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Long Paper

Access to IoT Technologies for Processing and Sharing Terrestrial Biodiversity Data for Sustainable Livelihoods among Rural Communities in Turkana County, Kenya

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Abstract

Purpose – This study aimed to evaluate the access to IoT devices and technologies in Turkana County, Kenya, to enhance sustainable livelihoods.

Method – The study used theoretical research findings to connect IoT theory and practice, as well as biodiversity data for sustainable livelihoods. The mixed method was used, with a sample of 384 households. Data was collected through questionnaires, Focus Group Discussions, and Key Informant Interviews.

Results – The study found that rural communities in Turkana County primarily use mobile phones and radio for accessing terrestrial biodiversity data. The findings emphasized the need for initiatives allowing rural populations to fully utilize IoT technologies for processing and sharing terrestrial biodiversity data.

Conclusion – The study's knowledge contribution took the form of an enhanced Sustainable Livelihoods (SLF), where varied responses and systematic analysis made terrestrial biodiversity data access and use via IoT relevant for understanding the relationship between terrestrial biodiversity data and sustainable livelihoods.

Recommendations – The findings can be used to provide policy recommendations and suggestions for Kenya's future terrestrial biodiversity data plans, policies, and strategies.

Implications – As IoT technologies continue to advance, their potential for positively impacting biodiversity conservation and environmental management will only grow, ensuring a brighter future for our planet's ecological health.

Keywords – access, IoT technologies, terrestrial, biodiversity, data, rural, community

INTRODUCTION

The Earth's ecosystems, including forests, marshes, rivers, and oceans, support an enormous number of creatures, including humans. Global terrestrial biodiversity data depends on parameters such as biomass, ecosystems, phyla, floras and faunas, hot spots, genetic erosion, and the impact of aliens (Mora et al.,2011). The objective of biodiversity data initiatives is to create systems that enable data interchange and knowledge synthesis across various local systems and incorporate them into global knowledge architectures (Soberson &, Llorente 2004).

Kenya is one of the 10 mega-biodiverse nations with over 35,000 species of flora and fauna. The country faces numerous environmental issues, including forestation, soil erosion, desertification, water catchment destruction, poaching, pollution, land degradation, loss of biodiversity, degradation of ecosystem and resources, droughts, invasion flash floods, and invasive alien species (Catherine, 2023). Data plays a significant role in allowing businesses to gain competitive advantages and researchers to develop new insights and technologies.

The Internet of Things (IoT) has become the norm for addressing human concerns such as biodiversity conservation and livelihoods. This study was inspired by the growing challenges of terrestrial biodiversity data processing, sharing, and access concerns, which is a problem in Turkana County, Kenya. IoT is no longer a support function but a critical enabler for service delivery and management in all sectors. It enhances the effectiveness and efficiency of the operations of modern organizations, playing a critical role in driving economic, social, and political developments in Kenya.

Terrestrial biodiversity contributes to human well-being through supporting, provisioning, regulating, and cultural ecosystem services. However, biodiversity loss and deterioration of ecosystems remain major concerns. Terrestrial biodiversity is also crucial in regulating climate, water quality, pollution, and pollination among others (USAID, 2010).

Climate variability influences terrestrial biodiversity, such as extreme weather events that directly influence ecosystem health and the productivity and availability of ecosystem goods and services for human use. Longer-term climate changes affect the viability and health of ecosystems, influencing shifts in the distribution of plants, pathogens, animals, and even human settlements.

The Internet of Things (IoT) is currently changing the telecom landscape and penetrating every aspect of our lives. Mobile IoT technology, such as narrowband IoT (NB-IoT) and long-term evolution (LTE) for machines (LTE-M), represents significant breakthroughs in this rapidly developing area of IoT technology (Smith, 2012). Sensor-enabled mobile phones are now the center of the next revolution in environment monitoring, social networks, green applications, and transport systems due to their pervasive embedded sensors that collect, process, and distribute data around people. Smartphones can be augmented to provide sensing nodes and give gateway functionalities to the internet and cloud.

The Internet of Things (IoT) is transforming the way we live, work, and interact with the world around us. By addressing these challenges and fostering a more sustainable future, we can work towards preserving and protecting our planet's diverse ecosystems and promoting sustainable development. The Internet of Things (IoT) has revolutionized the way we connect and communicate with devices, enabling a new kind of data flow. The Internet will consist of heterogeneously connected devices that will further outspread the borders of the world with physical entities and virtual components (Akhil, 2019). Mobile phones, smartphones, and radio stations are used by people from all walks of life, regardless of class, region, or gender. Many modern mobile phones have radio capabilities, providing portable information via mobile phones.

For marginalized communities, terrestrial biodiversity data, including biological data, physical factors of the environment, biodiversity management, and threats to biodiversity, is vital (Nelson et al., 2016). However, accessing and using this data is challenging due to the lack of information and the uncertain nature of environmental issues. This has led to food insecurity, poverty, and loss of livelihoods in rural areas like Turkana County (GoK, 2014).

There is an urgent need to expand rural people's application of IoT-based terrestrial biodiversity data to address food and nutrition shortages, raise agricultural yields, and improve pastoralists' livelihoods. IoT makes it feasible to rapidly gather, examine, and evaluate a lot of data, and it can also improve human behavior, business operations, and societal systems by making good use of the knowledge gleaned from terrestrial biodiversity (Yohannis et al., 2016).

Effective information gathering and usage can help prevent and reduce biodiversity loss, encourage sustainable development, and maintain and extend biodiversity. The study focused on households in Turkana County to see what combinations of IoT technologies can improve their access to terrestrial biodiversity data for sustainable livelihoods while considering intra-household decision-making dynamics. The study also examined the social-cultural context and terrestrial biodiversity data change dynamics, as well as the challenges that this entails, and how this community uses specific IoT devices.

In conclusion, the evaluation of access to IoT technologies has the potential to significantly improve the lives of rural Kenyans, particularly those living in rural areas with a high prevalence of poverty and limited access to terrestrial biodiversity data. By leveraging IoT technologies and devices, we can better understand and address the challenges faced by these communities and work towards a more sustainable future for all.

LITERATURE REVIEW

Access of IoT Technologies to Process and Share Terrestrial Biodiversity Data (TBD)

The underdeveloped infrastructure in rural areas, such as Turkana County, limits the potential of IoTs for social and economic growth (Cramer et al., 2016). Kenyans have not fully embraced IoTs due to a reluctance to restructure the industry to enable rural populations to access and use IoT technologies, particularly in addressing biodiversity imbalances that make living difficult. For instance, the perennial drought and food insecurity in Turkana County require adopting IoTs to share information on livelihood strategies (Cramer et al., 2016; McOmber et al., 2013; Owusu et al., 2018).

Low use of IoTs affects rural people more than any other population group, leading to inequities in livelihood assets such as income, education, time, and mobility. However, diverse variables, such as age and place of residence, can produce differing experiential results in some rural areas. The application of IoTs in rural areas is hampered by a lack of skills, awareness, and livelihood capital resources group (Wyche and Olson, 2018).

