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Analyzing the Contribution of Extension Services and Innovative Approaches to the Advancement of Sustainable Agricultural Development in Somalia

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Abstract

This study critically examines the involvement of extension and innovation strategies in advancing sustainable agriculture in Somalia. Agricultural extension services, which involve disseminating agricultural knowledge, information, and technologies to farmers, are essential for enhancing farmers' skills, practices, and decision-making abilities. The study explores the complex relationship between socioeconomic challenges-such as limited access to resources, infrastructure, and markets-extension strategies, and sustainable agricultural development in Somalia. A key obstacle identified is the inadequate infrastructure for mobile phone applications in agriculture, which limits the effectiveness and widespread adoption of farming technologies. Utilizing a descriptive research design, data was gathered from 211 participants across seven regions, including Southwest, Hirshabelle, Benadir (Mogadishu), Galmudug, Puntland, Jubaland, and Somaliland. The analysis assessed the demographic and educational characteristics of the participants and the impact of extension services and innovation strategies on sustainable agricultural practices. The variability in the support provided by extension services emphasizes the need for targeted improvements to foster sustainable agriculture and enhance food security in Somalia. Institutional challenges, including policy frameworks, governance issues, and capacity-building deficits, also impede the effective implementation of agricultural innovation and extension strategies. Additionally, resistance to change, cultural differences, and a lack of supportive policies hinder the adoption of new practices. Unpredictable weather patterns, overuse of natural resources, and extreme climatic events further complicate the success of sustainable practices. Despite these challenges, agricultural extension services play a critical role in facilitating the dissemination of knowledge, training, and community engagement for sustainable farming practices. The study underscores the need for strengthened infrastructure, improved governance, and targeted interventions to overcome existing barriers and promote sustainable agricultural development in Somalia.

Keywords: Extension Services, Innovation Strategies, Sustainable Agriculture, Environmental Sustainability, Somalia.

1. INTRODUCTİON

Agricultural extension, synonymous with agricultural advisory services, entails the dissemination of scientific research and innovative knowledge to enhance farming practices through farmer education (Chowdhury *et al*., 2014). In essence, extension involves equipping farmers, particularly smallholders in developing nations like Somalia, with advanced agronomic techniques and skills to enhance productivity, food security, livelihoods, and livestock management (Özçatalbaş and Imran, 2017). Agricultural extension comprises two key elements: the dissemination of practical insights, including enhanced seeds, soil management, tools, irrigation, and crop and livestock practices, and the implementation of this knowledge in agricultural operations (Sennuga, 2021). Extension plays

a pivotal role in agricultural research and rural development by bridging technical innovation from research institutions with farmer adoption and integration into practical farming systems (Kaur, 2015). Participatory partnerships encompass government entities (e.g., agriculture ministries, research centers), the non-profit sector (NGOs, foundations, community boards), and the for-profit sector (commercial firms, input suppliers, and farmer-led enterprises) (Kaur and Kaur, 2018). The livelihood gap in Somalia has been exacerbated by prolonged conflict and recurrent climatic shocks, disrupting entrenched political, economic, and social systems that traditionally sustain communities (le Sage and Majid, 2002). Agricultural education in Turkey started in 1848. However, the main developments in agricultural research and extension have occurred since the 1930s (Atalba, 2016). Somalia's agro-ecology is predominantly arid to semi-arid, with annual rainfall varying from under 50 mm in northern coastal areas to approximately 600 mm in southern regions, and potential evapotranspiration ranging between 1900-2500 mm (Devereux, 2010). With abundant grazing land, over 70 % of the Somali population are nomadic pastoralists. Therefore pastoralism and agro-pastoralism are common systems of land production and the primary source of livelihood (Hassan, 2014). Pastoralists in areas with low agricultural production depend on animals that forage vegetation uneatable for humans and convert it into a form suitable for human consumption (FAREH Abdulkadir Mohammed, 2011). Somalia's livestock sector contributes significantly to national income, food production, and export revenues. Livestock is critical in poverty reduction and resilience building in pastoralist communities (Mohamud *et al*., 2023). Turkey has much experience in the application of agricultural extension systems and approaches in terms of relationships between farmers and extension research organizations (Savran *et al*., 2011). Sustainable agriculture discourses some broader ecological, economic, social, and political dimensions. Sustainability, ecosystems, and natural resource management are the challenges for farmers and agriculture (Mustapit *et al*., 2019). Mechanization has revolutionized traditional agriculture, boosting efficiency and productivity by reducing labor intensity with machinery like tractors and harvesters and addressing rural labor shortages (Sekhar *et al*., 2024). Indigenous Traditional Knowledge (ITK) is culture-specific local knowledge that, while seemingly simple to outsiders, serves as a vital mechanism for sustaining livelihoods in local communities (Pandey *et al*., 2017). Farmers do not earn high incomes because their innovations and practices are mostly organized and accumulated through experience, and these Indigenous technologies are applied in isolation (Lwoga *et al*., 2010). The adoption of climate-smart agricultural practices has been widely recognized as a promising and successful alternative to lessen the adverse impacts of climate change (Negera *et al*., 2022).

