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Characterization of Small-Scale Farmers and Assessment of Their Access to Crop Production Information in Selected Counties of Kenya

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Abstract

Small-scale farming accounts for 78% of total agricultural production in Kenya and contributes to 23.5% of the country's GDP. Their crop production activities are mostly rainfed subsistence with any surplus being sold to bring in some income. Timely decisions on farm practices such as farm preparation and planting are critical determinants of the seasonal outcomes. In Kenya, most small-scale farmers have no reliable source of information that would help them make timely and accurate decisions. County governments have extension officers who are mandated with giving farmers advisory services to farmers but they are not able to reach most farmers due to facilitation constraints. The mode and format of sharing information is also critical since it's important to ensure that it's timely, well-understood and usable. This study sought to assess access to geospatial derived and other crop production information by farmers in four selected counties of Kenya. Specific objectives were to determine the profile of small-scale farmers in terms of age, education and farm size; to determine the type of information that is made available to them by County and Sub-County extension officers including the format and mode of provision; and to determine if the information provided was useful in terms of accuracy, timeliness and adequacy. The results indicated that over 80% of the farmers were over 35 years of age and over 56% were male. Majority had attained primary education (34%) or secondary education (29%) and most farmers in all the counties grew maize (71%). Notably, fellow farmers were a source of information (71%) with the frequency of sharing information being mostly seasonal (37%) and when information was available (43%). Over 66% of interviewed farmers indicating that they faced challenges while using provided information. The results from the study are insightful and helpful in determining effective ways of providing farmers with useful

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information to ensure maximum benefits.

Keywords

Small Scale Farmers, Farmers, Crop Production, Information Services, Geospatial Information, Information Access

1. Introduction

Small scale farmers are defined in various ways depending on context and purpose. FAO in a working paper [1] observed that 70% of literature defines smallholders in terms of land size, with an upper limit of 2 hectares (approximately 5 acres) typically identified on the land area or number of livestock operated or owned by individual farmers and their families. Similarly, Thapa [2] indicated that small farms have been defined in a variety of ways, and with the most common measure being farm size: "many sources define small farms as those with less than 2 hectares of cropland". Other factors used to define smallholders include degree of involvement of the family, market orientation and the economic size of the holding [1].

Some of the reasons leading to the small size of farms are population growth and traditional land inheritance systems [3] [4]. Kenya has only 15% - 17% arable land [5] with a population of 47.6 million in 2019 and a growth rate of 2.3% [6], the mean population density in the arable areas is 411 persons/km^2 meaning the farm sizes are getting smaller [7]. Family land is sub-divided to immediate family members, and from generation to generation, the portions have grown smaller. The sentimental attachment to these portions also affects the sizes as many are unwilling to sell and move to areas where they can acquire bigger portions of land [8].

In previous studies, it was observed that shrinking farms are associated with increasing land intensification and increases in the net value of crop production per unit of land [7] [9], which is a positive outcome. However, the intensification tends to plateau at 500 - 600 persons/km^2. The same studies observed that rural household income per adult also declines as population density rises and broader structural land transformations may get constrained, which is a negative outcome of small size farms.

Kenya's economy is supported by several sectors which include agriculture, forestry and fishing, manufacturing, trade, finance & insurance, service industry including tourism, transport and communications, among others [10] [11], and agriculture contributing to 23.5% of the country's gross domestic product (GDP). Small scale farmers, who account for 78% of total agricultural production [12], form an integral part of the country's economy and understanding their characteristics is crucial for formulating targeted policies that address their specific needs. While outcomes of their farming activities depend on decisions that they make based on available information, their sources of information are

multiple and they may be complementary or substitutes to each other [13]. In the analysis by Mittal and Mehar [13], it is observed that factors such as age, education level and farm size influence farmer's behaviour in selecting different sources of information. This includes but is not limited to weather forecasts and soil nutrients. The information is obtained from various sources which include extension officers, radio and television broadcasts, print media and sometimes fellow farmers.

A hallmark of small-scale farming in Kenya is the cultivation of diverse crops. According to the Kenya National Bureau of Statistics' Population and Housing Census report [6], small-scale farmers strategically grow a mix of staple crops, ensuring food security and exploring opportunities in cash crops for enhanced income. This diversity of crops is also sometimes meant to cushion the farmers against loss by distributing the crop failure risk [14] [15]. Multiple cropping also increases biodiversity, brings about improvement in soil fertility, and reduces persistence of pests and diseases on the farms [16].

Many small-scale farmers in Kenya rely on rainfed agriculture, exposing them to climate-related risks [17] [18] [19]. Research by Kalele, *et al.* [20] emphasizes the vulnerability of these farmers to climate change due to their dependence on rainfall.

With relevant and appropriate information, farmers are able to make decisions such as selection of what crops to cultivate based on factors such as climatic conditions, soil type, market demand and even indigenous traditional knowledge [21]. They are also able to make timely decisions on when to plant or harvest, decide on management practices such as weeding, application of fertilizer and pest control [22]. Access to modern technology is also a factor that influences decisions by small-scale farmers [23] since they are able to access information in a timelier manner and sometimes more relevant to their farms based on location.

Understanding the characteristics of the small-scale farmers is fundamental to ensuring that they receive relevant information for their crop growing activities [23]. The suitability of types of crops grown in a certain area depends on various factors such as climatic conditions, weather patterns, soil types and drainage patterns [24]. These characteristics vary spatially with varying resolutions and could result in different outcomes for farmers of similar crops.

This study sought to understand the characteristics of small-scale farmers in four selected counties of Kenya and also to understand their access to geospatial and related information relevant to crop production. The results will be used to improve farmers access and utilization of information with the expectation that this will subsequently increase their farms' productivity.

2. Materials and Methods

2.1. Geographical Scope

The study was conducted in four selected Counties of Kenya: Vihiga, Wajir, Kili-

fi 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 [12] [13] [14] across the selected counties (highlands, arid and semi-arid areas, tropical and coastal); 3) regional representation and ethnic diversity. **Figure 1** shows the counties that were covered.

A County is sub-divided into sub-Counties with a sub-County being subdivided into wards, the lowest administrative area. All sub-Counties in Vihiga, Kilifi and Wajir were covered in the survey, while in Nyeri, 8 out of 10 were covered. The two that were not covered were Aberdare Forest and Mt. Kenya Forest due to their very low population and insignificant farming activities [6].

2.2. Sampling Method

The study took the form of a survey that was carried out among small scale farmers in the four selected Counties. It included individual farmer interviews and focus group discussions with farmer groups.

For the individual farmer interviews, the sampling was done at County level. The sample size in each County was determined based on a population of farming households in each County as per the 2019 Kenya National Population and

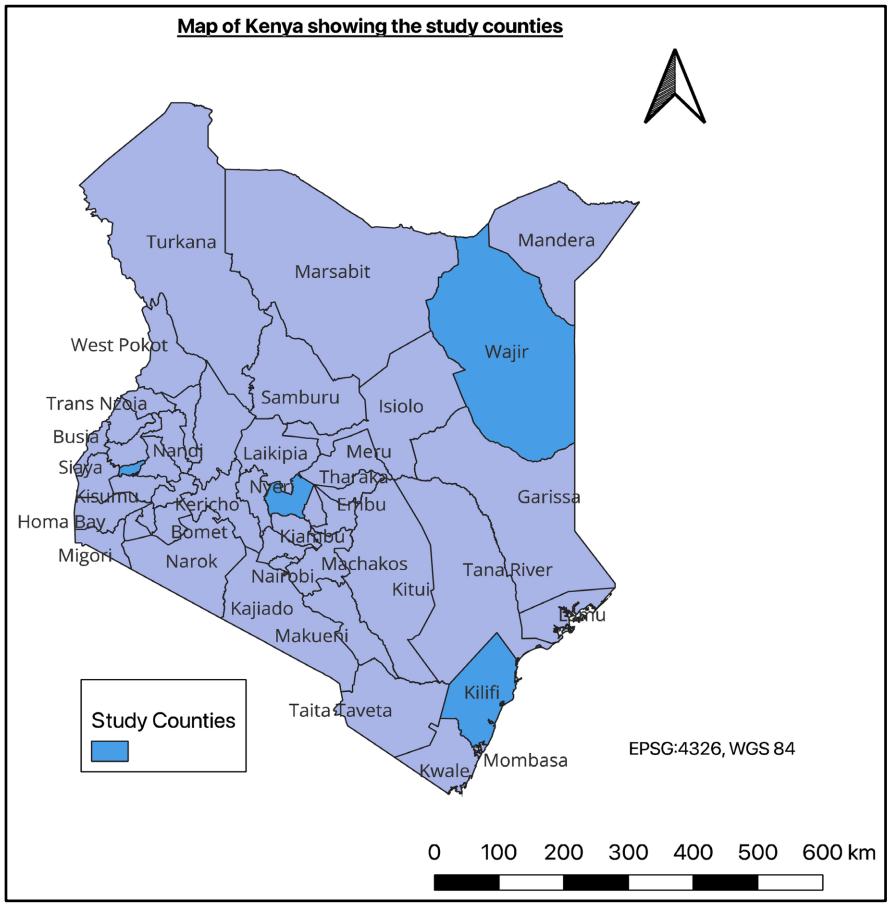

Figure 1. Map showing selected Counties for the study.