The current study focuses on the intersection of age and place of residence in rural Turkana County, examining how IoTs can affect these variables in integrating biodiversity information and livelihood strategies. The intervention will be based on the information that other parties, such as Non-Governmental Organizations (NGOs), have started programs incorporating rural populations and IoTs in various aspects of life.

Rural Communities Access to IoT Initiatives

In recent years, wireless technologies have been utilized by various NGOs and non-state players to provide information to rural areas (FAO & CARE, 2019). For example, the Arid Lands Information Network, Eastern Africa (ALIN-EA) partnered with the World Space Foundation (WSF) and the Rural Information Service of Rongo (Kenya) to use digital satellite broadcasting to provide information on agriculture, micro-enterprise, conflict resolution, and health-related information in Kenya, Uganda, Tanzania, and Ethiopia. However, its broad thematic and regional scope made it difficult to assess its influence on a specific area like Turkana County's informational needs.

This study aims to close the gap by integrating biodiversity, climate, and agro-related data into livelihood plans among rural populations in Turkana County. This will aid policymakers and stakeholders in implementing appropriate interventions to improve food security in dry locations. Climate and biodiversity changes have negative consequences for sectors directly affecting rural communities' lives, such as farming and home obligations (McOmber et al., 2013),

Rural Communities' Voices fosters the use of IoTs to communicate and share information in Kenya, Peru, and Zimbabwe. The initiative uses video to demonstrate rural women's poor living conditions, health, and alcohol and drug-related difficulties, ensuring that decision-makers hear the voices of women and rural people. The African Center for Information and Communication Technology (ACWICT) promotes IoTs among girls and women in the Greater Horn of Africa to improve women's livelihoods. The Horn of Africa Regional Women's Knowledge Network (HAWKNet) also pools radio and Internet resources to help rural communities communicate information.

IoTs are being employed in education today, with urban communities making more progress than rural communities. ICT-based distance education can assist impoverished populations in remote locations, such as Turkana, in obtaining education and training using ICTs. Selecting programs based on the diverse requirements of the rural population can have a significant impact and give Turkana's rural population a second opportunity.

ICT and the Internet of Things (IoT)

ICTs have gained popularity among Kenya's rural population, particularly through Cyber Cafes and Tele-centers (Kituyi-Kwake & Adigun, 2008). These centers offer affordable services for low-income individuals, such as mobile telephone, word processing, photocopying, and email access. By 2004, over 200 E-Touch Centres had been established in rural Kenya, thanks to Africa Online, one of Kenya's earliest Internet service providers. Mobile phones have become a ubiquitous ICT outlet in urban and rural life, and

FM radio stations broadcast in local languages (Kituyi-Kwake & Adigun, 2008). The Kenya Broadcasting Corporation and Royal Media Services have targeted ethnic and linguistic communities with information packages in local languages, often addressing local issues. Information on agriculture and farming difficulties is disseminated to many people from all over the country.

However, there are two significant gaps in ICT use in rural communities. First, the activities are broad in terms of focus, population categories, and ICT channels. Second, they often focus on general information, rather than specific biodiversity, climatic, and agricultural data that rural populations can use to make decisions affecting their livelihood strategies. This study aims to explore the gendered decisions made by communities in rural areas to enhance their households' livelihoods, despite differing access to resources.

RESEARCH METHODOLOGY

Research Design

This research utilized a pragmatic approach, combining positivist and interpretivist techniques to better understand the study problem. The mixed-methods approach was employed in Turkana County, Kenya, which is the largest county by land area and has a population of 926,976 (males 52% and 48% females). The study targeted 164,519 households, with 52% being males and 48% being females.

Sampling and Sample Size

The study used Krejcie and Morgan's table to obtain a sample size of 384 households, combining perspectives from Kumar's (1989), Mason's (2010), Glasser and Strauser's (1967), and Miles and Huberman's (1994) perspectives. Twenty-four individuals were selected for the Key Informant Interviews (KIIs) due to their diverse experiences and knowledge of IoTs, livelihoods, and biodiversity data in Turkana County, particularly in Eco-Climatic Zones.

Data Collection

The study employed various data collection processes, including participant observation, document analysis, surveys, questionnaires, interviews, and more. The power of case study research lies in the ability to use all methodologies within the data-collection process and compare within and across cases for research validity.

Data Analysis

The researcher analyzed, described, and interpreted data based on research objectives and questions, and presented the data in various forms such as frequencies, tables, percentages, and explanatory notes. The mixed-methods approach allowed for flexibility in interpreting field data, allowing for a better understanding of the study problem. The study's findings can be used to inform future research on IoTs, livelihoods, and biodiversity in Turkana County.

RESULTS

The study involved a household survey, focus group discussions, and 24 interviews with ICT Managers and terrestrial biodiversity professionals. The study involved 348 questionnaires, 2 focus group discussions, and 24 key informant interviews. The response rate for household survey respondents was 90.63%. Table 1 summarizes respondents' results.

Table 1. Response Return Rate

Respondents	Questionnaires Administered	Duly filled and returned Questionnaires	Return Rate (%)
Household Survey Questionnaires	384	348	90.63
	Conducted	**Returned**	**Return Rate (%)**
Pastoralists FGDs	2 (8)	2 (8)	100%
Key informant Interviews	24	24	100%

Source: Field Survey (2023)

Distribution of Respondents per Sub-County

This study examines respondents' distribution per sub-county and eco-climatic zones to analyze the adoption of the NB-IoT model for processing and sharing biodiversity data in eco-climatic zones. Table 2 shows the respondent's distribution per Sub County.

The study found that Turkana West had 28.4% of respondents, while Turkana Central had 25.6%. The lowest percentages were from Turkana North and Kibish sub-counties, with 7.8% and 3.2%, respectively. The respondents were grouped into Eco-Climatic Zones, with EZ VI having 48.56%, EZ V, and EZ IV having 28.45% and 22.99%, respectively. The 24 key informants were ICT managers and professionals working with biodiversity conservation organizations in the county.

Table 1. Distribution of Respondents per Sub-County & Eco-climatic Zones

Sub- County	Frequency	Frequency (%)
Turkana West	99	28.4
Turkana Central	89	25.6
Turkana South	44	12.6
Turkana East	36	10.3
Loima	42	12.1
Turkana North	27	7.8
Kibish	11	3.2
Total	**348**	**100**

Eco-climatic Zone (EZ)	Frequency	Frequency (%)
EZ VI	169	48.6
EZ V	99	28.5
EZ IV	80	22.9
Total	**348**	**100**

Source: Field Survey (2023)

Respondent's Demographic Characteristics

The study examined how demographic characteristics, including gender, age, marital status, literacy, and education, affect respondents' access to IoT devices for processing and sharing terrestrial biodiversity data for sustainable livelihoods.

