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Kenyan Counties Geospatial Data Knowledge to Monitor Crop Production

Anastasia Mumbi Wahome, John B. K. Kiema, Galcano C. Mulaku

Department of Geospatial and Space Technology, University of Nairobi, Nairobi, Kenya
Email: an_mumbi@yahoo.com, jbkkiema@uonbi.ac.ke, gmulaku@uonbi.ac.ke

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Abstract

Climate change effects have had negative effects on most farmers, both small and large-scale, with weather patterns increasingly becoming unpredictable, such that farmers are unable to plan well for their farming, resulting in reduced harvests and sometimes losses for farmers. Better availability of information such as weather patterns, suitable crops, nutrient requirements based on soil types and conditions would greatly alleviate these challenges. While geospatial information is being developed and improved continuously by researchers, its accessibility and use by the counties has not been established and cannot be identified as contributing to better crop production outcomes. The aim of this study, therefore, was to assess the awareness and status of geospatial data availability and use for crop production, and the level of the relevant capacities, both human and infrastructural, in selected Counties of Kenya. A survey was conducted in the four counties of Vihiga, Kilifi, Wajir and Nyeri and key informant interviews were conducted with both management and technical County Agricultural Officers, as well as sub-county agricultural extension officers. From the results of the survey, out of the four counties, only one has adequate infrastructure in terms of hard-ware, software and connectivity to conduct useful geospatial data acquisition and processing. While most indicated awareness of the existence of geospatial data, limited resources, low skills and knowledge have restricted any meaningful sourcing of and access to data, with only 38% moderately or highly skilled in acquisition, 48% in processing and 57% in interpretation and use of geospatial data. The study concludes that moderate skills and capacities available within the counties have considerable potential to make use the available geospatial data to inform farmers accordingly and improve their farming outcomes.

Keywords

Geospatial Data, Crop Production, Agriculture, Farmers, Small-Scale Farmers

1. Introduction

Kenya has only 15% to 17% of land with sufficient fertility and rainfall for farming [1], yet agriculture in Kenya is one of the main economic activities contributing 23.5% of the country's Gross Domestic Product (GDP) directly [2] and 27% indirectly through its linkages with other sectors. The sector employs over 60% of the total population and more than 70% of the rural populace [3]. Most farmers are small scale farmers and grow mainly subsistence crops, with at least 76% relying on rain-fed subsistence farming for their livelihoods [4]. The productivity of their farms greatly depends on timely decisions that either enable them to increase yields or mitigate losses.

The timeliness of their decisions and subsequent actions depends on availability of useful information in a timely manner [5]. Relevant and useful information may be different for different geographical areas [6]. While many farmers get this information from various sources, including agricultural extension officers and agro-dealers [7], the accuracy and reliability of the information is also a critical factor which sometimes depends on the source.

Climate change effects have had negative effects on both small and large-scale farmers with the uncertainty on rainfall patterns, the onset dates, duration and cessation often leading to the poor timing of farming activities such as planting date, resulting in negative yield outcomes [8]. Rainfall distribution is a big challenge for rain-fed farming even in the regions considered to be receiving enough rainfall such as the central Kenya highlands [9] and small-scale farmers are affected more by climate variability and they may experience more negative effects if there are no appropriate mitigation measures [10]. On the other hand, availability of geospatial data has greatly improved in the last decade with many previously commercial providers availing the data for free [11]. A good deal of geospatial data and information is in use at the national level by national institutions but there is little evidence of its usage in the counties [12].

With the devolved system of government in Kenya, agriculture is one of the devolved sectors and extension officers in the counties are the main contact point for farmers for crop production services. Their work includes giving advisory information relating to farming activities to the farmers. However, previous studies show varied impacts of these extension services by governments [13], [14]. The use of different methods of agricultural extension to farmers has also been reported to have varying impacts [7].

While geospatial data for crop production is being collected and information from it being produced by researchers, individuals and other professionals for various uses, the capacity in terms of knowledge and skills in geospatial technologies by the county officers is paramount in ensuring its utilization [15]. Various studies have been done that demonstrate the value of using Earth Observation data for crop monitoring. Orusa [16] discusses a Google Earth Engine algorithm that can be used to map phenological metrics in mountainous areas around the world. These metrics measured at the start of the crop season and

end of season can be used to by farmers to make more informed farming decisions. Burke and Lobell [17] also demonstrate the use of very high-resolution satellite data to assess yield variation in Western Kenya. Further, a review on application of remote sensing in estimating maize grain yield in heterogeneous African agricultural landscapes revealed that while use of satellite imagery to estimate maize yield offers possible and cost-effective options as compared to ground based surveys, their utilization in predicting maize yield in Africa is still scant [18]. The review also noted challenges in the models due to specific climatic conditions that were assessed and the limitations of scaling them to wider geo-graphical areas.

It is worth noting and recognizing that there are still limitations of Earth Observation (EO) data in agriculture as observed by Delgado [19], which include issues related to data standards and limited government support in the use of EO data. It is also worth noting that farm level data, while ideal for informing farm-level management decisions, requires high spatial and temporal resolution [20], which come at a high cost and this may hinder sustainability of its access.

Carletto [21] looked at the broader issue of improving agricultural data to enable governments make better policies and noted that many governments in Sub-Saharan Africa (SSA) remain poorly positioned to use readily available EO-data to inform agriculture and food security decisions and programs. A review of satellite-based global crop monitoring systems available for Africa by Nakalembe [22] also noted that Government departments lack the requisite technical capacity, computing infrastructure, and also lack the investments to improve on them.

In Kenya, while the at the national level there is considerable capacity and use of geospatial data [23], and the Counties are known to be advancing in usage of geospatial data in their operations, documented research in the area of crop production on usage of the same within their operational activities is scanty. A study by Mutua and Mwaniki in 2017 [12] on GIS needs assessments in Kenya noted that the presence of internal GIS setups within the counties did not necessarily mean that they were used substantially in geospatial analysis work. Availability of GIS data in the counties in digital format was also low at 19.5% of all data. This presents a challenging situation in application of geospatial data. The lack of adequate hardware and software was also identified in the study that surveyed 30 counties. The capacity of the county staff was also identified as inadequate with most of the counties contracting out geospatial services.

Given the structure of the County governments, the departments of agriculture have a critical mandate of ensuring adequate crop production within their respective counties. They also have the responsibility of ensuring adequate and qualified human resource as well as making available the required tools for agricultural extension services. The agricultural policy of 2021 [23], recognized the inadequate capacity in the sector including human resource and proposed to invest in agricultural education, research and extension capacity. In addition to

providing documented evidence of the status of the use of geospatial data and related capacity in the counties, the results of this study are expected to provide a needs basis for related investments and also provide useful information on where to target while addressing capacity gaps.