Housing Census [6]. The calculated sample size was then divided by the number of sub-counties that have farming activities. Within the wards, the sampling of farmers to be interviewed was randomly done [15].

The following formula was used to calculate the sample size in each county:

$$n = \frac{z^2 pqN}{e^2 (N-1) + z^2 pq}$$

where

- n is the required sample size
- Z is the Z-score corresponding to the chosen confidence level
- p is the estimated population proportion
- $q = 1 - p$
- N is the population size
- e is the desired margin of error

The confidence level used was 95% (Z-score = 1.96), with a 0.05 margin of error. N was the total number of farming households in the County, sourced from the 2019 Kenya Population and Housing Census [16], and p = 0.05. From the above formula, Table 1 shows the sample sizes that were used in each county.

2.3. Data Collection

A data collection questionnaire was designed in a web platform, Kobo Toolbox. The questionnaire included two main sections each looking at critical aspects of farmer characteristics and access to farming services and information. The first category focused on farmer characteristics, while the second category focused on farmers' access to information and their perception of the provided information.

All the questions were carefully formulated and phrased to ensure clarity of issues that were being assessed. Where possible the questions were formatted with pre-coded responses and options provided, so as to ensure sound analysis and interpretation of the responses. An option to specify responses that were not in the pre-coded list was provided.

The data collection was via a mobile app, Kobo Collect, that enabled online transfer of the data immediately after the interview. Data collection assistants were trained on how to use the mobile app and facilitated to conduct the interviews. The questionnaires were first pre-tested to ensure proper flow of the

Table 1. Sample sizes used in the four counties.

County	Number of Farming Households	Sample Size	Number of Interviews
Vihiga	111,139	383	400
Kilifi	154,803	383	385
Wajir	39,205	380	330
Nyeri	140,838	383	400

questions and identify any gaps or probable responses that could have been missed for pre-coding or those that could elicit responses that were not expected. The distribution of the sample size at sub-county level not only ensured a better distribution but was also found to be useful. This is because it was more logistically efficient to conduct the interviews since there were administrative boundaries that the data collectors could use to ensure that they selected farmers from the correct sub-county.

Data from all the four counties was collected between March and October 2022. In Wajir the sample size was not achieved because of security challenges with some sub-counties being inaccessible. Specifically, the sub-counties in the Eastern side (eastern side of Tarbaj, eastern side of Wajir South and eastern side of Wajir East) were sparsely covered as the County officers discouraged conducting the survey in those sub-counties without armed security escort.

At least two Focus Group Discussions (FGDs) were also conducted in separate sub-counties in each county, except Wajir where this was highly discouraged due to security concerns. The participants of the FGDs were drawn from existing farming groups in the sub-counties, and the discussions were moderated by the sub-county agricultural officers. The questions were focused on the most common crops grown and access to information for crop production.

3. Results

3.1. Farmer Characteristics

1) *Age and sex*

Across the four counties, most of the farmers were 36 - 45 years of age (29%) and 46 - 55 years (28%) with a significant proportion being over 55 years old (24%) (Figure 2). At the county level, in Kilifi, most of the farmers were in the

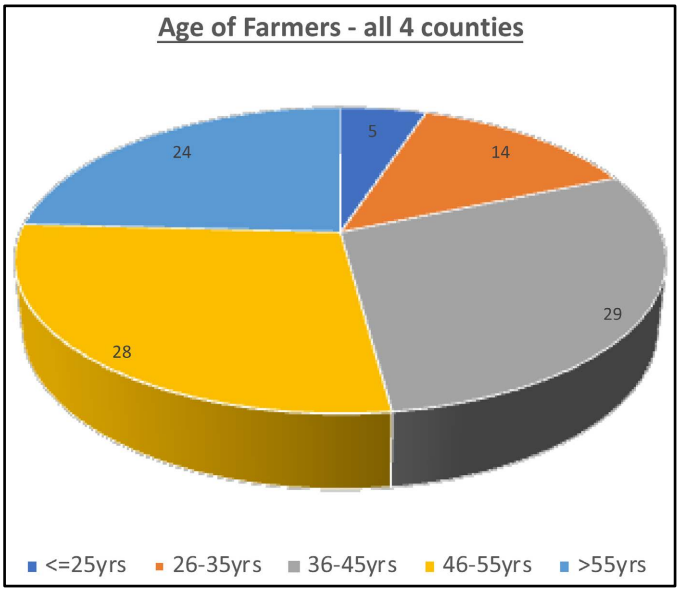

Figure 2. Age of interviewed farmers across the 4 counties.

36 - 45 years age group (30%) and 46 - 55 years (29%). A significant proportion was over 55 years old (24%). A similar trend was also evident in the other three counties of Vihiga, Nyeri and Wajir as shown in Table 2. Most of the interviewed farmers were male (56%). All the counties exhibited similar trends in sex of the farmers with all having more male than female farmers, at 53% in Kilifi, 55% in Vihiga, 55% in Nyeri and 62% in Wajir.

2) ***Level of Education***

The highest level of education attained by most farmers is primary school (34%) followed by secondary school at 29% (Figure 3). Those with no formal education were 25% while those with post-secondary education were only 12%.

While Kilifi had most farmers with only primary education at 48%, for Wajir the highest proportion was with no formal education at 61%. In Vihiga, on the other hand, most farmers have a secondary school education (51%) and Nyeri, most farmers had primary or secondary education (39% and 37% respectively) (Table 3).

3) ***Size of farms***

Across the four counties, 80% of interviewed farmers had less than or equal to 5-acre parcels of land. At the county level, the proportion of farmers with land parcels measuring 5 acres or less was 84% in Kilifi, 83% in Nyeri, 86% in Vihiga and 61% in Wajir.

Table 2. Age of farmers in each of the four counties.

County	Kilifi		Vihiga		Nyeri		Wajir	
Age	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
≤25 yrs	20	5.18	8	2	16	4	33	10
26 - 35 yrs	49	12.69	42	10.5	60	15	54	16.36
36 - 45 yrs	117	30.31	122	30.5	120	30	85	25.76
46 - 55 yrs	113	29.27	107	26.75	110	27.5	94	28.48
>55 yrs	87	22.54	121	30.25	94	23.5	64	19.39
Total	386	100	400	100	400	100	330	100

Table 3. Education level of farmers in the four counties.