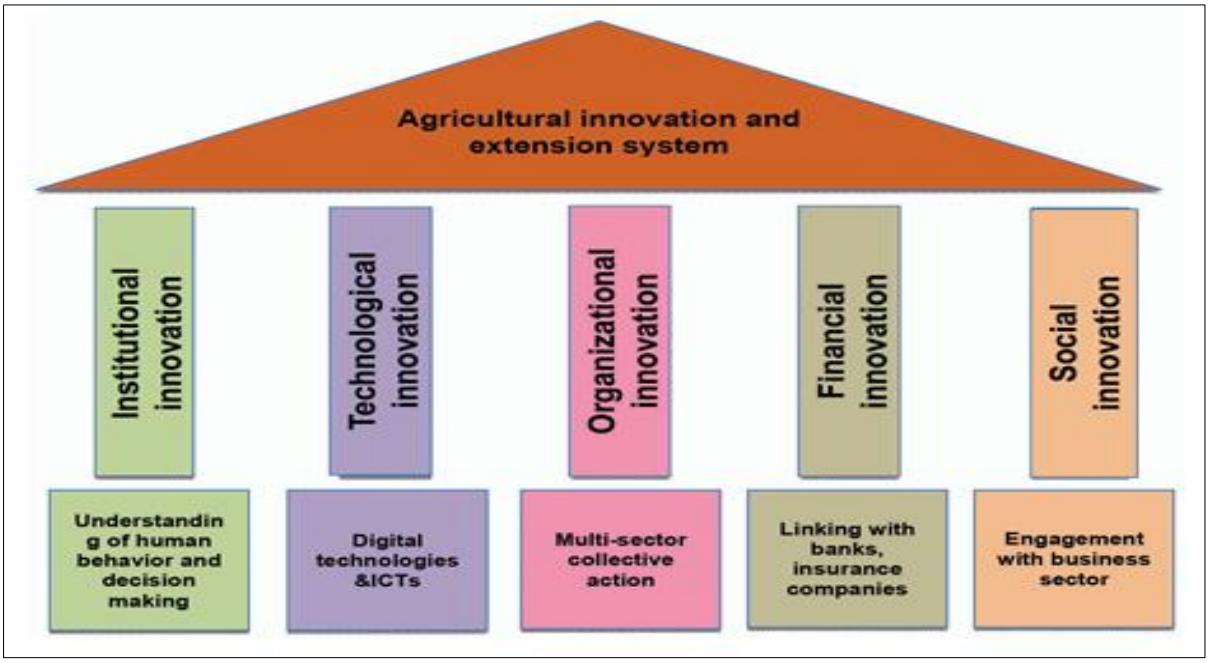

Figure 1: Agricultural innovation and extension system (Sahoo *et al*., 2024).

Improving food security demands an integrated understanding of food systems, with under-explored areas critical for effective policy change. Barriers hindering the knowledge flow between agricultural researchers and farmers have been identified (Eidt *et al*., 2012). Knowledge gaps regarding sustainable practices, including costs, benefits, and implementation methods, act as significant barriers to adoption, impacting agricultural outreach programs aimed at promoting sustainable practices (Lubell *et al*., 2011).

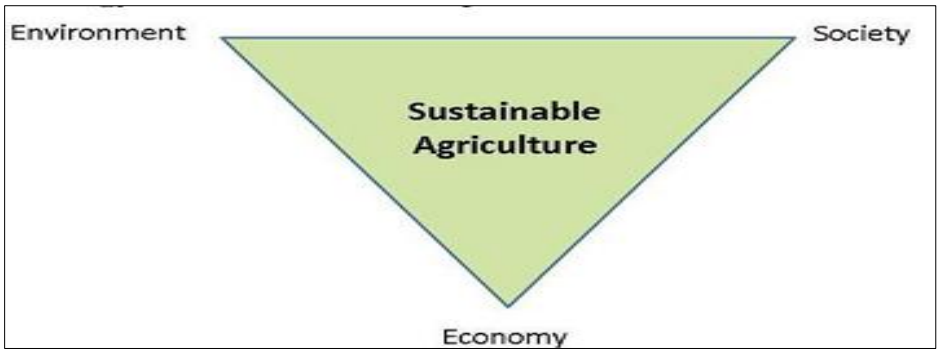

Figure 2: Technology for sustainable development (Blakeney, 2022).