Respondents' Gender

The study sought the gender of the respondents. Table 3 shows the respondents' gender as was established from the study.

Table 3. Respondents' Gender

Indicator Variable	Category	Frequency	Response (%)
Gender	Male	202	58.05
	Female	146	41.95
	Total	348	100

Source: Field survey (2023

The household survey included 202 male and 146 female respondents, with 58.05% and 41.95% being useful for joint intra-household decision-making consultations. Both genders were useful for consultations.

Respondents' Age

Respondents were asked about their ages, highlighting household responsibilities and the IoT device's role in processing and sharing biodiversity data for sustainable livelihoods. Table 4 shows respondents' age.

Table 4. Age of Respondents

Indicator Variable	Category	Frequency	Frequency (%)
Age	18-30 years	65	18.68
	31-45 years	178	51.15
	46-60 years	60	17.24
	Above 60	45	12.93
	Total	**348**	**100**

Source: Field Survey (2023)

The household survey revealed that the majority of respondents were aged between 31 and 45 years (51.15%), with 18.68% aged between 18 and 30 years. 87.07% were aged between 18 and 60 years, while 12.93% were above 60 years, with the lowest ratios.

Respondents' Marital Status

The study sought the respondents' marital status this was essential in finding out how the respondents use IoT devices for processing and sharing of terrestrial biodiversity data. Table 5 shows the respondents' marital status.

Table 5. Respondents' Marital Status

Indicator Variable	Category	Frequency	Frequency (%)
Marital Status	Never married with no children	23	6.61
	Never married with children	38	10.92
	Married living together	197	56.61
	Married living apart	41	11.78
	Divorced/ separated/ widowed	49	14.08
	Total	**348**	**100**

Source: Field Survey (2023)

The results in Table 5 show that the majority of the respondents (56.61%) are married and living together, while 14.08% were divorced/separated/widowed. 11.78% of respondents were married but living apart.

Respondents' Household Size

The study sought to find out the respondents' household size. Table 6 shows the household size of the people living in Turkana County. Table 6 indicates that 29.89% of the respondents had a household size of 5 to 7 members, while 26.15 % of the respondents had 8 to 10 members. The majority (81.33%) of the respondents had a household size of between 2 and 10 members.

Table 6. Respondents' Household Size

Indicator Variable	Category	Frequency	Frequency (%)
Household Size	One member	11	3.16
	2-4 members	88	25.29
	5-7 members	104	29.89
	8-10 members	91	26.15
	More than 10 members	54	15.51
	Total	**348**	**100**

Source: Field Survey (2023)

Literacy and Level of Education

Respondents' literacy and education levels were assessed to demonstrate their use of IoT devices for accessing, processing, and sharing terrestrial biodiversity data for sustainable livelihoods in Turkana County. Table 7 shows the literacy and education levels of the respondents.

Table 7. Literacy and Level of Education of the Respondents

Indicator Variable	Category	Frequency	Frequency (%)
Able to read	Yes	218	62.64
	No	130	37.36
	Total	**348**	**100**
Able to write	Yes	222	63.79
	No	126	36.21
	Total	348	100
Education	None	83	23.85
	Primary	93	26.72
	Secondary	99	28.45
	College	28	8.05
	University	45	12.93
	Total	**348**	**100**

Source: Field Survey (2023)

Most respondents as shown in table 7 had literacy skills (62.64%) and writing skills (63.79%). Primary and secondary education was the highest level of education, with 53% of residents having basic education. 23.85% had no education, while 20.98% had post-secondary education.

Demographic Characteristics of FGD Participants

The following demographic characteristics: age, household size, level of education head of household, years of experience in pastoralism, and marital status were also sought from FGD participants to find out how they affect their access and use of IoT devices to process and share terrestrial biodiversity data. Table 8 shows the demographic characteristics of FGD participants.

Table 8. Demographic Characteristics of FGD Participants

Indicator Variable	**Category**	**Frequency**	**Frequency (%)**
Age	18-30	3	18.75
	31-40	5	31.25
	41-60	5	31.25
	>60	3	18.75
	Total	**16**	**100**
Household Size	2-4	2	12.50
	5-7	9	56.25
	8- 10	4	25.00
	>10	1	6.25
	Total	**16**	**100**
Level of Education	Primary	8	50.00
	Secondary	5	31.25
	College	3	18.75
	Total	**16**	**100**
Head of Household	Yes	14	87.50
	No	2	12.50
	Total	**16**	**100**
Marital Status	Married Living apart	4	25.00
	Single	1	6.25
	Polygamous Marriage	3	18.75
	Widow	2	12.50
	Married living together	6	37.50
	Total	**16**	**100**
Years of Experience in Pastoralism	8-10	6	**37.50**
	11-20	5	**31.25**
	21-30	3	**18.75**
	31-40	2	**12.50**
	Total	**16**	**100**

Source: Field Survey (2023)

From Table 8 for the FGDs, the majority of the respondents had primary education as their highest level of education. Marital status was considered because it had implications on who was the household head and the decision-maker. While married women have to contend with challenges of cultural expectations that they should defer to the authority of their spouses, unmarried women tend to be deprived of the right to access and own land. These dynamics mean that for the policymakers and implementers who seek to deepen and spread the use of terrestrial biodiversity data in the ASAL pastoralists, the starting point must target men and women at household levels.

Age was a factor as it determines the chances of being household heads, gives indications of the extent of and experience in pastoralism, versatility with IoT devices, as well as the perceptions of pastoralism as an economic activity. All the participants had between 8-40 years of pastoralism experience. Many of the households had between 5 to 7 members. Male participants were considered decision-makers since they were the household heads.

Demographic Information of Key Informant Participants

The demographic information of the key informant interviewees was also sought to show their views on the factors that would influence the use and access of IoT devices for processing and sharing terrestrial biodiversity data. The demographic information was important as they provided information on the various requirements of NB-IoT infrastructure for designing the NB-IoT model. Table 9 shows the demographic information of Key Informant Interviewees.

Table 9. Demographic Information of Key Informant Interviewees

Variable Indicator	Category	Frequency	Frequency (%)
Age	18-30	6	25.00
	31-40	8	33.33
	41-60	10	41.67
Level of Education	PhD	1	4.17
	MA	2	8.33
	BSc. IT	8	33.33
	BSc. Environmental Science	4	16.67
	BA	7	29.17
	Diploma	2	8.33
Organization	National Government	8	33.33
	County Government	4	16.67
	NGO	6	25.00
	CBO	2	8.33
	Media	2	8.33
	Diocese of Lodwar	2	8.33
Position in Organization	County Directors	4	16.67
	Chairperson	1	4.17
	Head of Radio Programming	2	8.33
	ICT manager	8	33.33
	Station Manager	4	16.67
	Regional Directors	5	20.83
Years of work experience	3-6	12	50.00
	7-15	8	33.33
	>15	4	16.67
	Total	**24**	**100**

Source: Field Survey (2023)

From Table 9 the interviewees were aged 41-60, with eight between 31-40 and six between 18-30. They had various education levels, including Ph.D., Master's, Bachelor of Science, Bachelor of Arts, and Diploma holders. Most had 3-6 years of experience in generating biodiversity data, training, and disseminating it in Turkana County. Most had expertise in biodiversity adaptation and dissemination.