The main objective of this study was, therefore, to assess the awareness and status of geospatial data availability and use in crop production by county government officials and county agricultural officers. Specifically, it sought to assess the type of crop production activities supported by the institutions and county extension officers; the availability of geospatial data and where it is sourced from; the benefits realized from using the data and the challenges experienced while using it; and the level of the relevant geospatial technology capacities, both human and infrastructural. It is believed that adequate capacity of county officers in terms of basic geospatial knowledge and skills, and adequate infrastructural capacity within their work premises, would not only be useful in ensuring that they are able to source, access, interpret and use the data, but also make them more accurately informed to be able to advise farmers accordingly.

The methodology used consisted of survey and key informant interviews, conducted in the four selected counties of Vihiga, Kilifi, Wajir and Nyeri. The results of the survey indicate that while the levels of interaction with farmers are close and frequent for both the institutions and the county extension officers, the level of use of geospatial data is low. Additionally, out of the four counties, only one has adequate infrastructure in terms of hardware, software and connectivity to conduct useful geospatial data acquisition and processing and while most indicated awareness of the existence of geospatial data, but limited resources and low skills and knowledge have restricted any meaningful sourcing of and access to the data, with the results showing that only 38% moderately or highly skilled in acquisition, 48% in processing and 57% in interpretation and use of geospatial data.

2. Materials and Methods

2.1. Geographical Scope

The study was done in four Counties of Kenya namely: Vihiga, Wajir, Kilifi and Nyeri. Their selection was based on three criteria: 1) the county has agricultural activities being carried out; 2) representation of different agro-ecological zones [24] [25] [26] across the selected counties (highlands, arid and semi-arid areas, tropical and coastal); and 3) regional representation and ethnic diversity. **Figure 1** and **Figure 2** show maps of the study counties overlaid on agro-climatic zones of Kenya [27] and agricultural areas of Kenya [28] respectively. The agro-climatic zones map was based on a combination of both moisture availability zones (I-IV) and temperature zones (1-9) sourced from UNEP's Global Re-source Information Database. The combined rainfall and temperature conditions form the agro-climatic zones. On the other hand, the agricultural areas represent areas where there is some form of agricultural activity. The map excludes areas that have

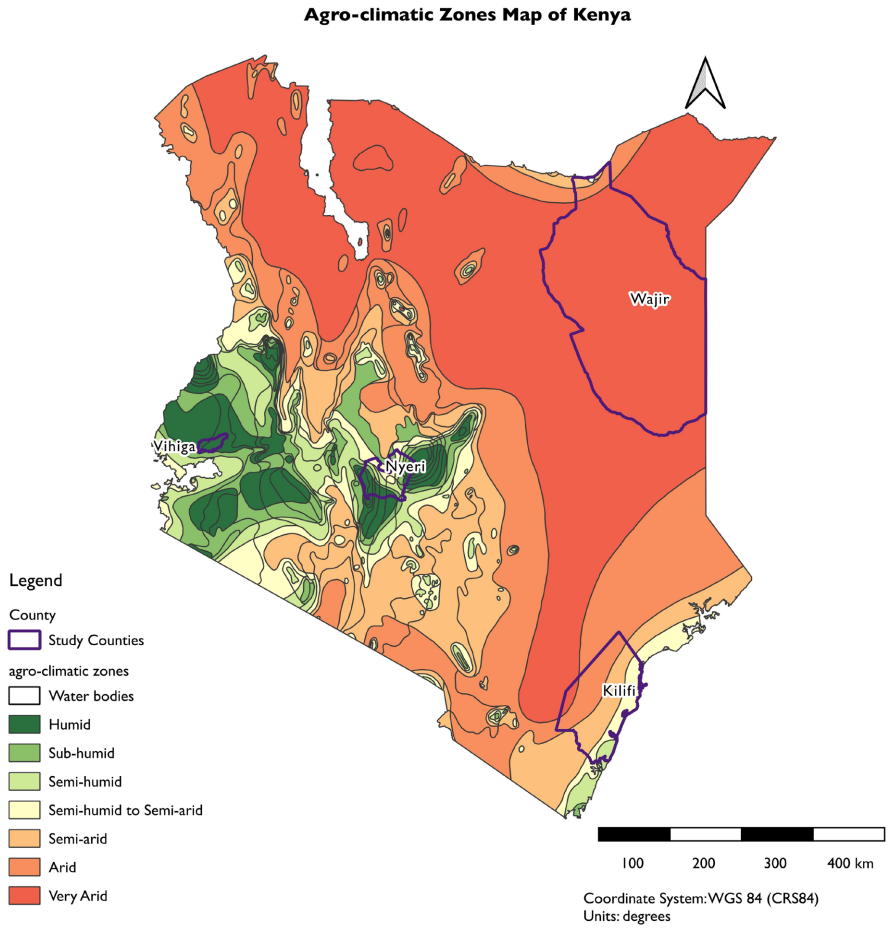


Figure 1. Map showing study Counties overlaid on agro-climatic zones of Kenya.

no agricultural activity, such as the very arid areas, water bodies, desert, and natural forests.

2.2. Structure of the Agricultural Function in Kenyan Counties

The agriculture function, under which crop production falls, is carried out by a Department in the counties and is headed by a County Executive Committee (CEC) member, and under him/her a Chief Officer [29]. Under the Chief Officer are Directors who head the sub-sectors (Agriculture, Livestock, Fisheries and/or Cooperatives), with Sub-county Agriculture Officers (SCAO) who work under them at the sub-county level, and at the ward level there are Agriculture Ward Administrators.

Vihiga has 5 sub-counties namely: Luanda, Emuhaya, Vihiga, Hamisi and Sabatia. All were covered in the survey. Wajir has 6 sub-counties (Wajir East, Wajir West, Wajir North, Wajir South, Tarbaj and Eldas) and all were covered in the survey. All 7 sub-counties in Kilifi (Kilifi North, Kilifi South, Malindi, Magarini, Rabai, Kaloleni and Ganze) were covered, while Nyeri has 10 sub-counties but only 8 (Tetu, Kieni East, Kieni West, Mathira East, Mathira West, Nyeri South, Nyeri Central and Mukurwe-ini) were covered. Aberdare Forest and Mt.