While yields of commercial crops and livestock have increased significantly, 20th-century agricultural progress was primarily driven by improvements in staple food crop productivity, a trend that is rapidly evolving (Sharma *et al*., 2014). Sustainable agricultural innovation is essential to address challenges such as climate change, which exacerbates desertification, salinity, pest infestations, and flooding. Intellectual property rights are critical for modern Agriculture's advancement (Blakeney, 2022). Climate-smart agriculture is increasingly promoted as a means to enhance food security and adapt agriculture to climate change while reducing carbon emissions (Festus *et al*., 2019). Climate change, Alongside structural and institutional challenges, threatens food security and livelihoods for smallholder farmers in Somalia. Current agricultural policies face issues such as shrinking frontiers, declining soil fertility, and the challenge of feeding a growing population (Wakweya, 2023). Agriculture, encompassing livestock raising and farming, is central to Somalia's economy, with approximately 50% of the population engaged in pastoralism and 20% relying on subsistence farming (Samatar,1985). The majority of Africa's rural population relies on farming and livestock for their livelihood, and Somalia, with its fertile soil and favorable climate, benefits from agriculture as the backbone of its economy (Sheikdon, 2020). However, the flexibility and adaptability of a farming system have seldom been the target of research on improving farming practices or designing technical innovations (Darnhofer *et al*., 2010). Climate change-induced challenges like drought and land degradation significantly impact rain-fed agriculture in the region, with recurrent droughts highlighting its vulnerability to climate change (Marie *et al*., 2020). These changes will affect water availability, grazing land productivity, livestock, and the distribution of pests and diseases, with regional variations in the impact on cropping systems and farm activities (Rosenzweig and Tubiello, 2007). The purpose of this research was to examine the involvement of extension and innovation strategies in sustainable agriculture in Somalia

2. MATERİALS AND METHODS

2.1. Measures

To evaluate the theoretical framework, a carefully designed questionnaire-based survey was distributed. The study's scales were developed through a comprehensive review of relevant literature, identifying five core dimensions. In Somalia, where agriculture and livestock are vital to the socioeconomic structure, integrating extension services and innovative strategies is essential for advancing sustainable farming practices. Farmers rely on both traditional and modern methods to address environmental challenges. For this study, measures for extension services and agricultural innovations were adapted to reflect their role in fostering sustainability in Somali agriculture. Survey questions were meticulously transcribed and simplified for clarity, considering the varied literacy levels of participants, including farmers, agricultural researchers, and government officials. After designing the scale items, the questionnaire was converted into an online format, and the research team thoroughly reviewed it for accuracy before distribution. The study's objectives were clearly communicated to participants, and confidentiality was assured to ensure honest responses. The survey was distributed via social media platforms frequently used by Somali farmers and stakeholders, and responses were monitored regularly for timely data collection. Participants were given the option to provide personal details for follow-up, including names, phone numbers, emails, and social media profiles. The questionnaire was translated into Somali and Arabic to enhance accessibility. A total of 16 experts-eight academics and eight agricultural professionals—reviewed the survey in the pre-test phase to ensure its validity and relevance. The Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), was used to measure participants' views on extension services and innovations in sustainable agriculture. This scale was adapted to gauge varying levels of agreement with strategies promoting agricultural sustainability.

2.2 Participants and Process of Data Collection

The study employed a descriptive research design integrating both qualitative and quantitative methodologies to collect data on a specific phenomenon within a defined timeframe. A cross-sectional survey

methodology was used, allowing for the concurrent observation of a large cohort, and providing significant advantages for scholarly research constrained by time limitations. The research was conducted across seven regional states of Somalia: Banaadir (Mogadishu), Puntland, Hirshabelle, Galmudug, Southwest, Somaliland, and Jubaland. Data collection occurred from January 2024 to August 2024. A total of 70 agricultural researchers/students, 47 business owners, 25 farmers, and 23 government officials participated. The study population comprised 210 individuals from diverse regions, including farmers, entrepreneurs, public authorities, and displaced persons affected by flooding. Due to resource constraints, a sample of 165 individuals was selected for participation.