Access to IoT Technology for Processing and Sharing TBD

This section presents the results of access to IoT technology by the respondents in Turkana County. Data from household surveys, FGDs, and KIIs are presented. It presents data on dimensions of access to IoT devices with parameters; accessibility, availability, affordability, and quality of service of IoT devices.

IoT Devices owned by Respondents

Ownership of IoT devices by the respondents was important to this study as it shows how the devices are used to access, process, and share terrestrial biodiversity data for sustainable livelihoods. Figure 1 shows the ownership of IoT devices by the respondents.

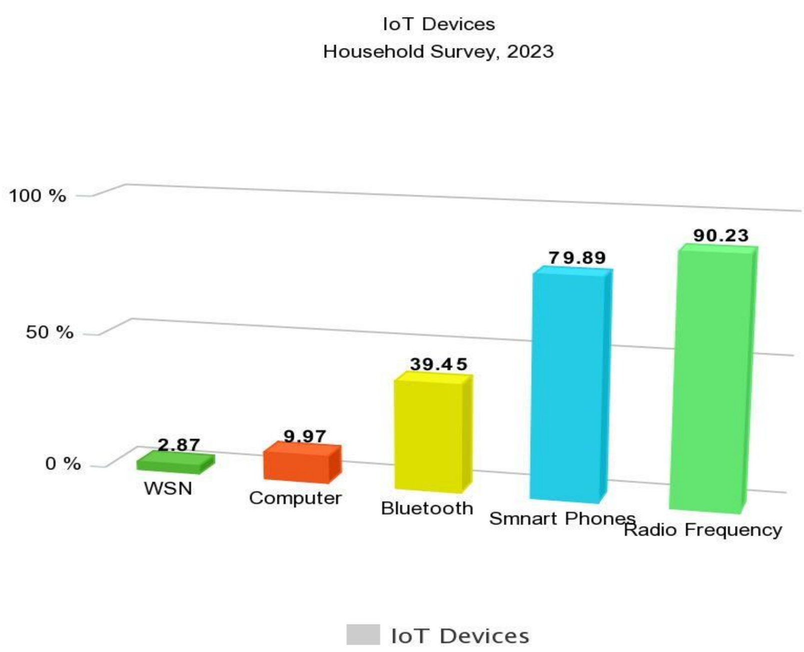

Figure 1. IoT Devices owned by the Respondents

The household survey revealed that 79.89% of respondents owned smartphones and 90.23%) owned radio sets, including those on smartphones. Only 2.87% owned wireless sensor network devices, and 97.7% owned laptops or desktop computers. A significant number owned both smartphones and radios, with 39.45% owning Bluetooth devices, with most having Bluetooth devices embedded on their phones.

Dimensions of Access to IoT Devices

This section presents respondents' ownership of IoT technologies, their accessibility, availability, affordability, and service quality. It also discusses their awareness, access, and use of NB-IoT for processing and sharing terrestrial biodiversity data.

Accessibility

The accessibility dimension of access to IoT devices was important for this study as it showed how the respondents access the IoT devices that are then used to process and share biodiversity data for sustainable livelihoods in Turkana County.

Access to IoT Device

This indicator variable sought to find out which IoT is accessed by the respondents for processing and sharing terrestrial biodiversity data. Table 10 shows access to IoT devices by the respondents.

Table 10. Access to IoT device

IoT Device Access	Neighbors/ Friends		Payphone/ Simu ya Jamii		Cyber Café		Community Center	
	f	(%)	f	(%)	f	(%)	f	(%)
I can access the Radio.	279	80.17	00	00	00	00	69	19.83
I can access my Smartphone.	253	72.70	22	6.32	49	14.08	24	6.90
I can access the Wireless Sensor Network.	11	3.16	00	00	9	2.58	00	00
I can access the Computer.	79	22.70	00	00	152	43.68	00	00
I can access Bluetooth.	253	72.70	00	00	81	23.28	00	00

Source: Field Survey (2023)

Table 10 shows that a good number of respondents went to neighbors and friends (f=279) and community center (f = 69) to access radio and neighbors/friends (f=253), cyber café (f =49) to access smartphones, while others also visited cyber cafés (f = 152) to access computers and laptop services. Some visited neighbors/ friends (f= 253) and cyber cafes (f = 81) to access Bluetooth services.

Security of IoT Device

The study sought to know how the security of the IoT device affects the respondent's use of the devices to access, process, and share biodiversity data for sustainable livelihoods in Turkana County. Table 11 shows respondents' responses on the security of IoT devices.

Table 11. Security of IoT device

Security of IoT Device *(5 = Strongly Agree; 4 = Agree; 3 = Neutral;2 = Disagree; 1 = Strongly Disagree)*	**5**		**4**		**3**		**2**		**1**	
	f	**(%)**	**f**	**(%)**	**f**	**(%)**	**f**	**%**	**f**	**%**
The radio is secure.	179	51.44	121	34.77	48	13.79	00	00	00	00
Smartphone is secure.	197	56.61	112	32.18	39	11.21	00	00	00	00
Wireless Sensor Network secure.	00	00	00	00	18	5.17	129	37.07	201	57.76
The computer is secure.	182	52.30	166	47.70	00	00	00	00	00	00
Bluetooth is secure.	181	52.00	151	43.40	16	4.60	00	00	00	00

Source: Field Survey (2023)

Table 11 on the security of the IoT device shows that most respondents strongly agreed (51.44%), agreed (34.77%) that radio is secure; Others strongly agreed (56.61%), agreed (32.18%) that smartphones are secure; strongly agreed (52.30%), agreed (47.70%) that computers/laptops are secure; strongly agreed (52.00%) and agreed (43.40%) that Bluetooth is secure to access, while for the case of wireless sensor network most of the respondents strongly disagreed (57.76%) and disagreed (37.07%) that it was secure to access.

Convenience of IoT Device

The researcher asked the respondents to know if the IoT devices were convenient for use. This was an important parameter as it shows if convenience would affect the respondents' choice of IoT device to adopt for access, processing, and sharing of terrestrial biodiversity data. Table 12 shows how convenient the IoT devices are. Table 12 shows that the respondents strongly agreed (f = 209), agreed (f = 117) that radio is convenient; strongly agreed (f = 251), agreed (f = 97) that smartphones are convenient; strongly agreed (f =192), agreed (f =138) that computers/laptops are convenient; strongly agreed (f = 175), agreed (f = 149) that Bluetooth is convenient to access, while some respondents strongly disagreed (f = 297), disagree (f = 39) that wireless sensor network is not convenient to access.