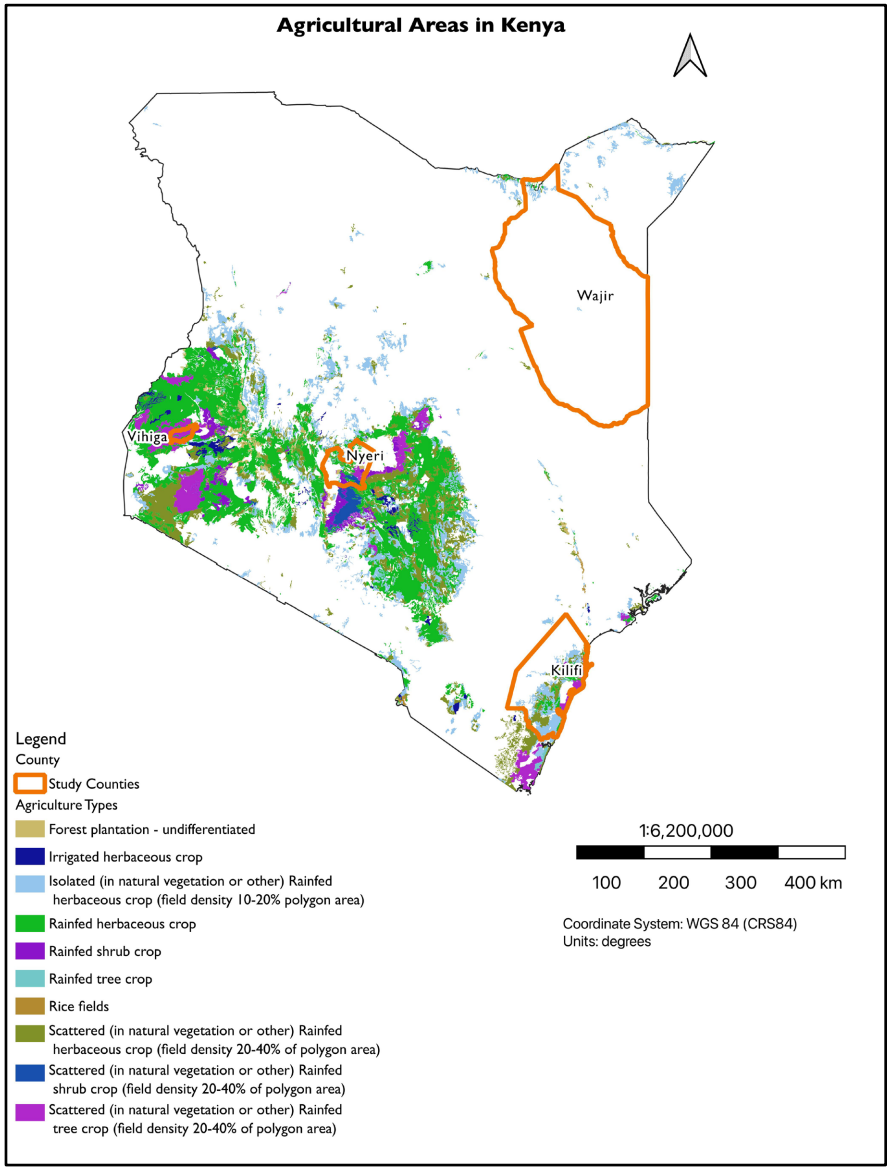


Figure 2. Map showing study Counties overlaid on agricultural areas of Kenya.

Kenya Forest were not covered due to their very low population and farming activities [30].

Figure 3 shows the structure of government in Kenya, which includes County governments [31]. The part of the structure boxed in blue is the one that was involved in this study.

Figure 4 outlines the structure of the agricultural function within the County governments. It was used to determine the key informants for the interviews. The four selected counties have different numbers of officers at the various levels with some wards lacking ward administrators.

2.3. Sampling Method and Data Collection

The assessment was done through a multi-level survey: management and technical

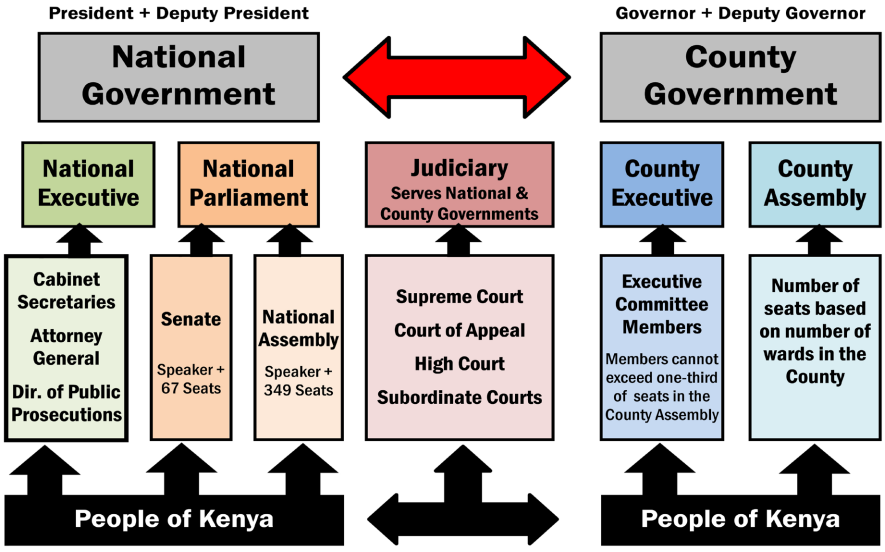


Figure 3. Structure of Government in Kenya. Source: The Citizen Handbook [31].

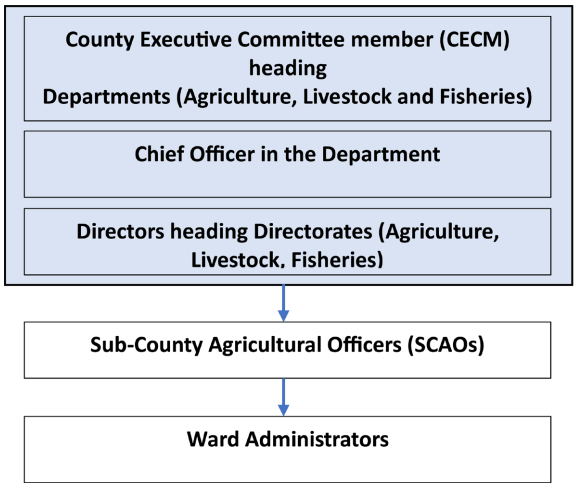


Figure 4. Structure of agricultural function within the County Governments in Kenya.