County/	*Kilifi*		*Vhiga*		*Nyeri*		*Wajir*	
Education Level	Freq	Percent	Freq	Percent	Freq	Percent	Freq	Percent
No formal Education	94	24.35	32	8	54	13.5	201	60.91
Primary Education	185	47.93	101	25.25	157	39.25	72	21.82
Secondary Education	74	19.17	204	51	146	36.5	20	6.06
Post-Secondary Education	33	8.55	63	15.75	43	10.75	37	11.21
Total	**386**	**100**	**400**	**100**	**400**	**100**	**330**	**100**

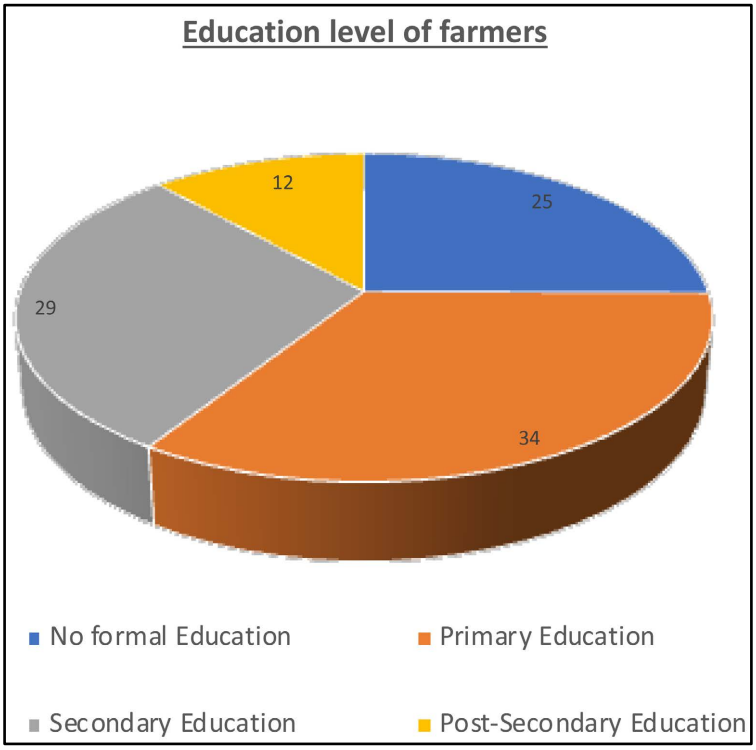

Figure 3. Education level of interviewed farmers across the 4 counties.

3.2. Main Crops Grown

As the staple crop of Kenya, maize was the main crop grown by farmers in all the four counties. Overall, 71% of farmers in all the 4 counties grew maize and within the counties (93% in Kilifi, 66% in Nyeri, 87% in Vihiga and 32% in Wajir). Beans was the next most common crop grown followed by bananas.

In Kilifi, green grams took second place and cowpeas was third, while in Nyeri coffee and beans were second and third respectively. In Vihiga, beans and bananas were second and third place respectively and in Wajir sorghum and grass are second and third most commonly grown crops respectively.

Across the 4 counties, most crops were grown for subsistence purposes only (53%) and only a small proportion was grown purely for commercial purposes (18%). Of the counties studied, Kilifi, Nyeri and Vihiga had most farmers growing crops for subsistence, while in Wajir the higher proportion of farmers grew crops for both subsistence and commercial purposes (62%). Nyeri had a notably high proportion of farmers growing crops for commercial purposes only at 33%. This can be explained by the second most commonly grown crop in the county which was coffee.

3.3. Access to Farming Information

1) *Information and Source*

Farmers were asked to indicate the types and sources of their farming information. The results of this study showed that the most sought-after information

by farmers was onset, cessation and intensity of rainfall (90% of farmers), soil nutrients (54%) and market information (commodity prices and available markets) (53%). A similar trend was also observed in the counties with all four counties having more than 85% of farmers indicating rainfall as the most sought-after information. This information was sourced from various sources, 71% of the farmers relied on fellow farmers as a source of information, 52% used Radio/TV as a source of information and 40% also depended on information from County extension officers and friends respectively as shown in **Figure 4**. It is worth noting that the Kenya Meteorological Department, which produces the country's weather forecasts was not identified as a common source of information, with only 13% getting their information from the department either through their officers or bulletins.

At the county level, Kilifi had 68% sourcing from fellow farmers, 55% also sourced information from county extension officers and 51% from Radio/TV; Vihiga 80% from fellow farmers, 61% from Radio/TV and 53% from friends; Nyeri 73% from fellow farmers, 69% from Radio/TV and 52% from county extension officers; Wajir 41% from county extension officers and 34% from fellow farmers. All the four counties had less than 20% of farmers sourcing information from Kenya Meteorological Department (KMD).

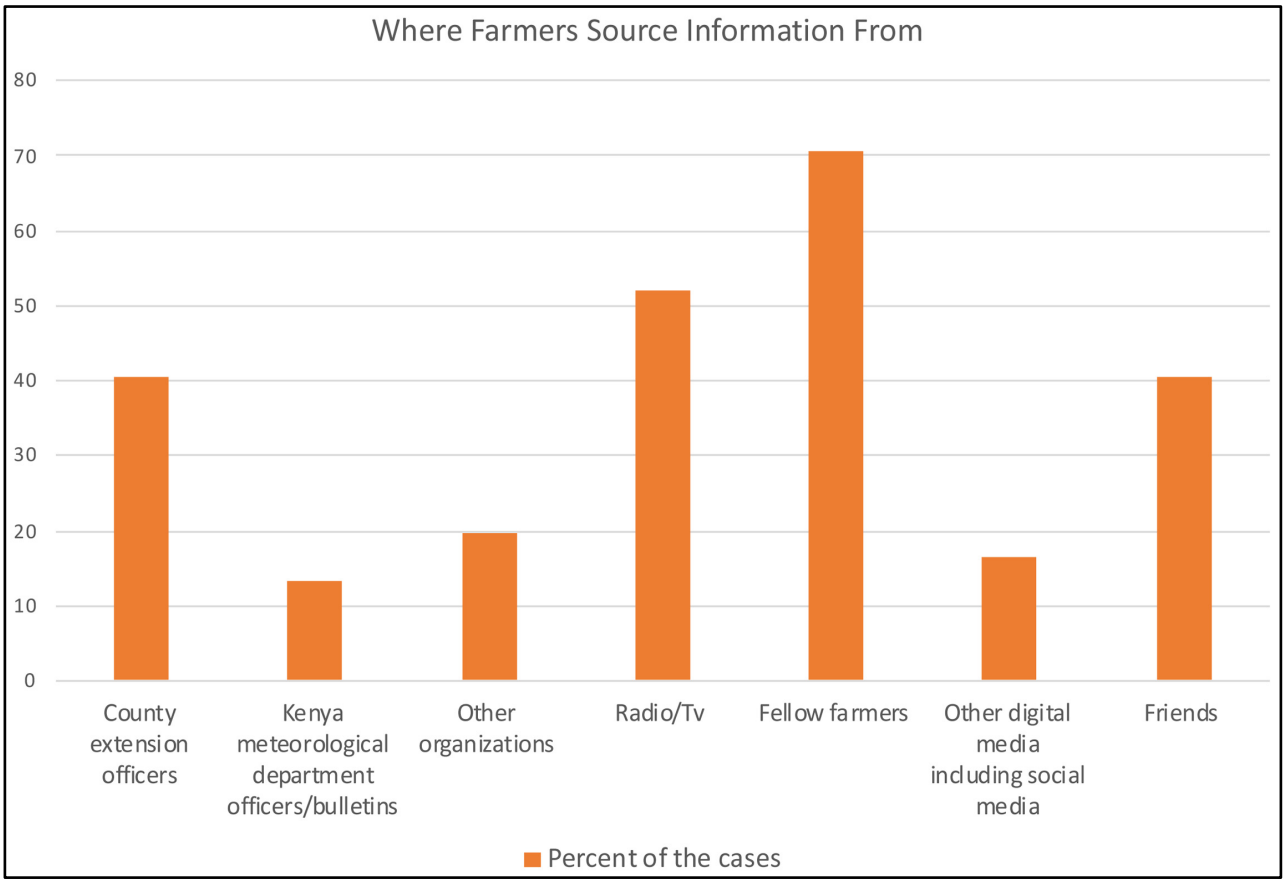

Figure 4. Source of information for farmers (this was a multiple response question).

2) *Frequency of Information Access*

Farmers need information on upcoming seasons early enough to enable them to prepare their land. More frequent weather information is also critical during the growing period. The study revealed that most of the weather information was shared based on its availability (43%) and seasonally (37%) (Figure 5). Similar results were observed at county level as shown in the Table 4.

3) *Usability of Shared Information*

The usability of shared information depends on critical aspects such as whether it is shared in a timely manner, if it is accurate and how it's delivered, *i.e.* how it is packaged [17]. The results from across the 4 counties show that 80% of the farmers obtained information verbally and this correlates with the most common sources which included fellow farmers, county extension officers and friends. About 58% of farmers acquired information through Radio/TV broadcasts and 32% also got information through social media messages (Figure 6).