Additionally, the study incorporated an examination of sustainable agricultural practices and the role of extension services and innovation strategies in Somalia's agricultural sector. This was designed to capture how these strategies address environmental challenges such as climate change, resource scarcity, and food insecurity. The study's findings aim to assess the effectiveness of these interventions in enhancing agricultural productivity, improving resilience, and ensuring long-term sustainability in Somalia's agricultural landscape.

2.3. Data Analysis Methods

The sample size was determined using Slovin's formula, yielding a sample of 165 participants from the target population of 210. The formula used was:

Where:

$$n = \frac{N}{1+N(e)2} = \frac{210}{1+210(0.0025)} = 165$$

n= Size of the sample
N = size of the population
e = significance level, estimated at 0.05

Data analysis was performed using descriptive statistics, primarily percentages, to summarize the findings. The Statistical Package for the Social Sciences (SPSS) and R programming software were employed as robust tools for quantitative analysis, enabling the examination of numerical data and deriving meaningful insights. This methodological approach ensures a high level of analytical rigor and enhances the validity of the results obtained from the sample population.

3. RESULTS AND DİSCUSSİONS

3.1. Demographic Results

The tables below provide the demographic characteristics of the study participants, including age, educational level, gender, occupation, and region of residence.

Table 1: Demographic Results

Age	Frequency	Percentage (%)
Under 20	65	30.8%
20-30	22	10.4%
31-40	51	24.3%
41-50	18	8.5%
Above 50	54	25.6%
Educational Level		
No formal education	81	38.4%
Primary education	41	19.9%
Secondary education	38	18.0%
Tertiary education (college/university)	32	15.2%
Vocational training	18	8.5%
Gender		
Male	144	68.2%
Female	67	31.8%
Occupation		
Farmer	20	21%
Extension worker	64	21.8%
Researcher	64	21.8%
Government official	73	24.9%
NGO worker	19	10.5%
Region of residence		
Southwest	34	15.7%
Hirshabelle	37	16.2%
Benadir (Mogadishu)	32	14.5%
Galmudug	31	14.4%
Puntland	30	14.2%
Jubaland	30	14.2%
Somaliland	28	14.1%

3.2. Demographic Analysis

The demographic breakdown provides essential context for interpreting the study's findings. A notable portion of the respondents (30.8%) is under the age of 20, which suggests a youthful and potentially dynamic perspective on agricultural practices. The 31-40 age group constitutes 24.3% of the participants, while those aged 41-50 and over 50 make up 8.5% and 25.6%, respectively. This age distribution indicates a relatively young to middle-aged demographic, which may influence their engagement with innovative agricultural practices and sustainable approaches. The educational profile reveals that 38.4% of respondents have no formal education, while a significant portion (19.9%) has received primary education and 18.0% secondary education. Tertiary education (15.2%) and vocational training (8.5%) are less common among respondents. This diverse educational background indicates a wide range of agricultural literacy, influencing the adoption of extension services and innovation strategies. Regarding gender, a predominant majority of respondents are male (68.2%), with female representation at 31.8%. This gender disparity aligns with the general trend in Somalia, where men are typically more involved in agricultural production. This imbalance highlights the need for targeted initiatives to encourage greater female participation in agricultural development and sustainability. The occupational distribution shows that government officials (24.9%) make up the largest group, followed by extension workers and researchers (21.8% each), farmers (21%), and NGO workers (10.5%). This diverse representation of key agricultural stakeholders offers a holistic view of the factors driving agricultural innovation and sustainability in Somalia. The study's focus on these various roles ensures a comprehensive analysis of the mechanisms behind sustainable agriculture in the region. Regional participation highlights the areas most engaged with agricultural innovation and extension services. The Southwest (15.7%) and Hirshabelle (16.2%) regions, both known for their fertile agricultural lands, exhibit the highest participation rates, indicating their central role in the country's agricultural activities. Benadir (Mogadishu), Galmudug, and Puntland follow closely, with Jubaland and Somaliland showing slightly lower participation. These areas, particularly those in the Southwest and Hirshabelle, are considered the agricultural hubs of Somalia, with robust agricultural extension services playing a crucial role in promoting sustainable farming practices.