County officials, sub-county extension officers and agricultural service institutions.

The questions that were included in the questionnaires were carefully selected, formulated and worded to ensure the responses answered to the issues that were being assessed. To ensure sound analysis and interpretation of the responses, where possible the questions were formatted to have pre-coded responses and options provided. An option to specify responses that was not in the pre-coded list was provided. All the questionnaires were pre-tested to ensure proper flow of the questions and identify any gaps or probable responses that could have been missed for pre-coding. The institution questionnaire was then coded as a mobile app using the Kobo ToolBox platform, deployed and tested with institutions in a County that was not part of the survey Counties before being re-deployed for data collection. Research assistants were trained on the use of the mobile app to

ensure that they were conversant with its use.

Key questions for this study included whether the officers and the institutions use any geospatial data in operational crop production services, the types of data they use, the source of the data, whether it is free or has to be purchased, and the type of decisions that they make using that data. They were also interviewed on whether and how they communicate the data or derived information to farmers. The questionnaires are included in Annex A.

The management and technical officers' surveys were done through key informant interviews using a questionnaire. All efforts were made to get an interview with the top most crop production officer, the County Director of Agriculture, who is in charge of crop production in the county, and where available, the GIS/technical officers were also inter-viewed.

At sub-county level, it was noted that not all wards have ward administrators and therefore the questionnaire was administered to sub-county agricultural officers, who in the absence of the ward administrators, work directly with the farmers. Efforts were made to interview as many sub-county officers as possible. In Vihiga 4 out of 5 officers were interviewed, in Wajir, 5 out of 6 sub-county officers responded to the questionnaire. In Kilifi, 6 out of the 7 responded while in Nyeri, 6 out of 8 responded.

The sampling of the agricultural service institutions was non-random as they were selected based on the type of agricultural services they offer, in this case, crop production services to farmers. Given that their location and nature of services could be influenced by business incentives, their identification was through the guidance of the respective sub-county officers with the target of at least 2 in each sub-county. They included suppliers of agricultural inputs such as seedlings, chemicals and fertilizers, training institutions and farmer cooperative societies. In Wajir, the numbers were low because some close shop when the area is out-of-season, and this coincided with the interview period.

The data was collected between the months of March 2022 and October 2022.

2.4. Data Analysis

The county level data was entered into SPSS software version 25. For the management and technical officers' survey at county level, the number of respondents in the four counties was less than 10 and therefore, no statistical analysis was done on the data. Furthermore, responses by different officers from the same county were similar on the county level activities and capacities, and were therefore considered as one response. The open-ended questions were coded into categories for easy interpretation. Individual capacities to access, process, use and interpret geospatial data, were however noted and used to get an averaged result for the county.

The institutional data was collected through a mobile app and was therefore ready for processing immediately after collection. It was exported into SPSS Statistics for Windows, Version 25.0 for further analysis. The data was first cleaned to ensure that there were no outliers or wrong entries, and also to check for con-

sistency and domain accuracy. Other cleaning aspects included rephrasing of and coding of data collected under other uncategorized open-ended options. The data was then tabulated to calculate summary statistics such as frequencies and percentages of the various parameters that were being assessed. For some of the questions, the results were exported to MS Excel to generate the charts and graphs.

Although Kobo Toolbox has functionality to visualize the location of the collected data, the geo-points were converted to KML and exported to ArcMap 10.3 in order to develop proper maps with the required map elements.

3. Results

3.1. County Level Assessment

At the county level, all the directors of agriculture and technical officers who responded to the survey, except Nyeri, indicated that they use geospatial data for crop production activities (Table 1). The three counties use weather data, sourced from Kenya Meteorological Department (KMD), such as in Figure 5, in addition to other data such as crop suitability and soil data (Kilifi) sourced from the Centre for Training and Integrated Research in ASAL Development (CETRAD), farmer mapping and potential risk areas (Vihiga) produced by the County GIS lab team, and water resources and locust maps (Wajir). Vihiga County has additionally purchased high-resolution satellite images to aid in farm mapping.

The weather data is used to make decisions such as timing of farming activities including planting and harvesting. Crop suitability maps are used to advise farmers on the most suitable crops they should grow in their areas. The information on crop suitability is based on the agro-climatic and agricultural areas data which is developed from the country's soil data, rainfall and temperature patterns. The farm maps and potential risk areas by Vihiga County are used to advise farmers on potential risks to their farms such as soil erosion and how to mitigate them. The high-resolution satellite images by Vihiga County were used to

Table 1. Geospatial data used by County agricultural officers.

Question/County	Kilifi	Nyeri	Vihiga	Wajir
Do you use any geospatial data (GIS, maps, satellite images) for crop production services?	Y[a]	N[b]	Y	Y
Is any of the data/derived information shared with the farmers?	N	NA[c]	Y	Y
How often is it shared?	NA	NA	As needed	As needed, seasonally
Do you share geospatial data with other institutions/individuals outside of your institution?	N	NA	Y	Y

[a]Y = Yes, [b]N = No, [c]NA = Not Applicable.

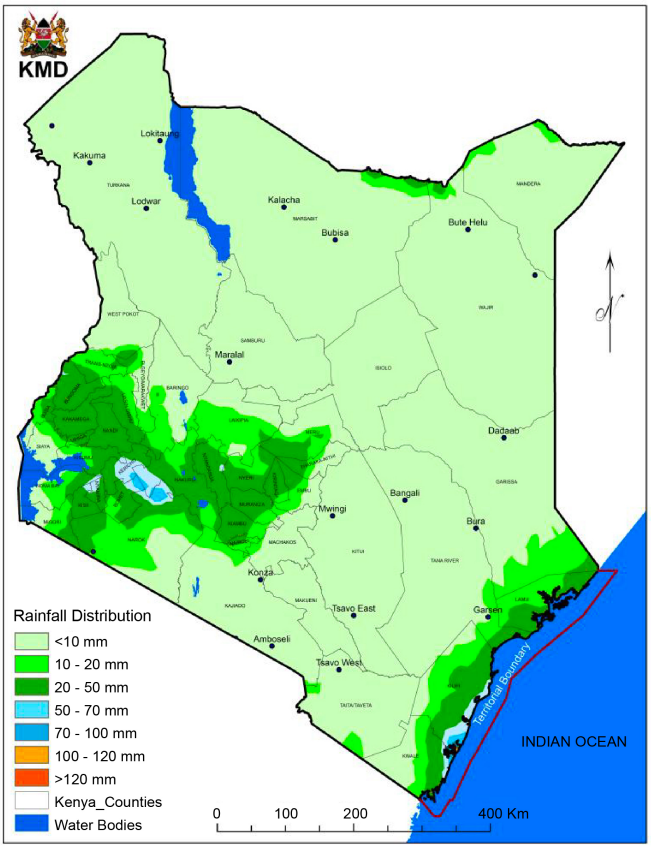


Figure 5. Map showing weather forecast. Source: KMD.

confirm farm locations and boundaries (not official boundaries). They were a one-time purchase and therefore did not provide continuous monitoring. In Wajir, the water point maps are used to identify the location of water points which are sometimes used as water sources for small-scale irrigation.