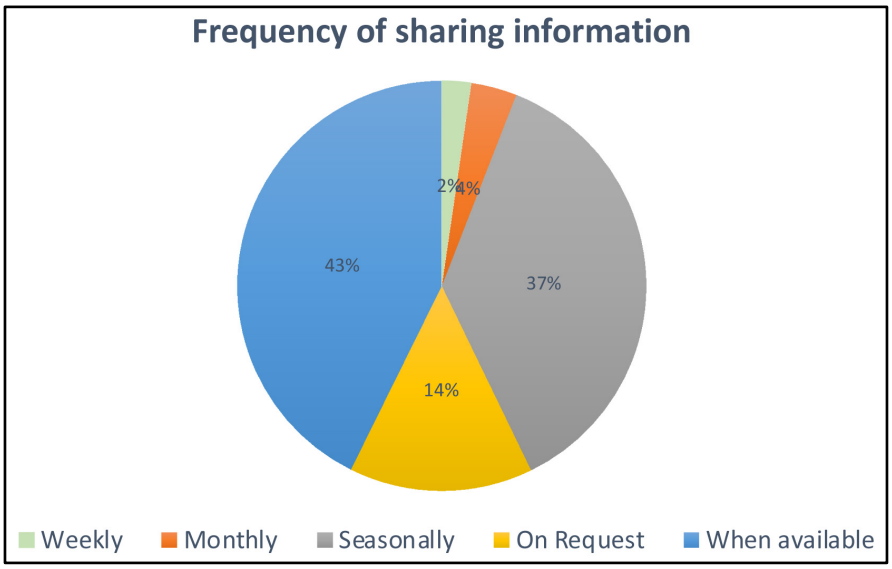

Figure 5. Frequency of information provision.

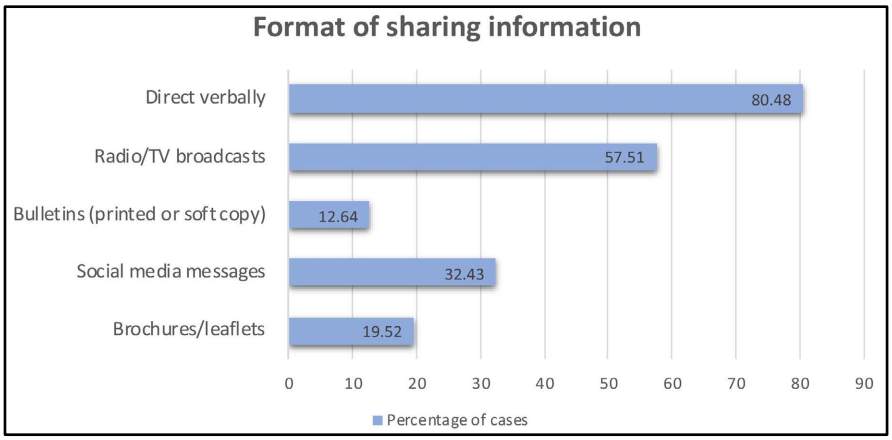

Figure 6. Format of sharing information in all four counties.

Figure 7 shows a similar trend within the four counties.

A large proportion (59%) of farmers indicated that the information shared was usually timely and 63% considered it accurate, while 62% considered provided information to be adequate for their farming activities. At the county level, notably higher proportion of farmers in Kilifi indicated that the information provided was timely, accurate and adequate for their farming activities, while in Wajir a very high proportion considered the information timely, accurate and adequate. However, in Nyeri and Vihiga, most farmers considered the information untimely, and about half considered it inaccurate. Table 5 shows the results for the 4 counties on timeliness, accuracy and adequacy of the information.

4) ***Challenges in Using Provided Information and Proposed Improvements***

Table 4. Frequency of information provision in the 4 counties.

County	Kilifi		Vihiga		Nyeri		Wajir	
How often is the information provided?	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Weekly	15	3.89	5	1.25	11	2.75	4	1.21
Monthly	14	3.63	26	6.5	7	1.75	8	2.42
Seasonally	135	34.97	135	33.75	186	46.5	103	31.21
On Request	62	16.06	78	19.5	48	12	32	9.7
When available	160	41.45	156	39	148	37	183	55.45
Total	386	100	400	100	400	100	330	100

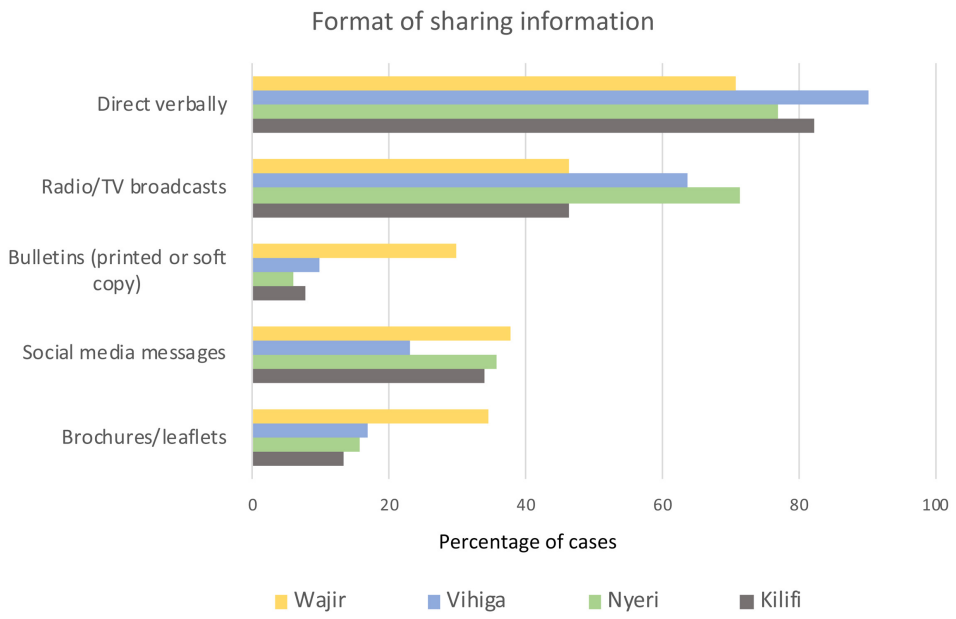

Figure 7. Format of sharing information within the counties.

Table 5. Timeliness, accuracy and adequacy levels as reported within the counties.

County	Kilifi		Nyeri		Vihiga		Wajir	
Parameter	**YES**	**NO**	**YES**	**NO**	**YES**	**NO**	**YES**	**NO**
Timeliness	64.51	35.49	39.25	60.75	44.5	55.5	94.55	4.45
Accuracy	67.36	32.64	49.5	50.5	48.5	51.5	93.94	6.06
Adequacy	65.8	34.2	44.75	55.25	49	51	94.55	5.45

Most farmers (66%) indicated that they faced challenges while trying to utilize the information they received. Some of the challenges reported include difficulty in understanding the language used (46% of farmers), high cost involved in utilizing the information (53%), and difficulty in interpreting the provided information (52%). The language challenge could be related to the education of farmers which was noted at 59% with primary or no formal education. The results for each county are shown in Figure 8. Notable Wajir which has a high percentage of farmers (75%) indicating difficulties in understanding the language used. The level of education in the county is relatable to the high figure (61% with no formal education and 22% with only primary education).

They indicated several improvements which they felt would improve the usability of provided information. The proposals included increase in timeliness and accuracy (suggested by 66% and 64% of farmers respectively), additional information to the weather information (57%), better interpretation of provided information (39%) and better packaging of information (34%).

3.4. Access to Farming Information

The quantitative survey results on the most common crops in Kilifi, Nyeri and Vihiga were similar to what farmers expressed in the FGDs. In Nyeri, coffee and tea were the most common commercial crops but tea was not grown in some parts of the county. Maize, beans, potatoes and vegetables such as cabbage and kales were also common in the two sub-counties of Nyeri Central and Nyeri South (Othaya) where the FGDs were conducted. Maize, beans and potatoes were grown mainly for subsistence while the cabbages and kales were planted for both commercial and subsistence. In Vihiga (Luanda and Emuhaya), the FGDs results also revealed that African leaf vegetables and sweet potatoes were common crops grown for both subsistence and commercial. In Kilifi, vegetables were the most common and in Ganze where one of the FGDs was conducted there were farmer groups that promoted the farming of vegetables.