Table 12. Convenience of IoT Device

Convenience of IoT device *(5 = Strongly Agree; 4 = Agree; 3 = Neutral;2 = Disagree; 1 = Strongly Disagree)*	**5**		**4**		**3**		**2**		**1**	
	f	**(%)**	**f**	**(%)**	**f**	**(%)**	**f**	**%**	**f**	**%**
Radio is convenient.	209	60.05	117	33.62	22	6.33	00	00	00	00
Smartphone is convenient.	251	72.13	97	27.87	00	00	00	00	00	00
Wireless Sensor Network is convenient.	00	00	00	00	12	3.45	39	11.21	297	85.34
The computer is convenient.	192	55.17	138	39.65	18	5.17	00	00	00	00
Bluetooth is convenient.	175	50.29	149	42.82	24	6.89	00	00	00	00

Source: Field Survey (2023)

Operation of IoT Device

The study sought to find out if the respondents knew how to operate the IoT devices that are used to access, process, and share biodiversity data for sustainable livelihoods. This was important since it would enable the respondents to access and share accurate data. Table 13 shows how the respondents operated the IoT devices.

Table 132. Operation of IoT Device

Operation of IoT device *(5 = Strongly Agree; 4 = Agree; 3 = Neutral;2 = Disagree; 1 = Strongly Disagree)*	**5**		**4**		**3**		**2**		**1**	
	f	**(%)**	**f**	**(%)**	**f**	**(%)**	**f**	**%**	**f**	**%**
I can operate a Radio.	317	91.09	31	8.91	00	00	00	00	00	00
I can operate a Smartphone.	342	98.28	6	1.72	00	00	00	00	00	00
I can operate a Wireless Sensor Network.	00	00	00	00	00	00	68	19.54	280	80.46
I can operate a Computer.	192	55.17	146	41.95	10	2.88	00	00	00	00
I can operate a Bluetooth.	144	41.38	132	37.93	72	20.69	00	00	00	00

Source: Field Survey (2023)

Table 13 shows the respondents' ability to operate the smartphones strongly agreed (98.28%), agreed (1.72%), radio strongly agreed (91.09%) agreed (8.91%) that they can operate. Some respondents were capable of operating a computer; strongly agreed (55.17%) agreed (41.95%) and Bluetooth strongly agreed (41.38%), agreed (37.93%). Most of the respondents did know how to operate a wireless sensor network; strongly disagreed (80.46%), and disagreed (19.54%).

Assistance to use IoT Device

The respondents were asked to state who assists them in case they are not able to operate the IoT device for access, processing, and sharing of terrestrial biodiversity data for sustainable livelihoods. Table 14 shows how the respondents were assisted in using the IoT device.

Table 14. Assistance to use of IoT Device

Assistance to use IoT Device	**Spouse**		**Child**		**Relative**		**Local Teacher**		**Cyber Café**	
	f	**(%)**	**f**	**(%)**	**f**	**(%)**	**f**	**%**	**F**	**%**
I get assistance with the use of Radio	128	36.78	186	53.45	34	9.77	00	00	00	00
I get assistance with the use of a Smartphone	120	34.48	205	58.91	23	6.61	00	00	00	00
I get assistance on the use of a Wireless Sensor Network	19	5.46	48	13.79	00	00	00	00	00	00
I get assistance with the use of a Computer	69	19.83	00	00	00	00	00	00	109	31.32
I get assistance on the use of Bluetooth	108	31.03	166	47.70	00	00	00	00	00	00

Source: Field Survey (2023)

From Table 14 most respondents sought assistance from their children and spouses for IoT devices, with children and spouses being the most common for radio, smartphones, and Bluetooth. Cyber cafés and spouses were also sought for computers and laptops

Understanding Technical Information (TI) on IoT Devices

Respondents' understanding of IoT device technical information was assessed for sustainable livelihoods, focusing on accessing, processing, and sharing biodiversity data. Table 15 shows respondents understand most information through radio, smartphones, and Bluetooth, with embedded Bluetooth on all smartphones. Some understand computers, while wireless sensor networks are not well understood.

Table 153. Understanding Technical Information of IoT Devices

Convenience of IoT device *(5 = Strongly Agree; 4 = Agree; 3 = Neutral;2 = Disagree; 1 = Strongly Disagree)*	**5**		**4**		**3**		**2**		**1**	
	f	(%)	f	(%)	f	(%)	f	%	f	%
I understand TI on the Radio.	259	74.43	89	25.57	00	00	00	00	00	00
I understand TI on Smartphones.	260	74.71	88	25.29	00	00	00	00	00	00
I understand TI on Wireless Sensor Network.	78	22.41	69	19.83	00	00	00	00	00	00
I understand TI on the Computer.	55	15.80	36	10.34	00	00	00	00	00	00
I understand TI on Bluetooth.	271	77.87	77	22.13	00	00	00	00	00	00

Source: Field Survey (2023)

Support if not understanding Technical Information (TI) on IoT Devices

The study sought information on who supports respondents when they do not understand the technical information of IoT devices. Table 16 shows most respondents seek IoT device support from children and spouses, with children supporting radio, smartphones, Bluetooth, and computers/laptops, while spouses support wireless sensor networks.

Table 164. Support if not understand Technical information on IoT Devices

Convenience of IoT device	**Spouse**		**Child**		**Relative**		**Local Teacher**		**Cyber Café**	
	f	(%)	F	(%)	f	(%)	f	%	f	%
I get TI support on the Radio.	118	33.91	176	50.57	00	00	00	00	00	00
I get TI support on Smartphones.	102	29.31	211	60.63	00	00	00	00	00	00
I get TI support on Wireless. Sensor Network	23	6.61	29	8.33	00	00	00	00	00	00
o I get TI support on the Computer.	96	27.58	00	00	00	00	00	00	119	34.20
I get TI support on Bluetooth.	81	23.28	106	30.46	00	00	00	00	00	00

Source: Field Survey (2023)

Format for Technical Information (TI) for IoT Devices

The study sought to find out what format would the respondents prefer to get the technical information for IoT devices for accessing, processing, and sharing terrestrial biodiversity data. Table 17 shows that a significant number of respondents with an average of 337 (96.84%) preferred to receive IoT-based terrestrial biodiversity data from all IoT devices in their vernacular language (Ng'aturkana), followed by English an average of 260 (74.71%) and Kiswahili with an average of 254 (72.99%).

Table 17. Format for Technical Information (TI) for IoT Devices

Format of Technical Information	Ng'aturkana		English		Kiswahili	
	f	(%)	f	(%)	f	(%)
Format TI for Radio	341	97.98	246	70.69	235	67.53
Format TI for Smartphone	344	98.85	250	71.84	236	67.82
Format TI for Wireless Sensor Network	328	94.25	258	74.14	281	80.75
Format TI for Computer	341	97.98	281	80.75	256	73.56
Format TI for Bluetooth	328	94.25	266	76.44	261	75.00
Mean	337	96.84	260	74.71	254	72.99

Source: Field Survey (2023)

Availability of IoT Device

This indicator variable sought to find out which IoT is available to the respondents for processing and sharing terrestrial biodiversity data. The parameters on availability of IoT devices were a source of power to charge the IoT device, trust of the IoT device, frequency of use of the IoT device, and infrastructural interface of the IoT device.