Wajir and Vihiga share the information with farmers through brochures and leaflets, social media forums and verbally during physical interactions with farmers, some of which are conducted through the sub-county extension officers. The frequency of sharing is as needed and mainly just before and during cropping season. In Kilifi the information obtained from geospatial data is not shared directly with farmers, but rather used to make decisions at county level. The crop suitability data is shared with KMD who integrate it with rainfall forecasts which are shared with farmers through extension officers.

It is worth noting that in Kilifi and Wajir, the spatial data used is in the form of maps and no processing is done by the County Officers. In Vihiga, the farming potential risk maps were developed by the County GIS officers in 2019 but have not been updated.

The officers in the three counties also identified some of the benefits of using the geo-spatial data as enabling them to advise farmers to plan better on their cropping calendars, *i.e.* when to prepare the farms and when to plant (**Figure 6**). The officers indicated that farmers have had better yields and reduced costs in

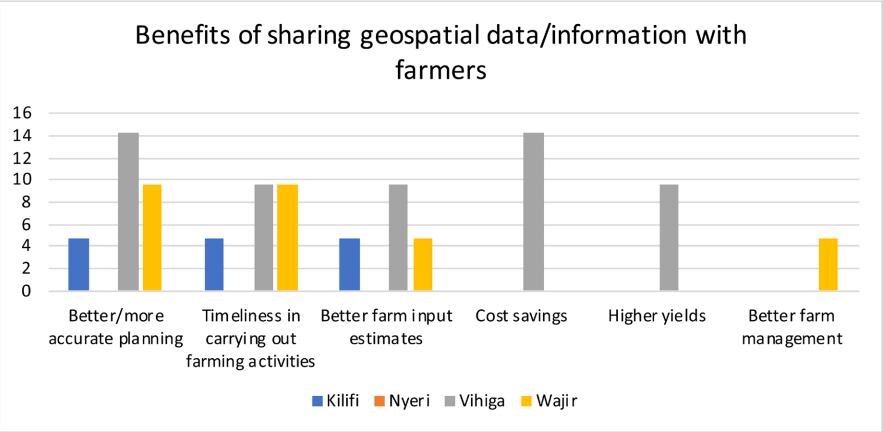


Figure 6. Benefits derived from sharing geospatial data/information with farmers.

their farming activities since they are able to purchase and apply the right inputs in a timely manner. However, a few also noted that they experience challenges while using the data, with some of the challenges identified as irregular and untimely availability of the data leading to delayed information to farmers which in turn may affect the timing of their activities; low ability to interpret the data when presented in form of maps, which affects the accuracy of information that would be shared with the farmers.

Further, Wajir and Vihiga indicated that they also share the data with other institutions and individuals mainly for research and reference. It's mostly shared in hard copies, soft copies and sometimes as printed materials such as reports.

The capacity at county level in terms of skills and knowledge to acquire, process and analyse, interpret and use geospatial data was low in Wajir, moderate to very high in Vihiga, and low on acquisition, moderate on processing and analysis and high on interpretation and use in Kilifi. The required infrastructure (internet connectivity, hardware and software) was rated as low in Wajir, adequate to highly adequate in Vihiga and moderately adequate in Kilifi. In Nyeri, there is no capacity to acquire, process and analyse or interpret and use geospatial data at the county level, and although there is adequate internet connectivity, there is no hardware and software that can be used for geospatial related activities.

3.2. Sub-County Level Assessment

The three most common services offered to farmers include advisories on farming practices (95%), information on markets and sales (67%) and support on agricultural sup-plies (71%) which includes advice on which products are applicable to their crops (Table 2). 71% of the sub-county officers have very close contact with the farmers with regular and frequent visits and meetings, while 29% moderately interact directly with farmers.

3.3. Application of Geospatial Data in Extension Services

At the sub-counties, 62% of the officers were found to have used geospatial data

Table 2. Services offered to farmers by sub-county agricultural officers.

Service	Frequency	Percentage[d]
Farming practices	20	95.24
Agricultural Supplies/support	15	71.43
Farmer Group/Cooperative advisory/support	14	66.67
Agricultural Marketing/Sales	14	66.67
Consultancy	9	42.86
Farming Equipment	9	42.86

[d]This was a multiple response question.

in their activities (Table 3), with all except one sharing the data or derived information with farmers. Within the Counties, however, Vihiga had no officer using geospatial data for their activities. Kilifi and Wajir had 33% and 40% respectively, not using any geospatial data, while in Nyeri, all indicated that they use geospatial data. The derived information is mostly shared through brochures and leaflets (36%), verbally during physical interactions with the farmers (20%) and social media (20%) (Table 4). The frequency of sharing is mostly when the information becomes available (58%) and seasonal (42%) (Figure 7).

The most common advantages of using the information were cited as enabling better and more accurate and timely planning of farming activities (64%), while a considerable number also mentioned higher yields and cost savings (16%) (Figure 8). Among the challenges faced while using the geospatial data and how they affect decision making for farmers, are low capacity in skills and knowledge on how to access and interpret the data, and inadequate equipment, software and internet connectivity for the SCAOs, which results in delayed or poor decision making.

Weather information to enable planning of farming activities and market prices of farm commodities were ranked highly as information that is of high interest to farmers and provided by the sub-county officers. Additional information includes prevalent pests, value addition technologies and crop protection for commodities, environmental conservation practices, climate change and related interventions.

3.4. Sub-County Geospatial Capacity

All respondent Sub-county officers answered the questions on their capacity to use geospatial data and accessibility to computing infrastructure, regardless of whether they are currently using it or not. Of the interviewed sub-county officers, only 38% are moderately or highly skilled and knowledgeable on geospatial data acquisition (Table 5). In terms of being able to analyze and process geospatial data, 48% are moderately or highly skilled and knowledgeable, while 52% has low or no skills and knowledge in the area. 57% indicated they are able to interpret and use geospatial data products, while 43% have low or no capacity at all.