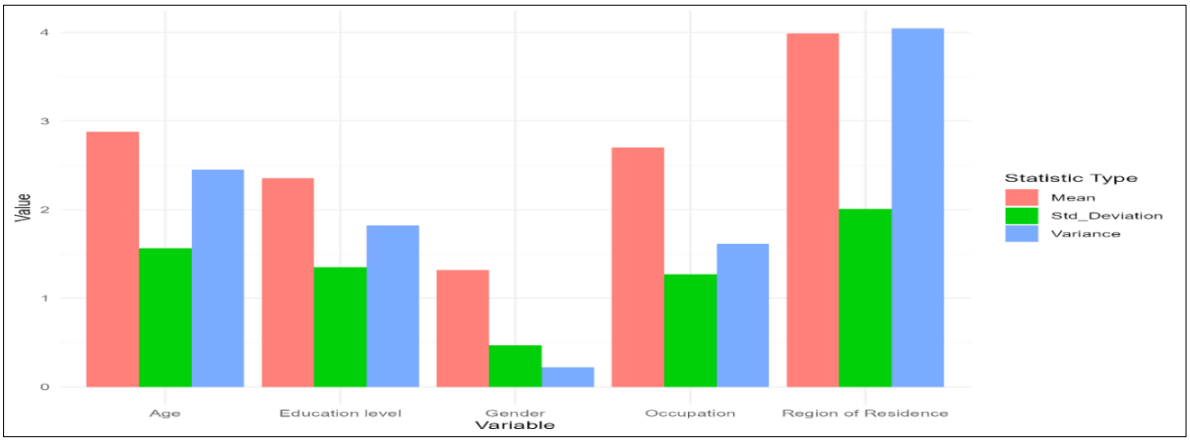

Figure 1: This demographic demonstrates respondents' Demographics such as Age, Educational level, Gender, Occupation, and Region of Residence

The figure presents an insightful overview of the respondents' demographic characteristics, critical for evaluating their engagement in agricultural extension and innovation strategies for sustainable agriculture in Somalia. The age distribution chart illustrates a youthful demographic, with a substantial proportion under 20 years old. This group represents emerging participants in sustainable agriculture, while older age categories add experience-driven perspectives. Educational levels notable variance in educational attainment is evident, with respondents ranging from no formal education to tertiary-level qualifications. This diversity reflects a spectrum of agricultural literacy and adaptability to extension strategies. Gender composition distribution highlights a significant disparity, with male respondents overwhelmingly dominating. This underscores the need for inclusive strategies to involve women in agricultural sustainability initiatives. Occupational engagement data reveal a balanced representation of stakeholders, including farmers, extension workers, researchers, government officials, and NGO workers. This occupational diversity provides a holistic understanding of factors influencing innovation. Regional representation such as Southwest and Hirshabelle lead in participation due to their fertile lands and robust extension services. Other regions like Benadir, Galmudug, Puntland, Jubaland, and Somaliland also demonstrate engagement, showcasing the broad geographic scope of agricultural activities.

Table 2: Integration of Extension Services and Technology

Integration of extension services and technology	Response	Frequency	Percent
Extension services effectively promote the adoption of new technologies	Strongly disagree	65	30.8%
	Disagree	2	15.9%
	Neutral	20	9.5%
	Agree	63	29.9%
	Strongly agree	60	28.4%
	Total	211	100.00
Perceived impact on sustainable agriculture	Not important	9	4.3%
	Slightly important	53	25.1%
	Moderately important	39	18.5%
	Very İmportant	73	34.6%
	Extremely important	37	17.5%
	Total	211	100.00%
Rate level of satisfaction with the agricultural technologies adopted	Very dissatisfied	45	9.0%
	Dissatisfied	19	6.2%
	Neutral	13	27.5%
	Satisfied	58	34.1%
	Very satisfied	72	1.9%
	Total	211	100.00
Effectiveness of the extension services received	Very ineffective	21	10.0%
	Ineffective	37	17.5%
	Neutral	50	23.7%
	Effective	76	36.0%
	Very Effective	27	12.8%
	Total	211	100.00