Source of Power to Charge IoT Device

The researcher sought to find out the source of power for charging the IoT devices owned by the respondents. This was important because it would the researcher understand the reasons behind one IoT device and not the other. Table 18 shows respondents used electricity, and solar for radio, smartphones, Bluetooth, wireless sensor networks, and computers, with fewer using electricity and solar for wireless devices.

Trust of IoT Device

The data on the trust the respondents have in the IoT devices was also sought. This data is important as it helps the researcher understand the IoT devices used by respondents, this was important for this study. Table 19 shows the majority of respondents trust radio, smartphones, and Bluetooth IoT devices, with some trusting wireless sensor networks and computers.

Table 18. Source of Power to Charge IoT Device

Source of Power	Electricity		Solar		Battery		Neighbors		Community Centre	
	f	(%)	f	(%)	f	(%)	f	%	f	%
I can charge the Radio	179	51.44	118	33.91	51	14.66	00	00	00	00
I can charge my Smartphone	156	44.83	124	35.63	68	19.54	00	00	00	00
I can charge the Wireless Sensor Network	58	16.67	46	13.22	00	00	00	00	00	00
I can charge the Computer	99	28.45	58	16.67	00	00	00	00	00	00
I can charge Bluetooth	199	57.18	121	34.77	28	8.05	00	00	00	00

Source: Field Survey (2023)

Table 19. Trust of IoT Device

Trust of IoT device *(5 = Strongly Agree; 4 = Agree; 3 = Neutral;2 = Disagree; 1 = Strongly Disagree)*	5		4		3		2		1	
	F	(%)	f	(%)	f	(%)	f	%	f	%
I trust Radio	288	82.76	60	17.24	00	00	00	00	00	00
I trust Smartphone	193	55.46	77	22.12	00	00	00	00	00	00
I trust the Wireless Sensor Network	52	14.94	33	9.48	00	00	00	00	00	00
I trust Computer	62	17.82	38	10.92	00	00	00	00	00	00
I trust Bluetooth	139	39.94	63	18.10	00	00	00	00	00	00

Source Field survey (2023)

Infrastructural Interface of IoT Device

The researcher sought to understand if the respondents were comfortable with the infrastructural interface of the IoT devices they were using to access, process, and share terrestrial biodiversity data. Table 20 shows respondents strongly agree with the interfaces of radio, smartphone, and Bluetooth devices. Some agree with the IoT device infrastructure interfaces of wireless sensor networks and computers/laptops.

Frequency of use IoT Device

The study further sought to know the frequency of use of the IoT devices by the respondents. Table 21 shows the frequency of use of IoT devices to process, access and share terrestrial biodiversity data, the majority of the respondents (f=348) confirmed they relied on their smartphones daily, (f=328) respondents relied on radio and (f=205) respondents relied on Bluetooth. Some small groups of respondents reported that they sometimes rely on computers (f=9) and wireless sensor networks (f=11).

Table 20. Infrastructural interface of the IoT device

Interface of IoT device *(5 = Strongly Agree; 4 = Agree; 3 = Neutral;2 = Disagree; 1 = Strongly Disagree)*	**5**		**4**		**3**		**2**		**1**	
	f	**(%)**	**f**	**(%)**	**f**	**(%)**	**f**	**%**	**f**	**%**
I like the interface of the Radio.	208	59.77	69	19.83	00	00	00	00	00	00
I like the interface of the Smartphone.	136	39.08	89	25.57	00	00	00	00	00	00
I like the interface of Sensor Network.	48	13.79	37	10.63	00	00	00	00	00	00
I like the interface of the Computer.	72	20.69	28	8.05	00	00	00	00	00	00
I like the interface of Bluetooth.	103	29.60	93	26.72	00	00	00	00	00	00

Source: Field Survey (2023)

Table 21. Frequency of use IoT Device

Frequency of use of IoT device *(5 = Daily; 4 = Sometimes; 3 = Not Sure;2 = Rarely; 1 = Never)*	**5**		**4**		**3**		**2**		**1**	
	f	**(%)**	**f**	**(%)**	**f**	**(%)**	**f**	**%**	**f**	**%**
I frequently use of Radio.	328	94.25	00	00	00	00	00	00	20	5.75
I frequently use of Smartphone.	348	100	00	00	00	00	00	00	00	00
I frequently Wireless use a Sensor Network.	14	4.02	11	3.16	00	00	00	00	00	00
I frequently Computer.	18	5.17	9	2.59	00	00	00	00	00	00
I frequently use Bluetooth.	205	58.91	88	25.29	00	00	00	00	00	00

Source: Field Survey (2023)

Affordability of IoT Device

This indicator variable sought to find out which IoT is affordable for the respondents for processing and sharing terrestrial biodiversity data. The constructs under this variable were sustainability of the use of IoT devices and enjoying the use of the IoT device by the respondents.

Sustaining Use of IoT Devices

The study sought to know if the respondents were able to sustain the use of IoT devices for processing and sharing terrestrial biodiversity data for sustainable livelihoods.

Table 22 on perceived affordability to sustain the use of IoT services, (f=199) respondents were able to maintain the use of radios with batteries, while (f=205) sustained their use of smartphones with solar power and buying (f=322) airtime, although some few (f=88) could afford to buy Internet bundles. Very few respondents (f=51), (f=21), and (f=24), could afford to sustain the use of computers, wireless sensor networks, and Bluetooth respectively.

Table 52. Sustaining Use of IoT Devices

Sustainable use of IoT devices *(5 = Strongly Agree; 4 = Agree; 3 = Neutral;2 = Disagree; 1 = Strongly Disagree)*	**5**		**4**		**3**		**2**		**1**	
	f	**(%)**	**f**	**(%)**	**f**	**(%)**	**f**	**%**	**f**	**%**
I can afford to sustain the use of Radio.	199	57.18	102	29.31	99	28.45	00	00	00	00
I can afford to sustain the use of Smartphones.	205	58.91	322	92.53	00	00	88	25.29	00	00
I can afford to sustain the use of a Wireless Sensor Network.	102	29.31	24	6.90	00	00	156	44.83	201	57.76
I can afford to sustain the use of the Computer.	51	14.65	21	6.03	00	00	178	51.15	221	63.50
I can afford to sustain the use of Bluetooth.	102	29.31	24	6.90	00	00	00	00	00	00

Source: Field Survey (2023)

Enjoy the use of IoT Device

The researcher sought to know if the respondents enjoyed the use of the IoT devices they had access to. Enjoying the use of the IoT device is important in this study as this would make the respondents use the particular IoT device more for accessing, processing, and sharing terrestrial biodiversity data for sustainable livelihoods. Table 23 shows that the respondents agreed that they enjoy using smartphones, radios, and Bluetooth IoT devices; strongly agree (f=252), agree (f=96) for smartphones; strongly agree (f=211), agree (f=107) for radios; strongly agree (f=121), agree (f=61) for Bluetooth. Very few respondents agreed that they enjoy using computers strongly agree (f=27), agree (f=19) and wireless sensor network strongly agree (f=34), agree (f=27).

