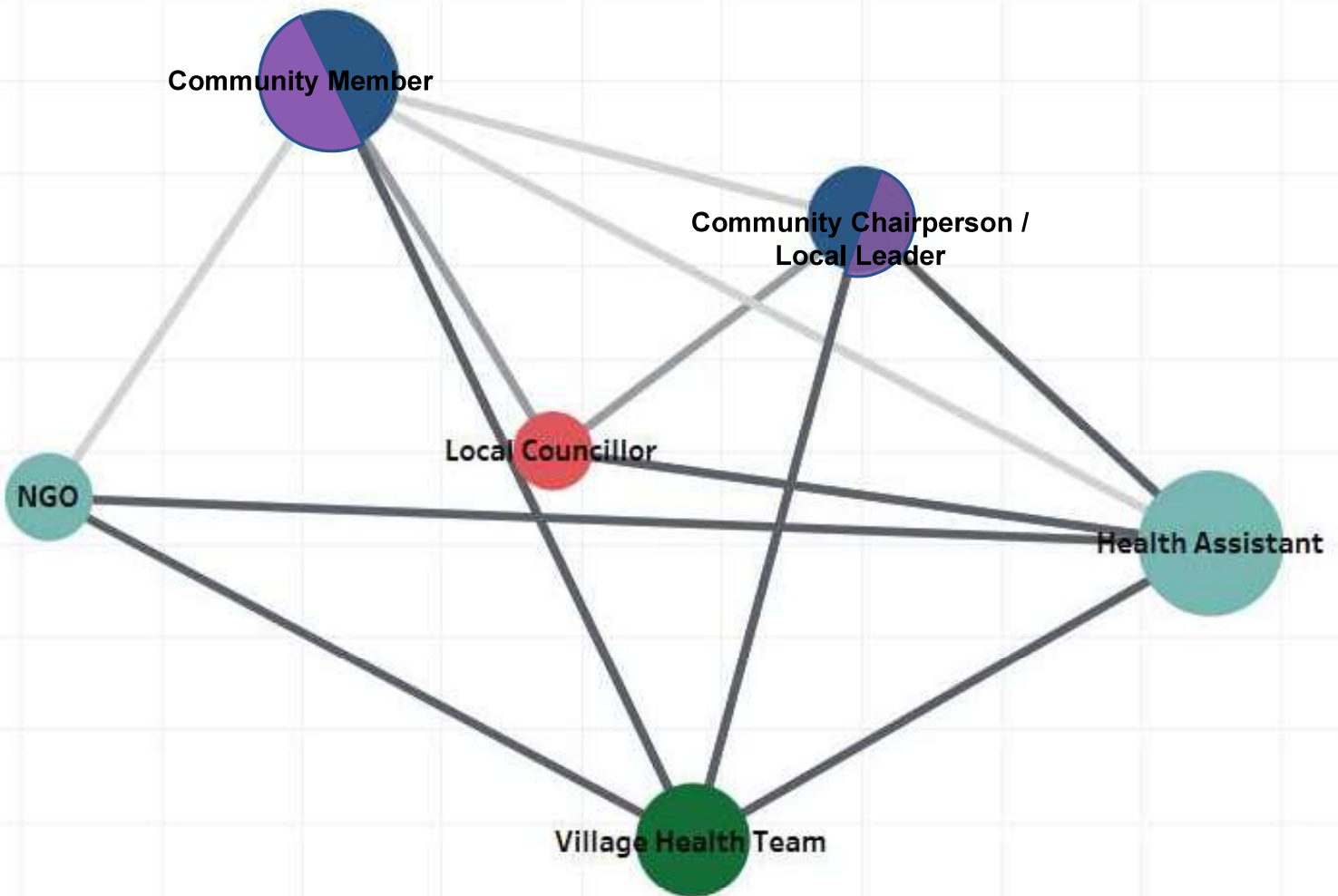
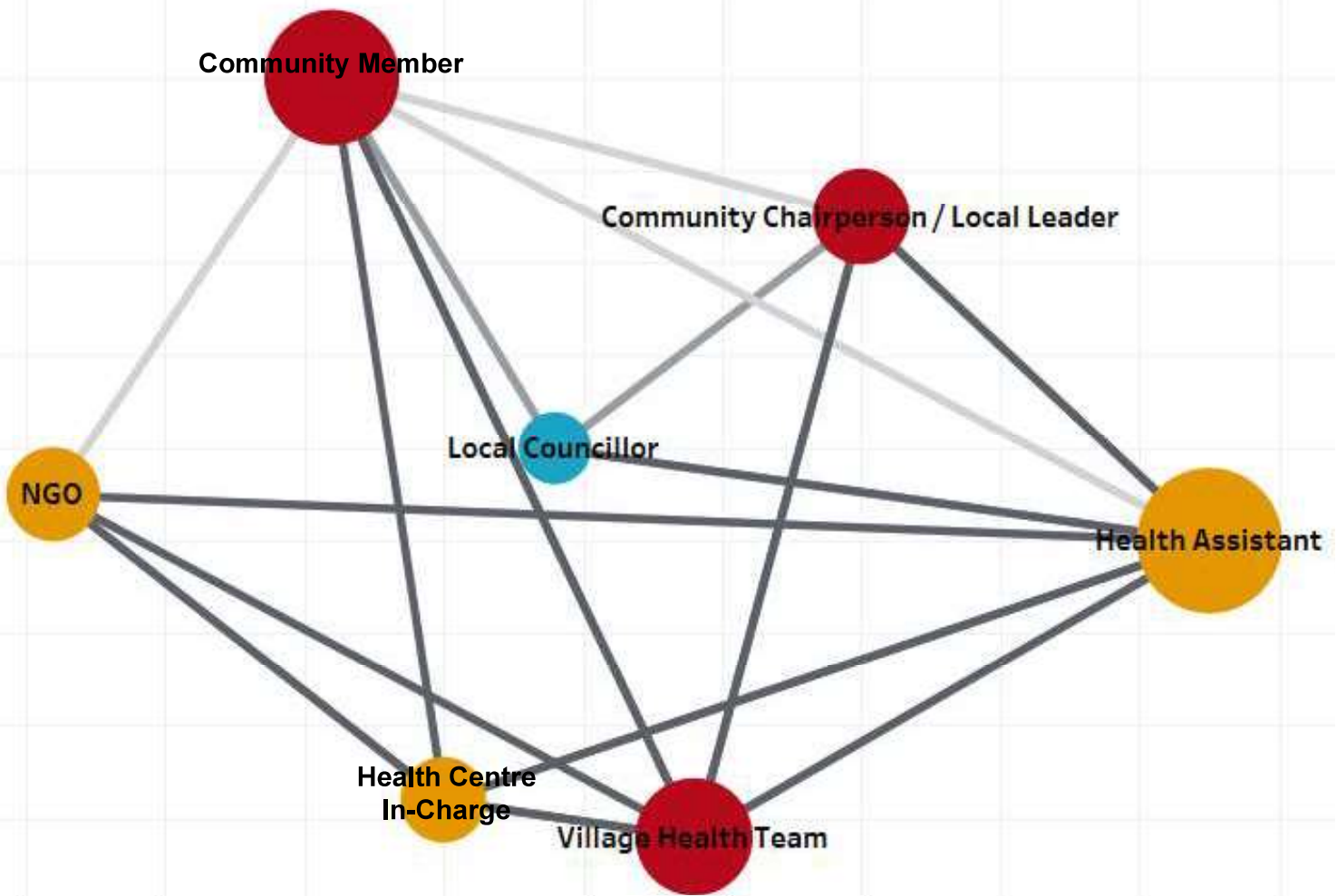


**Figure 2.** Four components used to inform the surveillance initiation and problem definition in a place-based integrated climate-food-health surveillance systems.

**Figure 3.** Flow of categorical attributes used to define knowledge holders.

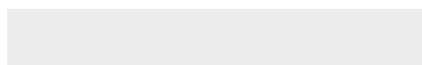
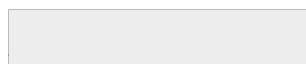
LEVEL 1 MONITORING INFORMATION	LEVEL 2 KNOWLEDGE NETWORK	LEVEL 3 ADMINISTRATIVE LEVEL
Health	Political	District
		Sub-County
		Parish
		Village
	Indigenous	District
		Sub-County
		Parish
		Village
	Local	District
		Sub-County
		Parish
		Village
	Western Scientific	District
		Sub-County
		Parish
		Village
	Administrative	District
		Sub-County
		Parish
		Village
Subsistence Food	Political	District
		Sub-County
		Parish
		Village
	Indigenous	District
		Sub-County
		Parish
		Village
	Local	District
		Sub-County
		Parish
		Village
	Western Scientific	District
		Sub-County
		Parish
		Village
	Administrative	District
		Sub-County
		Parish
		Village







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