Table 3. Percentage of officers using geospatial data in extension services by county.

County	% who have not used	% who have used
Kilifi	9.52	19.05
Nyeri	0	28.57
Wajir	9.52	14.29
Vihiga	19.05	0
Total	38.09	61.91

Table 4. Format of sharing geospatial/information derived from geospatial data with farmers.

Format of Information sharing	%
Brochures/leaflets	36
Direct word of mouth	20
Social media messages	20
Bulletins (printed or soft copy)	16
Radio/TV broadcasts	8

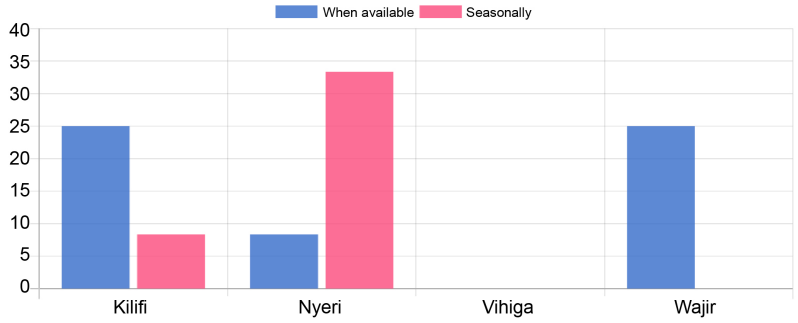


Figure 7. Frequency of sharing geospatial data/derived information with farmers.

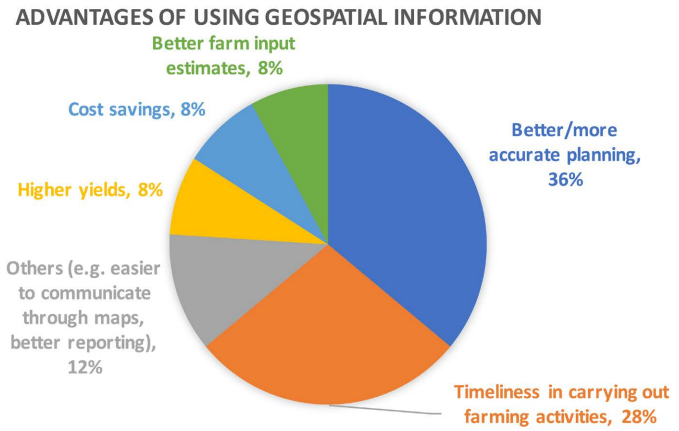


Figure 8. Advantages of using geospatial information.

Table 5. Capacity to acquire geospatial data.

Skill Level	Percentage of Extension Officers
High	9.52
Moderate	28.57
Low	38.1
Non-existent	23.81

Interestingly, the skills and knowledge in acquisition of geospatial data for those who do not use the data in their extension services ranged from non-existent to moderate, with half of them having no capacity at all, while the group that used the data had better ratings ranging from low to high, 15% being highly skilled and knowledgeable (**Figure 9**). A peculiar observation was where an officer indicated that they have no skills or knowledge in geospatial data but they use GIS data to locate farms. Further probing revealed that some sought the help of younger or knowledgeable colleagues or friends to interpret and direct them on the location of farms from point data. Similar trends were observed in the ability to process and analyze, and also in interpretation and use geospatial data.

Availability of hardware, software and internet connectivity which are key drivers of the utilization of geospatial data were also assessed. 57% of the officers indicated they have moderately adequate to adequate access to internet connectivity, 52% of them have access to adequate or moderately adequate usable hardware, while only 38% indicated that they have moderately ad-equate or adequate access to geospatial software (**Table 6**).

Analysis of the three by disaggregating the data by use of geospatial data in extension services revealed a similar trend to the skills and knowledge. Those using geospatial data had better hardware and software capacity, ranging from moderately adequate to adequate (62%, and 46% respectively), while those not using the data had lower capacities (50% with no hardware, 37.5% with no software).

3.5. Institutions Supporting Crop Production Activities

A total of 79 institutions that offer crop production services to farmers were inter-viewed in the four counties (5 in Wajir, 12 in Vihiga, 35 in Nyeri and 26 in Kilifi). Not all sub-counties had the different types of institutions, while some sub-counties in Wajir had none operating at the time of the interviews. **Figure 10(a)** & **Figure 10(b)** show the distribution of institutions in Nyeri and Wajir Counties respectively.

As is evident on the above maps, in Wajir the institutions are mainly found near the highly populated areas which also happen to be areas where there are some crop production activities. The bigger part of the county is not arable and most farmers practice irrigation farming. In Nyeri there's a wider spread because the county relies on agriculture as its main economic activity.

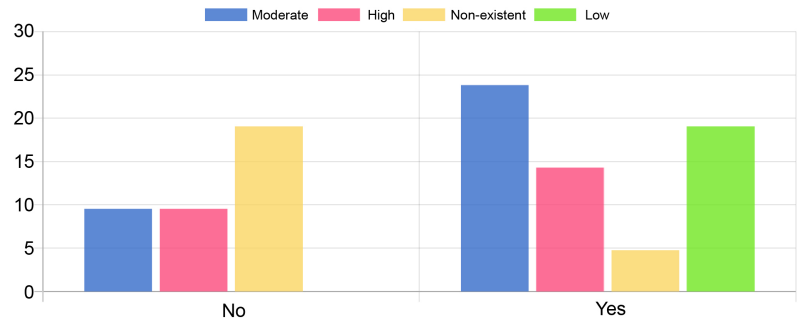
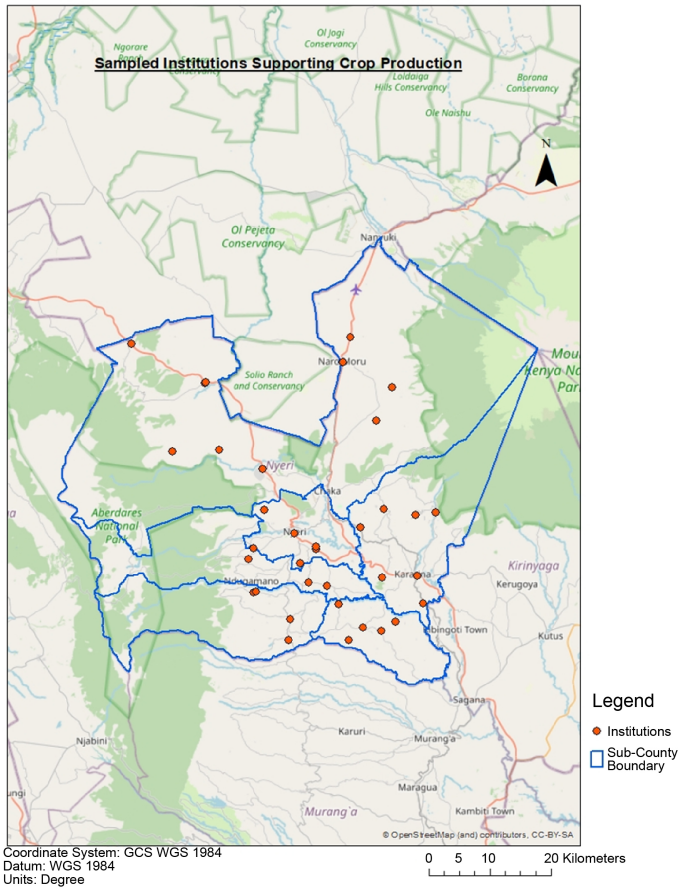