On information required for crop production, Kilifi farmers had similar responses with rainfall onset, cessation and duration being critical to enable farmers plan on when to prepare and plant, and also what to plant. Although soil testing to enable farmers know the deficient nutrients in their soils was also indicated as a critical service, this was however not readily available. In Nyeri, information on rainfall was also considered very important in addition to market

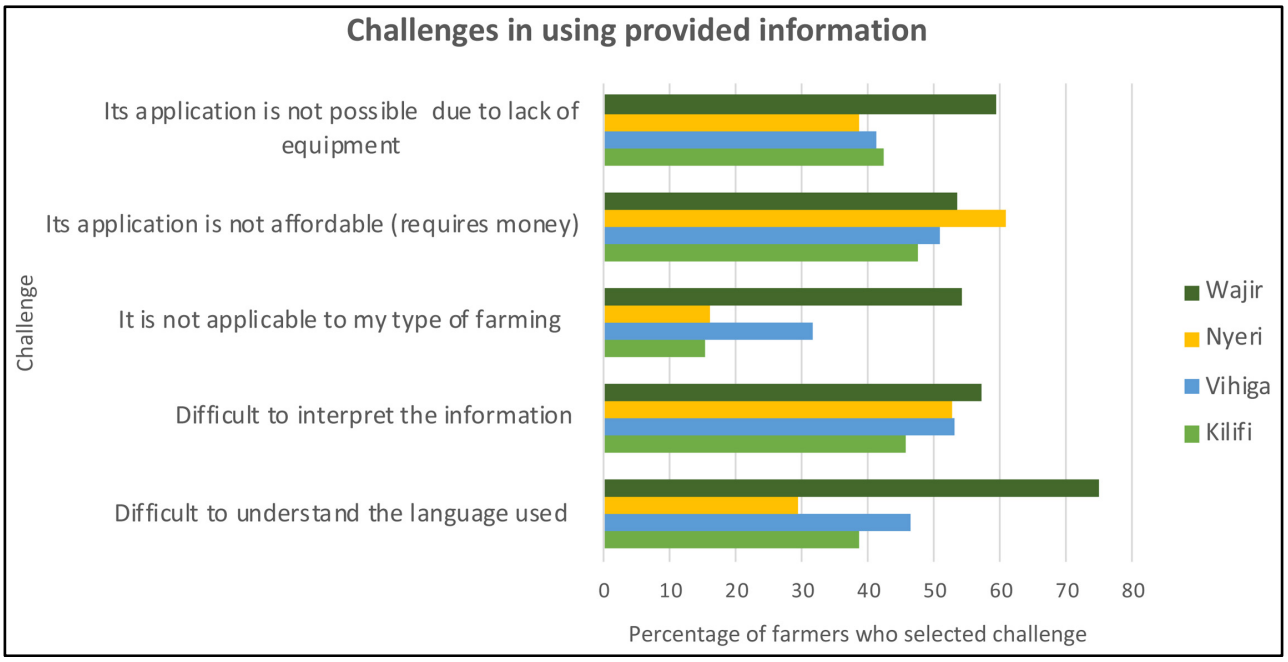

Figure 8. Challenges in using shared information within the counties.

information, *i.e.* where to sell and commodity prices. In Vihiga, in addition to rainfall information, farmers expressed the need to have soil testing done regularly and to get access to market information. Information on pests control and diseases were highlighted as important in all three counties where FGDs were conducted.

Whereas most farmers indicated their main source of information as the extension officers in Nyeri and Vihiga, TV and radio were also common. However, in Kilifi there were reservations over use of TV and radio as not all farmers owned either a TV or a radio. In Kilifi, there was high confidence and preference for information shared by extension officers through public forums (barazas).

Timeliness and accuracy were the main characteristics that farmers valued in all the three counties. They indicated that without timely and accurate information, they suffered losses since they could not plan well in advance or sometimes their plans turned out to be off the seasonal calendar. They indicated better packaging of the information, interpretation, more timely delivery and increase in accuracy as the main areas of improvement that would enable them increase productivity.

3.5. Regression Analysis on Timeliness and Accuracy

1) *Timeliness and format of sharing*

Logistic regression analysis was done on the different parameters to determine the relationship between timeliness and the format used to share the information across the four counties and within each county. As shown in Table 6 the odds ratios and p-values were analyzed to evaluate the statistical significance of this

Table 6. Logistic regression on timeliness of information in relation to sharing format across the 4 Counties.

Infor_Timeliness	Odds Ratio	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Brochures/Leaflets	1.231	0.202	1.27	0.205	0.893	1.698	
Social Media Messages	1.583	0.201	3.61	0	1.234	2.032	***
Bulletins (Printed and Soft Copy)	2.442	0.51	4.27	0	1.621	3.678	***
Radio/TV Broadcast	0.544	0.063	−5.25	0	0.433	0.683	***
Directly Verbal	0.703	0.1	−2.47	0.013	0.531	0.93	**
Constant	2.069	0.328	4.59	0	1.517	2.822	***
Mean dependent var	0.591		SD dependent var		0.492		
Pseudo r-squared	0.039		Number of obs		1516		
Chi-square	79.799		Prob > chi2		0.000		
Akaike crit. (AIC)	1983.294		Bayesian crit. (BIC)		2015.237		

***p < 0.01, **p < 0.05, *p < 0.1.

association. With the reference group being brochures and leaflets, bulletins and social media messages were the two most likely channels to be most timely with an odds ratio of 2.442 (p < 0.001, 95% CI [1.621, 3.678]) and 1.583 (p < 0.001, 95% CI [1.234, 2.032]) respectively. Inverse correlation for radio/TV and direct verbal was observed with an odds ratio of 0.544 (p < 0.001, 95% CI [0.433, 0.683]) and 0.703 (p = 0.013, 95% CI [0.531, 0.930]) respectively. These findings suggest that the format of information sharing significantly influences the timeliness of information, with Social Media Messages and Bulletins (Printed and Soft Copy) being associated with higher timeliness compared to Brochures/Leaflets, while Radio/TV Broadcast and Directly Verbal were associated with lower timeliness.

At the county level, in Kilifi, social media messages had a highest positive correlation with timeliness followed by bulletins, as shown in Table 7, with an odds ratio of 2.045 (p = 0.007, 95% CI [1.214, 3.447]) and 1.181 (p = 0.686, 95% CI [0.527, 2.65]) respectively. In Nyeri, while bulletins had the highest positive correlation with timeliness, followed by brochures/leaflets, social media messages and direct verbal formats, all whose odd ratios were close to each other as shown in Table 8.

In Vihiga County, direct verbal and social media messages had the highest significant odds ratios respectively (1.864 (p = 0.078, 95% CI [0.932, 3.726]) and 1.577 (p = 0.069, 95% CI [0.965, 2.575])) as shown in Table 9. Lastly, Wajir showed no significant correlations between timeliness and format of information sharing, as shown in Table 10.

2) ***Accuracy of information in relation to source***

The sources were analysed for accuracy through a logistic regression. From the results shown in Table 11, county extension officers and Radio/TV showed

Table 7. Logistic regression on timeliness of information in relation to sharing format in Kilifi County.

Infor_Timeliness	Odds Ratio	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Brochures/Leaflets	0.74	0.262	−0.85	0.394	0.37	1.479	
Social Media Messages	2.045	0.545	2.69	0.007	1.214	3.447	***
Bulletins (Printed and Soft Copy)	1.181	0.487	0.41	0.686	0.527	2.65	
Radio/TV Broadcast	0.696	0.164	−1.53	0.125	0.438	1.106	
Directly Verbal	0.415	0.141	−2.58	0.01	0.213	0.809	**
Constant	3.715	1.354	3.60	0	1.818	7.591	***
Mean dependent var	0.645		SD dependent var		0.479		
Pseudo r-squared	0.038		Number of obs		386		
Chi-square	19.196		Prob > chi2		0.002		
Akaike crit. (AIC)	494.944		Bayesian crit. (BIC)		518.679		

***p < 0.01, **p < 0.05, *p < 0.1.

Table 8. Logistic regression on timeliness of information in relation to sharing format in Nyeri County.