Quality of Service of IoT Device

This indicator variable sought to find out if the quality of service of the IoT device was effective, and if prior experience to use of IoT device was also considered by the respondents for processing and sharing terrestrial biodiversity data in Turkana County. The constructs under this variable are effectiveness and prior experience with the IoT device.

Table 23. Enjoy the Use of IoT Device

Enjoy the Use of IoT Device *(5 = Strongly Agree; 4 = Agree; 3 = Neutral;2 = Disagree; 1 = Strongly Disagree)*	5		4		3		2		1	
	f	(%)	f	(%)	f	(%)	f	%	f	%
I enjoy the use of Radio.	211	60.63	107	30.75	30	8.62	00	00	00	00
I enjoy the use of Smartphones.	252	72.41	96	27.59	00	00	00	00	00	00
I enjoy the use of Wireless Sensor Networks.	34	9.77	27	7.76	00	00	201	57.76	86	27.71
I enjoy the use of the Computer.	27	7.76	19	5.46	00	00	246	70.69	56	16.10
I enjoy the use of Bluetooth.	121	34.77	61	17.53	00	00	106	30.46	60	17.24

Source: Field Survey (2023)

Effectiveness of the IoT Device

This study sought to find out from the respondents how effective the IoT devices to processing and sharing terrestrial biodiversity data. This was important to this study as an effective IoT device would enable good quality of service of the IoT model. Table 24 shows that most of the respondents said that radio, smartphones, and Bluetooth are effective; strongly agree (f=281), agree (f=67) for radio, strongly agree (f=242), agree (f=106) for smartphones, strongly agree (f=163), agree (f=79) for Bluetooth. Other respondents also said wireless sensor networks and computers are not effective; disagree (f=201), strongly disagree (f=68) for WSN, disagree (f= 230), strongly disagree (f=41) for computers/laptops.

Table 64. Effectiveness of the IoT Device

Effectiveness of the IoT Device *(5 = Strongly Agree; 4 = Agree; 3 = Neutral;2 = Disagree; 1 = Strongly Disagree)*	5		4		3		2		1	
	f	(%)	F	(%)	f	(%)	f	%	f	%
Radio is effective.	281	80.75	67	19.25	00	00	00	00	00	00
Smartphone is effective.	242	69.54	106	30.46	00	00	00	00	00	00
of Wireless Sensor Network is effective.	43	12.36	36	10.34	00	00	201	57.76	68	19.54
The computer is effective.	38	10.92	39	11.21	00	00	230	66.10	41	11.78
Bluetooth is effective.	163	46.84	79	22.70	00	00	66	18.97	40	11.49

Source: Field Survey (2023)

Prior Experience in the Use of IoT Devices

Prior experience in the use of IoT devices by the respondents was also sought. Table 25 shows that many of the respondents said they have had prior experience with radio strongly agree (f=292), agree (f=56), smartphone strongly agree (f=272), agree (f=76) and Bluetooth strongly agree (f=153), agree (f=89). A few other respondents who have also had prior experience with wireless sensor networks strongly agree (f=33), agree (f=46) and computers/laptops strongly agree (f=28), agree (f=46).

Table 75. Prior Experience in the Use of IoT Devices

Prior Experience in the Use of IoT Devices	**5**		**4**		**3**		**2**		**1**	
(5 = Strongly Agree; 4 = Agree; 3 = Neutral;2 = Disagree; 1 = Strongly Disagree)	**F**	**(%)**	**F**	**(%)**	**F**	**(%)**	**f**	**%**	**f**	**%**
I have prior experience in the use of Radio.	292	83.91	56	16.09	00	00	00	00	00	00
I have prior experience in the use of Smartphones.	272	78.16	76	21.84	00	00	00	00	00	00
I have prior experience in the use of Wireless Sensor Networks.	33	9.48	46	13.22	00	00	201	57.76	68	19.54
I have prior experience in the use of Computers.	28	8.05	49	14.08	00	00	228	66.10	43	11.78
I have prior experience in the use of Bluetooth.	153	43.96	89	25.57	00	00	56	18.97	50	11.49

Source: Field Survey (2023)

Access of IoT Devices by FGDs and KIIs

The study aimed to understand FGDs and KIIs' views on IoT devices and access dimensions, guiding researchers on NB-IoT models for processing and sharing terrestrial biodiversity data for sustainable livelihoods in Turkana County. From Table 26 the study focused on the use of IoT devices in the rural population of Turkana, particularly among pastors. Most households own a smartphone or radio, and those without one share it within the household or from nearby neighbors. These devices are often embedded with Bluetooth, allowing the community to obtain data and information immediately and regularly. The growth of smartphones and their penetration has led to a greater captive market, particularly among rural populations. DigiCow and i-conserve platforms provide information via basic SMS, and the platform sends regular updates to key intermediaries, enabling them to make informed decisions.

Table 26. IoT Devices and Dimensions of Access IoT devices for FGDs & KIIs

Construct Variable	Key Findings
IoT Devices	• Smartphones and radio were easily accessible and affordable to the community in,comparison to the Wireless Sensor Network and the computer/laptop. • The IoT devices of preference in the access of terrestrial biodiversity data are the local radio and smartphones due to their availability and affordability. • Key Informants used a hybrid of IoT devices to reach the community for capacitybuilding and terrestrial biodiversity data dissemination.
Dimensions of access to IoT devices	• Poor network connectivity, inadequate IoT infrastructure, limited operational skills,and lack of finances for airtime and internet bundles to subscribe to informative news. • The quality of service of IoT is a consideration in choosing which device to acquire • IA good IoT infrastructure will enable many users to adopt its use • Inadequate electricity coverage to power IoT devices; many are reliant on solar power. • The digital divide in rural areas due to dimensions of access to IoT devices challenges.

Source: Field Survey (2023)

FGD respondents reported that all respondents were unable to afford computers or laptops but relied on costly internet data bundles. This finding was expected due to education levels and may explain limited innovations in facilitating communication between people. Some respondents highlighted the role of 'flash-back', 'Please Call Me' calls, and reverse call services as enablers of communication.

However, there is a challenge to operational competence and access to terrestrial biodiversity data apps provided by some terrestrial biodiversity data providers. Some respondents have to rely on relatives, children, and neighbors for help in operating and manipulating the devices. Awareness training that is locally relevant to the use of these devices is possible, but it can be intimidating if one is not empowered to manipulate or operate them.