Figure 9. Sub-County officers' capacity in interpretation and use of geospatial data, grouped by whether they use the data in their services to farmers.

Table 6. Access to computing infrastructure by sub-county agricultural officers.

Level	Internet Connectivity	Hardware	Geospatial Software
Adequate	19.05	9.52	14.29
Moderately adequate	38.1	42.86	23.81
Low	19.05	23.81	23.80
Non-existent	23.80	23.81	38.1
Total	100	100	100



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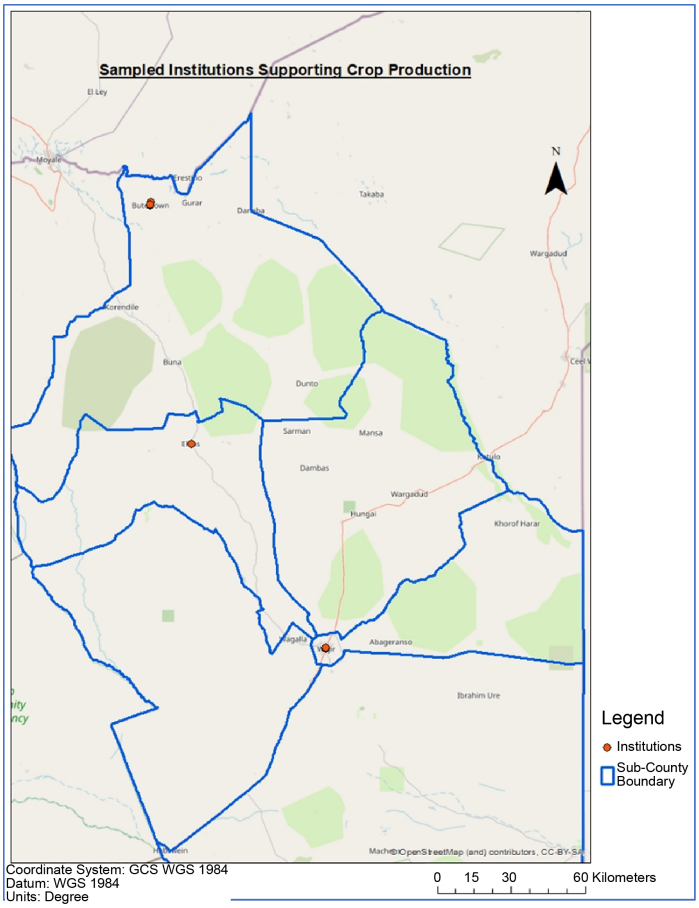

(b)

Figure 10. (a). Map of institutions supporting crop production in Nyeri County; (b). Map of institutions supporting crop production in Wajir County.

More than 80% are private institutions, all offering more than one service to farmers. Common services offered include agricultural products supplies and advisory services to farmers mainly on the use of the products that they sell. Most of them closely interact with farmers (75%) (**Table 7**), and only 20% of the institutions use some geospatial data in their activities, which is limited to weather advisories which are obtained from the Kenya Meteorological Department (KMD) and other free and online apps.

Of those that use geospatial data or derived information, 94% share it with farmers and mostly through word of mouth (48%) and social media messages (28%) (**Figure 11**).

The information is mostly shared as needed or seasonally (60%) and usually done as farmers source for inputs, with the advantages of sharing the information being better farm management and more accurate planning, timeliness in carrying out farming activities and better farm input estimates, which leads to cost savings and higher yields. Some of the challenges that were highlighted in using the geospatial information are low capacity in interpretation of the maps

Table 7. Institutions' level of interaction with farmers.

	Vihiga	Kilifi	Nyeri	Wajir	Total
Very Close	12.66	26.58	29.11	6.33	74.68
Moderately close	2.53	6.33	12.66	1.27	22.79
Low	0	0	2.53	0	2.53

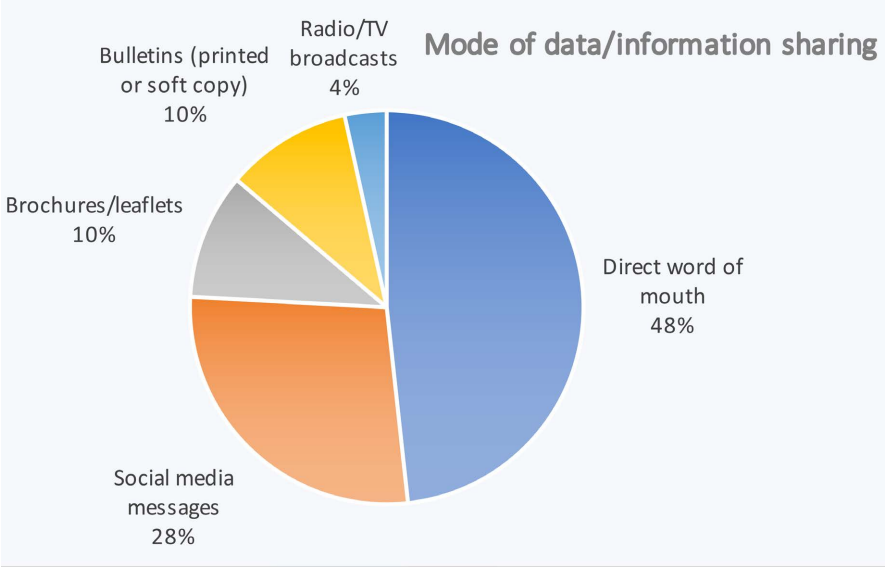

Figure 11. Mode of data/information sharing by institutions.

and also language barriers when informing farmers as the information is only in English but most farmers speak only their local languages.