Infor_Timeliness	Odds Ratio.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Brochures/Leaflets	1.806	0.538	1.98	0.047	1.007	3.238	**
Social Media Messages	1.6	0.362	2.08	0.038	1.027	2.492	**
Bulletins (Printed and Soft Copy)	3.479	1.663	2.61	0.009	1.363	8.88	***
Radio/TV Broadcast	0.648	0.156	−1.80	0.071	0.405	1.038	*
Directly Verbal	1.534	0.417	1.57	0.116	0.899	2.615	
Constant	0.445	0.146	−2.46	0.014	0.234	0.848	**
Mean dependent var	0.393		SD dependent var		0.489		
Pseudo r-squared	0.045		Number of obs		400		
Chi-square	24.312		Prob > chi2		0.000		
Akaike crit. (AIC)	523.571		Bayesian crit. (BIC)		547.519		

***p < 0.01, **p < 0.05, *p < 0.1.

likelihood of high accuracy than other sources, and were both statistically significant ($p < 0.01$)

In Kilifi County, information from county extension officers (Odds Ratio = 2.353, $p < 0.01$) and radio/TV broadcasts (Odds Ratio = 0.485, $p < 0.01$) was likely to be more accurate than information from other sources as reported by interviewed farmers as shown in Table 12.

In Nyeri, significant odds ratios were found for information obtained from county extension officers (OR = 3.219, $p < 0.001$), fellow farmers (OR = 2.919, $p < 0.001$), and other digital media such as social media (OR = 3.382, $p < 0.001$)

Table 9. Logistic regression on timeliness of information in relation to sharing format in Vihiga County.

Infor_Timeliness	Odds Ratio	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Brochures/Leaflets	0.686	0.21	−1.23	0.218	0.377	1.249	
Social Media Messages	1.577	0.395	1.82	0.069	0.965	2.575	*
Bulletins (Printed and Soft Copy)	0.757	0.295	−0.71	0.476	0.352	1.627	
Radio/TV Broadcast	1.109	0.239	0.48	0.63	0.727	1.693	
Directly Verbal	1.864	0.659	1.76	0.078	0.932	3.726	*
Constant	0.421	0.154	−2.37	0.018	0.205	0.862	**
Mean dependent var	0.445		SD dependent var		0.498		
Pseudo r-squared	0.018		Number of obs		400		
Chi-square	9.751		Prob > chi2		0.083		
Akaike crit. (AIC)	551.917		Bayesian crit. (BIC)		575.866		

***p < 0.01, **p < 0.05, *p < 0.1.

Table 10. Logistic regression on timeliness of information in relation to sharing format in Wajir County.

Infor_Timeliness	Odds Ratio.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Brochures/Leaflets	1	.	.	.	.	.	
Social Media Messages	0.916	1.032	−0.08	0.938	0.101	8.341	
Bulletins (Printed and Soft Copy)	1	.	.	.	.	.	
Radio/TV Broadcast	0.456	0.438	−0.82	0.413	0.069	2.994	
Directly Verbal	0.157	0.178	−1.64	0.101	0.017	1.438	
Constant	56.091	64.739	3.49	0	5.841	538.678	***
Mean dependent var	0.914		SD dependent var		0.281		
Pseudo r-squared	0.031		Number of obs		209		
Chi-square	3.815		Prob > chi2		0.282		
Akaike crit. (AIC)	126.858		Bayesian crit. (BIC)		140.228		

***p < 0.01, **p < 0.05, *p < 0.1.

(Table 13). Although, TV and Radio had a high proportion of farmers as a source of information from the quantitative analysis, the regression on accuracy showed a lower significance level of 0.058 compared to fellow farmers and extension farmers.

In Vihiga, although the odds ratio was low for KMD, the significance level was high with a p-value of 0.001 (Table 14). There was a high proportion of farmers getting information from fellow farmers and radio/TV but from this regression, the significance levels for both were much lower than KMD.

The logistic regression for Wajir did not show any meaningful association

Table 11. Logistic regression on accuracy of information in relation to source of the information for all 4 counties.

Infor_Accuracy	Odds Ratio	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
County extension officers	2.353	0.279	7.22	0	1.865	2.969	***
Kenya Meteorological Department officers/bulletins	0.781	0.131	−1.47	0.141	0.562	1.085	
Other organizations	1.023	0.146	0.16	0.873	0.773	1.353	
Radio/TV	0.485	0.056	−6.30	0	0.387	0.607	***
Fellow farmers	1.057	0.132	0.44	0.658	0.827	1.351	
Other digital media including social media	1.266	0.199	1.50	0.133	0.931	1.723	
Friends	1.102	0.126	0.85	0.396	0.881	1.379	
Constant	1.701	0.22	4.12	0	1.321	2.191	***
Mean dependent var	0.635		SD dependent var		0.482		
Pseudo r-squared	0.045		Number of obs		1516		
Chi-square	90.098		Prob > chi2		0.000		
Akaike crit. (AIC)	1916.354		Bayesian crit. (BIC)		1958.944		

***p < 0.01, **p < 0.05, *p < 0.1.

Table 12. Logistic regression on accuracy of information in relation to source of the information in Kilifi County.

Infor_Accuracy	Odds Ratio	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
County extension officers	2.353	0.279	7.22	0	1.865	2.969	***
Kenya Meteorological Department officers/bulletins	0.781	0.131	−1.47	0.141	0.562	1.085	
Other organizations	1.023	0.146	0.16	0.873	0.773	1.353	
Radio/TV	0.485	0.056	−6.30	0	0.387	0.607	***
Fellow farmers	1.057	0.132	0.44	0.658	0.827	1.351	
Other digital media including social media	1.266	0.199	1.50	0.133	0.931	1.723	
Friends	1.102	0.126	0.85	0.396	0.881	1.379	
Constant	1.701	0.22	4.12	0	1.321	2.191	***
Mean dependent var	0.635		SD dependent var		0.482		
Pseudo r-squared	0.045		Number of obs		1516		
Chi-square	90.098		Prob > chi2		0.000		
Akaike crit. (AIC)	1916.354		Bayesian crit. (BIC)		1958.944		

***p < 0.01, **p < 0.05, *p < 0.1.

Table 13. Logistic regression on accuracy of information in relation to source of the information in Nyeri County.

Infor_Accuracy	Odds Ratio	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
County extension officers	3.219	0.737	5.10	0	2.055	5.043	***
Kenya Meteorological Department officers/bulletins	1.016	0.297	0.06	0.956	0.573	1.801	
Other organizations	1.449	0.39	1.38	0.168	0.855	2.457	
Radio/TV	0.622	0.156	−1.90	0.058	0.38	1.016	*
Fellow farmers	2.919	0.835	3.75	0	1.667	5.113	***
Other digital media including social media	3.382	0.965	4.27	0	1.933	5.918	***
Friends	1.087	0.258	0.35	0.725	0.682	1.732	
Constant	0.228	0.075	−4.51	0	0.12	0.433	***
Mean dependent var	0.495		SD dependent var		0.501		
Pseudo r-squared	0.117		Number of obs		400		
Chi-square	64.609		Prob > chi2		0.000		
Akaike crit. (AIC)	505.868		Bayesian crit. (BIC)		537.800		

***p < 0.01, **p < 0.05, *p < 0.1.

Table 14. Logistic regression on accuracy of information in relation to source of the information in Vihiga County.

Infor_Accuracy	Odds Ratio	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
County extension officers	1.492	0.475	1.25	0.209	0.799	2.785	
Kenya Meteorological Department officers/bulletins	0.15	0.065	−4.36	0	0.064	0.351	***
Other organizations	2.406	0.578	3.65	0	1.502	3.852	***
Radio/TV	1.399	0.323	1.46	0.146	0.89	2.198	
Fellow farmers	1.311	0.376	0.94	0.345	0.747	2.302	
Other digital media including social media	1.383	0.398	1.13	0.26	0.787	2.43	
Friends	1.96	0.451	2.93	0.003	1.249	3.076	***
Constant	0.333	0.101	−3.62	0	0.183	0.603	***
Mean dependent var	0.485		SD dependent var		0.500		
Pseudo r-squared	0.079		Number of obs		400		
Chi-square	43.509		Prob > chi2		0.000		
Akaike crit. (AIC)	526.648		Bayesian crit. (BIC)		558.580		

***p < 0.01, **p < 0.05, *p < 0.1.

between the sources of information and accuracy (Table 15).