Another KII respondent affirmed that there were some levels of illiteracy among the communities in Turkana, who needed help operating the IoT devices for terrestrial biodiversity data access. The region experienced poor network connectivity and a lack of electricity connectivity in some parts. Most people in the area used solar to charge their smartphones and radios, but most did not have access to solar themselves due to the prohibitive cost of the initial installation of a solar panel. Some residents used batteries to power their radios.

A KII respondent from Ejok FM Radio Station noted that Kopa Credo and Okoa Jahazi services from Airtel and Safaricom have made it easy for customers to communicate to radio stations even when they are cash-strapped, allowing them to repay later or when they go to the shops and purchase airtime/minutes. The question remains, How much data and how timely this data is reaching them?

DISCUSSIONS

The study found a positive relationship between data on terrestrial biodiversity and IoT technologies, with the types of data and pastoral advisories available by providers like KFS, KWS, and others determining whether or not pastoralists have access to that data. Interactive local community FM radio stations (Ejok FM and Akicha FM) and smartphones were primarily used to access, process, and share terrestrial biodiversity data with pastoralists. With the potential to engage additional pastoralists in Turkana County at growing scales, they broadened their strategy.

In processing and sharing terrestrial biodiversity data, smartphones, and local community radios were found to be more accessible, affordable, available, and of higher quality of service than wireless sensor networks and Bluetooth. The report of the Communications Authority of Kenya [CA] (2022) confirmed the high rate of smartphone penetration. The qualitative study revealed that although smartphones, which are Internet of Things (IoT) devices, were the easiest and fastest way to transmit data about terrestrial biodiversity, participants could also receive that information via local community FM radio stations in their native Ng'aturkana, which is the language most commonly spoken.

Pastoralists got the chance to listen to the programs to learn vital information on terrestrial biodiversity and pastoralists. The study also highlighted the disparities in media access and IoT control across gender-based user categories. The lack of financial resources and educational restrictions prevented rural residents of Turkana County from owning and controlling access to IoT devices. Even with access, differences in education and literacy led to less proficient use. The triple role of rural residents, particularly women, was found to hinder their ability to listen to radio programs due to the time of broadcast. Radio programming was used with increasing regularity in Ng'aturkana to address these constraints.

Many respondents in the FGDs stated that they would want additional radio broadcasts of statistics and information about terrestrial biodiversity throughout the day to increase their likelihood of listening to the programs. Some of their comments agreed with the Tanzanian study that supported rural populations' preferences and acknowledged the barriers that prevent rural residents from freely listening to the radio. To allow pastoralists to listen to the radio, it is advised that terrestrial biodiversity forecasts and pastoral advisories be broadcast at regular intervals throughout the day.

The Information Needs Assessment Model (INAM) helped clarify the underlying hurdles cited throughout the findings. It was preferred that terrestrial biodiversity information be disseminated via community radios in the area and translated using local languages and dialects. The perception of the quality and validity of the data and information transmitted, as well as the timeliness of the data and information, are additional fundamental aspects determining the obstacles to the usability of the data and information revealed in the findings.

The study also revealed how literacy and education levels affected how well people understood and interpreted data on terrestrial biodiversity. Male rural residents were more capable of interpreting periodic forecasts, while female rural residents found it difficult to access pastoral data and information sent via SMS; they preferred voice messaging. To determine if providers of terrestrial biodiversity data services had created media and IoT-based channels that were specific to the needs of rural communities, the INAM model played a key role.

In conclusion, the preferences of rural communities for terrestrial biodiversity data include the content of the data communicated, the urgency of the communicated data, the scale and type of data (regular predictions at the national or local scale), dependability and trust in data sources, accessibility of the communication channel and the type of data, and the availability of reliable and trustworthy intermediaries.

CONCLUSIONS

The results showed that a variety of factors affected how well IoT-based terrestrial biodiversity data performed and how it affected sustainable livelihoods. Finding a thorough grasp of the TBD requirements of various pastoralists to biodiversity hazards within their unique technological, social-cultural, and social-economic contexts was the starting point for the success of IoT-based TBD services.

The results showed that contextual and intrinsic factors that affected sustainable livelihood had an impact on the interpretation and utilization of terrestrial biodiversity data. Intrinsic elements typically entailed communication strategies like IoT channels and packaging of the data on terrestrial biodiversity. The community's customs and religious beliefs, as well as social networks and systems and indigenous knowledge, were contextual elements. Locality (rural versus urban), content-related, and technology constraints were also included.

The preferred channels for processing, sharing, and communicating terrestrial biodiversity data in Turkana County were local community FM radio stations and mobile phones. This finding was broadly supported by literature from other jurisdictions (Caine et al., 2015; Hampson et al., 2014; Jones and Siemering, 2012; Mittal, 2016). How to economically and sustainably provide local-specific, timely, and relevant terrestrial biodiversity data to pastoralists was one challenge that was noted. The radio and smartphones seemed to be better delivery techniques, using the local language instead of data from the internet via computers, so a combination of delivery approaches was preferred.

The results of this study have demonstrated that IoTs give rural households quick and convenient communication options, boosting their capacity to access and utilize the assets necessary for their subsistence to the maximum. The most popular IoT devices, smartphones, and local community FM radio stations helped in many ways to reduce poverty and improve rural residents' standard of living. The growth and fortification of social networks improved people's capacity to respond to crises and collaborate, which decreased costs and enhanced productivity.

Rural pastoralists were able to reduce travel expenses by using smartphones. This reduced the physical dangers and improved the results by avoiding unnecessary trips. It increased productivity and the capacity to send and receive money. Rural traders and pastoralists can obtain better markets and pricing as well as save time with the aid of NB-IoT devices, especially smartphones. They were able to communicate TBD in real time as a result.

RECOMMENDATIONS

The research aims to enhance local stakeholders' understanding of using IoT devices to access terrestrial biodiversity data. It suggests connecting with pastoralist experts and exchanging technical information. IoT service providers, such as mobile phone companies and community radio stations, can increase their clientele in rural areas through innovative packages, budget-friendly packages, and tailored messaging.
This knowledge will benefit policymakers, researchers, practitioners, and rural communities, promoting better use of IoTs for data on terrestrial biodiversity and commissioning relevant research. The study's shortcomings may serve as a foundation for further research, aiming to understand the many IoT devices that enable the timely transmission of data to meet development goals.

IMPLICATIONS

The practical implications of access to IoT technologies for processing and sharing terrestrial biodiversity data are far-reaching. From real-time monitoring to informed decision-making, these technologies empower stakeholders to take proactive conservation actions and drive sustainable development practices. As IoT technologies continue to advance, their potential for positively impacting biodiversity conservation and environmental management will only grow, ensuring a brighter future for our planet's ecological health.

Declarations

Conflict of Interest

All authors declared no conflict of interest.

Informed Consent

Respondents were requested for their consent to participate.

Ethics Approval

The School of Graduate Studies and NACOSTI approved the study.

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