The institutions' capacities were low with acquisition of data at 58% low or non-existent in the four counties, 52% low or non-existent in processing and analysis but slightly tilting the other way to 56% moderate to very high on interpretation and use (Table 8).

As shown in Table 9, the capacity for internet connectivity, hardware and software are similarly low or non-existent at 44%, 47% and 57% institutions respectively. The internet connectivity fairs much better compared to the other infrastructure components.

4. Discussion

Farmers who get weather and climate information in a timely manner are able to plan activities including when and what to plant, and perform other farm management activities efficiently resulting in reduced losses [32]. The utilization of such information largely depends on the ability to access and interpret it. While most smallholder farmers have only primary education or no formal education [33], the format of the information at their disposal can determine if it is usable or not, *i.e.* if it is understandable by the user and is disseminated on time [34]. The extension officers who are largely tasked with advising farmers need to be

Table 8. Percentage of Institutions with various capacity levels of data acquisition, processing and analysis, interpretation and use.

Capacity Level/type	Acquisition	Processing and analysis	Interpretation and use
Non-existent	30.38	27.85	26.58
Low	27.85	24.05	17.73
Moderate	22.79	32.91	25.31
High	12.66	8.86	17.72
Very High	6.34	6.33	12.66

Table 9. Percentage of Institutions with various capacity levels of internet connectivity, hard-ware and software.

Capacity Level/Type	Internet	Hardware	Software
Non-existent	29.11	29.11	35.45
Low	15.19	17.73	21.52
Moderately adequate	27.85	36.71	27.84
Adequate	16.46	12.67	7.6
Highly adequate	11.4	3.8	7.61

able to understand the information and interpret accordingly and also disseminate it to the farmers in good time. Their capacity to do this is therefore critical.

Lack of supportive institutions as an enabling environment is considered one of the hindrances to effective use of climate information [35]. Based on the results obtained from the sample that was surveyed, it is evident that the counties are still struggling to embrace geospatial technologies. Whereas it is a constitutional requirement that every county develops a spatial plan [36] [37] to guide their development activities, the uptake of the geo-spatial technologies for sectoral services is still low. The Van Den Homberg framework [38] recognizes software and hardware required as well as data literacy to enable trans-formation of data into information, as key components that enable effective use of weather and climate information. However, the awareness on the existence of the geospatial data and technologies is low while the levels of skills and capacities to use the technologies, are inadequate in some of the counties, and even where they are adequate, access to computing infrastructure is low, making their ability to utilize any available data challenging.

During the key informant interviews, it was noted that some of officers were not aware of the existence of geospatial data and for others a description of the data had to be done to ensure they understood the kind of data that they were being interviewed about. This makes the whole chain of access, processing and analysis, interpretation and use a challenge. It would be difficult to make use of data that one does not understand or is not aware of its existence. While previous literature indicates that provision of usable climate information includes

the capabilities of the users to inform active practice [39], the same is expected to apply across other types of information that enable more effective decision making, meaning the officers would need to have their capacity increased.

While the capacity of the institutions that support agricultural activities was also found to be low, notwithstanding their close contact with farmers, the nature of their activities is mostly for-profit. Most are private businesses and their willingness to increase their geospatial capacity in terms of skills and knowledge, might therefore be largely determined by the expected profit margins rather than a pure need to help farmers. Capacity development for agro-dealers, who formed the larger number of institutions, is mainly focused on business management and their ability to sustain and provide inputs for farmers [40] [41]. Their understanding of geospatial data and how such information can add value to the advice they give to farmers has not been evaluated or considered. This is an area that would require expert intervention to ensure a mutually beneficial outcome for both farmers and the institutions.

Looking at specific counties, it is worth noting that while there's no use of geospatial data in operational extension services in Vihiga (**Table 3**), the County is well equipped in terms of hardware, software and internet connectivity and even has a fully functional GIS laboratory. The laboratory is housed at the County headquarters, while the officers work in the sub-county offices which are not as well equipped with similar equipment. They therefore have challenges accessing it and even utilizing its functionalities. The existence of the laboratory, however, offers a great opportunity to facilitate the sub-county Officers with geospatial information that is beneficial to farmers.

In Kilifi, on the other hand, there's a great deal of information that is provided to the County by their partners such as CETRAD and utilization of this information by the sub-county officers is an opportunity that could be exploited. In Wajir, the management level officers' capacity is low and therefore challenging in accessing and using geospatial data, and despite the county having a GIS laboratory, it's not fully operational therefore not adequate for use in providing required agricultural data and services. In Nyeri County, although the officers indicated having used geospatial data in their services to farmers, the type of data was limited to weather maps provided by KMD and GNSS points used while locating farms. The availability of the computing infrastructure required is also inadequate for acquisition and processing of geospatial data.

Another critical issue that was revealed by the study is that the actual use of geospatial data, where it is being used, is not well structured and coordinated to ensure effectiveness. The agricultural officers are not guided by any regulations from their office or national government on how to share the information. Mitheu in her study on identifying barriers and opportunities in provision and use of weather and climate information [39], noted that for the information to be usable, the packaging in terms of language, timeliness of sharing the information and the method of dissemination are critical. Lack of these guidelines leaves a gap that needs to be addressed by the Counties to ensure more effective use of

geospatial information for crop production.

5. Conclusions

The study revealed big gaps, in skills, knowledge and infrastructure, in the Kenyan Counties' capacities to be able to consume and use geospatial data in their agricultural crop production activities. The close interaction levels of agricultural extension officers and the farmers is, however, a big opportunity that would enable the county governments to disseminate information to farmers. The services offered would be enriched and more valuable if the institutions applied geospatial data to improve the accuracy of the information and advice they give to farmers. The results of this study are a good basis for future County operational improvements in relation to use of geospatial data in both the agricultural and other sectors since the capacity gaps when improved are expected to be beneficial to all sectors.

While the capacity gaps are now known, there remains the effort by the county governments to improve them. This is a resource intensive undertaking and it requires great commitments, especially financial support. It is expected that these findings will be a guide on how to design and implement a capacity improvement strategy. Lack of guide-lines on how best to provide and disseminate geospatial data and related information to farmers is another gap that Counties need to address. A follow-on study on this area would provide guidance on designing best practices.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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