3.6. Challenges Encountered in Using Information in Relation to the Format

Analysis on the challenges encountered while using provided information in relation to the format used was also done. The results for Vihiga County show slightly higher proportion of farmers had difficulties understanding the language used and interpreting the information for brochures/leaflets and bulletins than other formats such as social media and verbal formats (Figure 9).

Similar to Vihiga, Kilifi County results show that farmers experienced challenges in understanding and interpreting the information prepared more with brochures/leaflets and bulletins than with other formats (Figure 10). It is also worth noting that those who indicated that the shared information was not applicable to their type of farming were considerably fewer indicating that the shared information was largely relevant for the farmers.

A high proportion of farmers in Nyeri indicated having challenges in applying the provided information due to affordability across all formats, while low proportions indicated that the provided information was not applicable across all formats (Figure 11).

In Wajir County, whereas the proportion of farmers who indicated having challenges with brochures/leaflets and bulletins is higher than other formats, social media and Radio/TV proportions were also high compared to other counties (Figure 12).

Table 15. Logistic regression on accuracy of information in relation to source of the information in Wajir County.

Infor_Accuracy	Odds Ratio	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
County extension officers	1	.	.	.	.	.	
Kenya Meteorological Department officers/bulletins	1	.	.	.	.	.	
Other organizations	1	.	.	.	.	.	
Radio/TV	0.498	0.571	−0.61	0.543	0.053	4.714	
Fellow farmers	0.71	0.901	−0.27	0.787	0.059	8.532	
Other digital media including social media	1	.	.	.	.	.	
Friends	0.81	1.103	−0.15	0.877	0.056	11.696	
Constant	13.182	17.233	1.97	0.049	1.017	170.928	**
Mean dependent var	0.902		SD dependent var		0.299		
Pseudo r-squared	0.005		Number of obs		193		
Chi-square	0.592		Prob > chi2		0.898		
Akaike crit. (AIC)	131.567		Bayesian crit. (BIC)		144.617		

***p < 0.01, **p < 0.05, *p < 0.1.

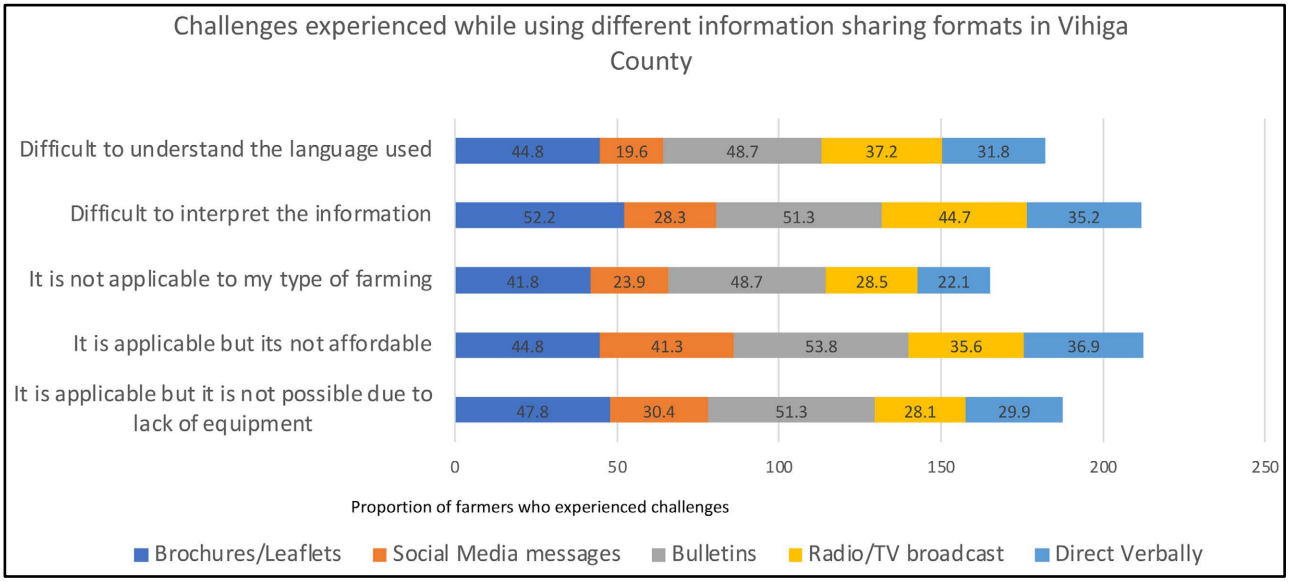

Figure 9. Challenges encountered while using information sharing formats in Vihiga County.

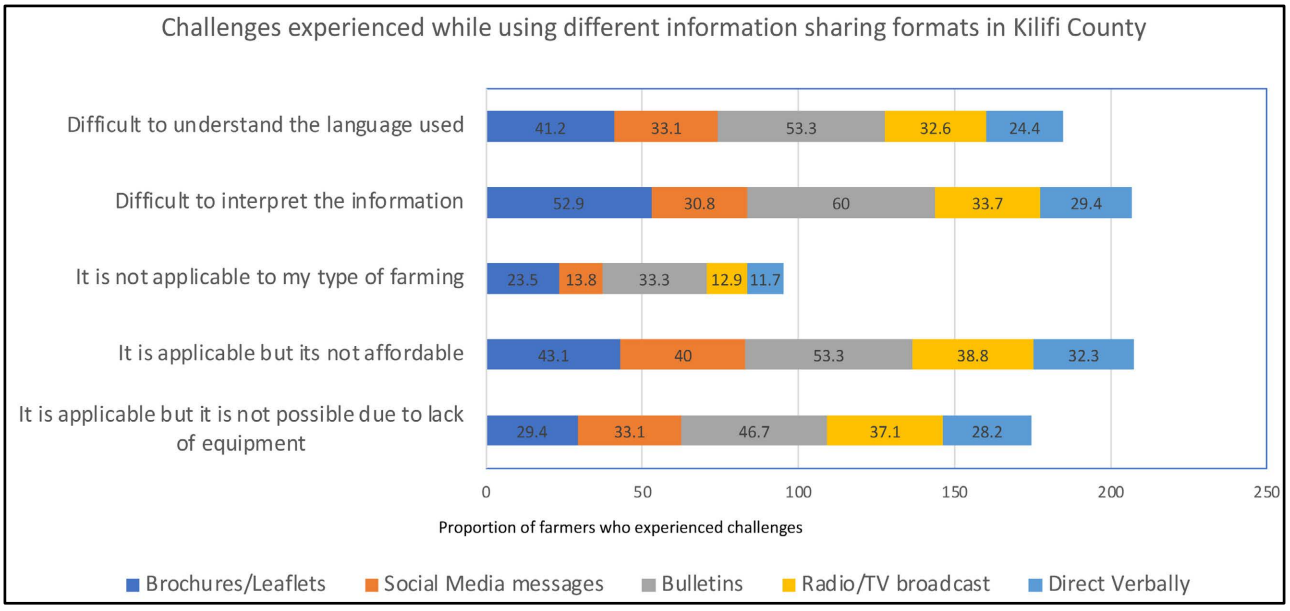

Figure 10. Challenges encountered while using information sharing formats in Vihiga County.

4. Discussion

The results give very insightful information on the characteristics of the farmers. It is clear that over 80% of farmers are over 35 years of age and most have secondary or primary education. This information is useful when making decisions on the mode of information provision based on the different categories so as to ensure that it reaches the highest number of farmers possible. For example, sharing information in written form with farmers that have no formal education at all might mean that they would not get to use it due to language constraints and even if they were to get someone to help, the timeliness and accuracy would

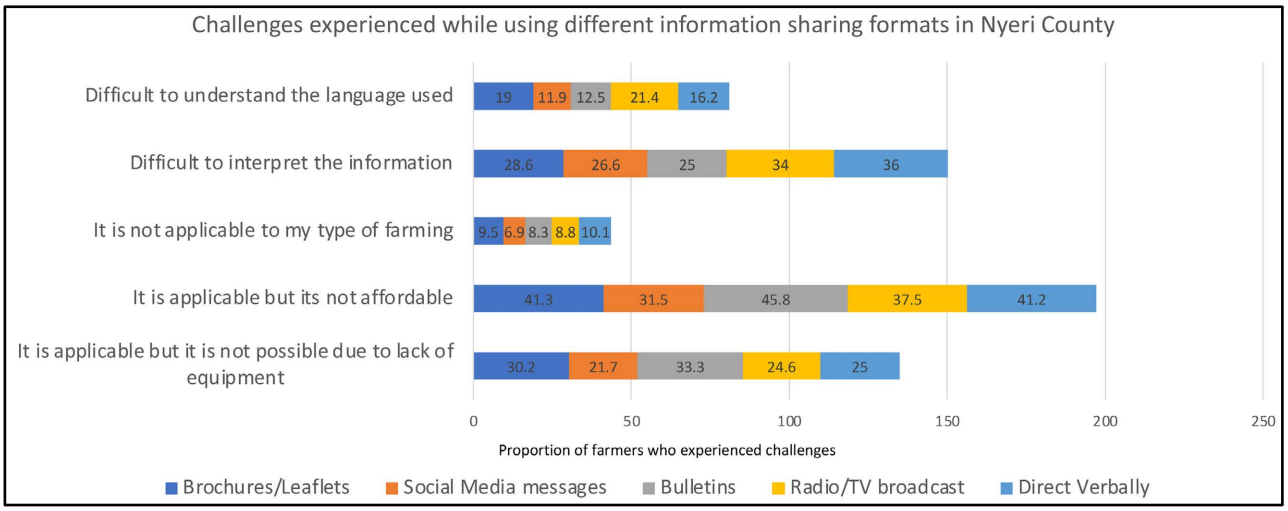

Figure 11. Challenges encountered while using information sharing formats in Nyeri County.

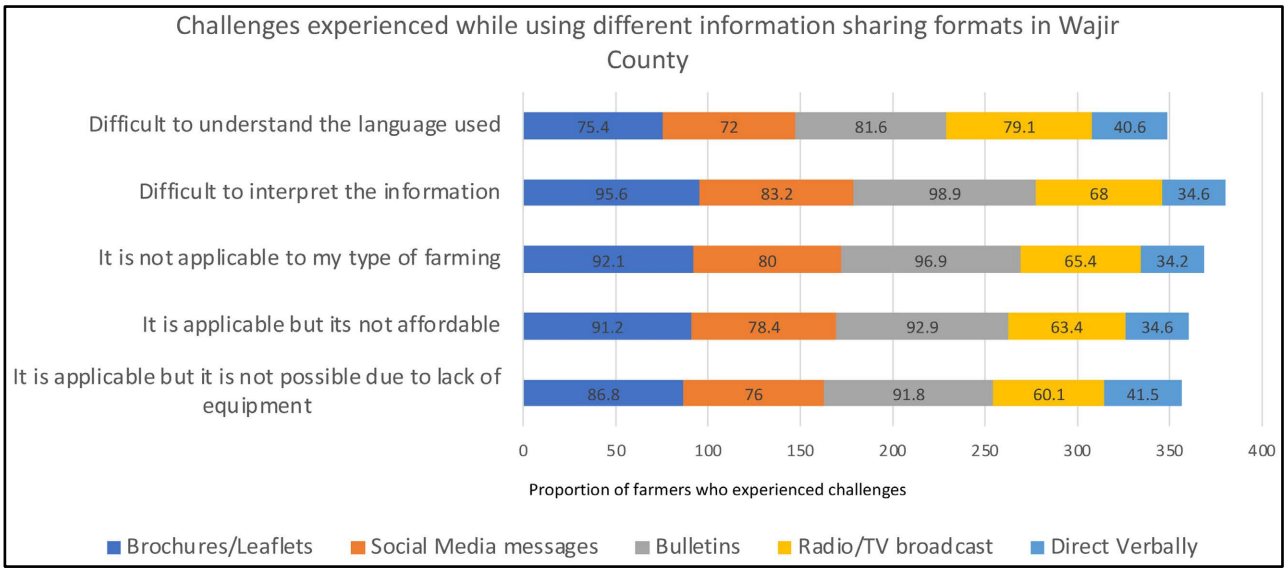

Figure 12. Challenges encountered while using information sharing formats in Wajir County.

decrease in the process. The variations within the counties reflect the fact that each county has different farmer characteristics which should be taken into account. The decisions on how to share information should therefore ideally be made based on a combination of characteristics to ensure maximum effectiveness.

The farm sizes are also a factor in the type of information shared. Given that about 80% of farmers have 5 acres or less, and grow more than one type of crop, the information required becomes complex because the different crops may have different requirements not just for rainfall and temperatures but also soil nutrients. This puts a high level of responsibility on the type and detail of advisory services relayed to the farmers and also calls on the farmer to seek suitable information for all their activities. The size of farms is also a challenge when using

Earth Observation data to monitor crops due to resolution constraints that may hinder discrimination of different types of crops and also coverage of farms smaller than the image's pixel size.

The human-based provision of information is the most common with over 70% of farmers indicating at least one of them (extension officers, fellow farmers or friends) and radio and TV is also a significant source at 21%. However, the perception of the usability of the information ranges from 60% - 63% for adequacy, timeliness and accuracy. The logistic regressions showed interesting results where most common sources of information were not necessarily the ones considered more accurate, e.g. most farmers in Vihiga had their source of information as fellow farmers, but the significance of its accuracy was low compared to other sources. These results are useful in deciding on which sharing formats to improve for accuracy and coverage.

The results indicate that although not many farmers (only 17%) were using digital and other social media to source for farming information, up to 32% indicated that they obtained information through digital format. This is an area that requires further investigation as the reasons behind these figures could give more insightful information on how to improve sharing of information. A probable scenario is where the information shared by fellow farmers, friends or extension officers is already interpreted and being shared in an understandable language and format, while the digital and social media information which are not targeted to a specific farmer could be in a language that's not understandable to the farmer and therefore not used.

The comparison between the challenges encountered while using provided information against the format used did not show highly significant variations. While it was clear that bulletins, brochures/leaflets and radio/TV were indicated by a slightly higher proportion of farmers as having challenges in understanding the language and interpreting the information, the small variations could mean that the format was not the problem but the content was itself not easy to understand. In Wajir, only direct verbal format has low proportion farmers indicating it as a challenge and could mean it is more effective. The inapplicability of the shared information has high proportions in Wajir compared to other counties and this could mean the shared information was not relevant for the county, although this needs further investigation. Also, in Wajir, the proportion of farmers who indicated that they had challenges using Radio/TV and social media formats was notably higher than in other counties. While these results could reflect the true situation, they could also indicate a bias in the data collection and therefore further investigation would be required before utilizing them.

5. Conclusions

The insights from this study are very enlightening. The determination of the type of formats to use in order to ensure maximum efficiency in sharing information is made easier with these results. While the results have been analyzed at County lev-

el, it is possible that there exist variations at sub-County levels too and these would need to be studied further. It is also worth noting that there could be limitations in using the most effective formats based on factors such as costs and logistical challenges. However, whatever choices need to be made, they would be better informed with these results. Notably, KMD is not used by many farmers as a source. While the department is most probably the source of all weather data that is shared, the awareness of its existence and authority in provision of weather data by farmers could be low, or it's methods of sharing not suitable or accessible to farmers. The fact that extension officers mostly get weather information from KMD county officers and that KMD also disseminates weather alerts and forecasts through radio and TV cannot be overlooked and KMD could therefore be reaching many farmers but indirectly. Lastly, it's clear that the most common formats used to disseminate information are direct verbal, Radio/TV broadcasts and social media messages indicating a developmental departure from printed materials and the progressive change towards digital formats.

From the results of this study, some of the measures that could be taken to improve sharing of information for crop production include: ensuring the information is easy to understand and use by the farmers; timely dissemination (early enough to enable land preparation and acquisition of seeds and inputs for seasonal forecasts); increasing information accuracy; selection of appropriate modes of dissemination based on the farmer characteristics, e.g., use social media in areas with high mobile and internet connectivity; appropriate packaging based on the type of farmer, e.g. translation for farmers who have language challenges. While these are not exhaustive, thorough examination of the farmers' characteristics in an area would be helpful in determining the most appropriate methods of dissemination.

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Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Conflicts of Interest

The authors declare no conflict of interest.

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