Table 2 presents an in-depth analysis of extension strategies in Somalia, emphasizing the efficacy of agricultural extension services, farmer engagement, and the adequacy of resources accessible to service providers. The findings underscore the pivotal role of extension services in promoting the adoption of innovative and sustainable agricultural technologies, reflecting diverse respondent perceptions. Approximately 29.9% and 28.4% of respondents agree and strongly agree that extension services effectively disseminate knowledge and best practices to enhance sustainable agricultural techniques (Antwi-Agyei & Stringer, 2021). However, a significant 15.9% disagree, and 30.8% strongly disagree, while 9.5% remain neutral, indicating challenges in service delivery. The perceived impact of sustainable agriculture on Somali farmers reveals unfavorable assessments by some respondents. Specifically, 4.3% and 25.1% rate the availability of these services as not important or slightly important, respectively, emphasizing barriers such as limited financial resources and access to markets. Conversely, 34.6% and 17.5% view sustainable agriculture as very important and extremely important, respectively, aligning with findings by Jankowska, 2021. Regarding satisfaction with agricultural technologies, only 1.9% of respondents are very satisfied, while 34.1% express satisfaction. However, 9.0% and 6.2% report being very dissatisfied and dissatisfied, respectively. This highlights a gap requiring attention to improve adoption rates and satisfaction levels (Jimale *et al*., 2023). Respondents' evaluations of the effectiveness of extension services reflect variability. While 36.0% rate these services as effective and 12.8% as very effective, a notable 17.5% and 10.0% rate them as ineffective and very ineffective, respectively, with 23.7% remaining Neutral. Overall, inadequate access to financial services, infrastructure limitations, and environmental challenges-such as water scarcity, soil degradation, and climate change-remain critical barriers to sustainable agricultural practices. Similar studies (Kerubo, 2021) corroborate these findings. The diversity of responses illustrates inconsistent service effectiveness, influenced by factors such as governmental capacity, accessibility, and security constraints. Addressing these challenges through improved policies, infrastructure development, and enhanced financial access would amplify the impact of extension services, strengthen food security, and foster long-term resilience in Somalia's agricultural sector.

Table 3: Demographic results

Knowledge and Perception of Extension Services in Somalia	Frequency	Percentage (%)
Training and Education	21	10.1%
Technical assistance	48	22.9%
Market information	100	47.6%
Access to inputs (seeds, fertilizers, etc.)	57	27.1%
Adoption of Agricultural Technologies in Somalia		
Cost	18	8.6%
Lack of information	34	16.2%
Lack of technical skills	58	27.6%
Cultural resistance	76	36.2%
Inadequate infrastructure	24	11.4%
Mobile phone applications for agriculture	63	30%
Renewable energy systems	66	30.4%
Precision agriculture tools	34	16.4%
Drought-resistant crops	40	19%
Perceived Impact on Sustainable and İnnovation Agriculture in Somalia		
Climate variability	59	28.8%
Political instability	31	14.7%
Limited financial resources	24	11.4%
Inadequate infrastructure	38	18.0%
Lack of knowledge/skills	59	28.0%
Strengthened community engagement	12	5.7%

3.3. Descriptive Statistics of Agricultural Extension and Technology Adaptations

This section examines the relationships and interdependencies between Agricultural Extension Services, Agricultural Development, and Technology Adoption for Sustainable Agriculture. It explores the extent to which these elements are interconnected and their influence on one another. In terms of the knowledge and perception of agricultural extension services in Somalia, 10.1% of respondents receiving training and 22.9% benefiting from technical assistance view these services as effective in disseminating best practices, and fostering the adoption of innovative, sustainable agricultural techniques (Kerubo, 2021). However, dissatisfaction is prevalent, with 47.6% of respondents relying on market information and 27.1% accessing inputs, such as seeds and fertilizers, expressing dissatisfaction with extension service effectiveness. Additionally, 9.5% of respondents remain neutral, indicating a need for improvement (Pender *et al*., 2001). Adopting agricultural technologies is hindered by key challenges. A lack of information (8.6%) and insufficient technical skills (16.2%) limit the effectiveness of technologies (Weber *et al*., 1998). Cultural resistance is significant, cited by 27.6% of respondents. Furthermore, inadequate infrastructure for mobile phone applications, affecting 27.6%, and reliance solely on mobile applications (36.2%) hinder widespread technology adoption (Andersson *et al*., 2021; Dallimer *et al*., 2009). Conversely, 30.4% regard renewable energy systems as key to sustainable agriculture, while 16.4% emphasize precision agriculture tools. Access to financial resources and high-quality, drought-resistant crop varieties is crucial for 19% of respondents, aligning with Abubakar *et al*., (2021). These findings highlight the need for targeted investments in infrastructure, capacity building, and financial access to enhance modern agricultural practices. Despite favorable perceptions of government policies, climate variability (28.8%) and political instability (14.7%) remain concerns (Abdullahi & Arısoy, 2022). Moreover, limited financial resources (11.4%), inadequate infrastructure (18.0%), lack of knowledge/skills (28.0%), and insufficient community engagement (5.7%) present barriers to adoption (Abu Harb *et al*., 2024).

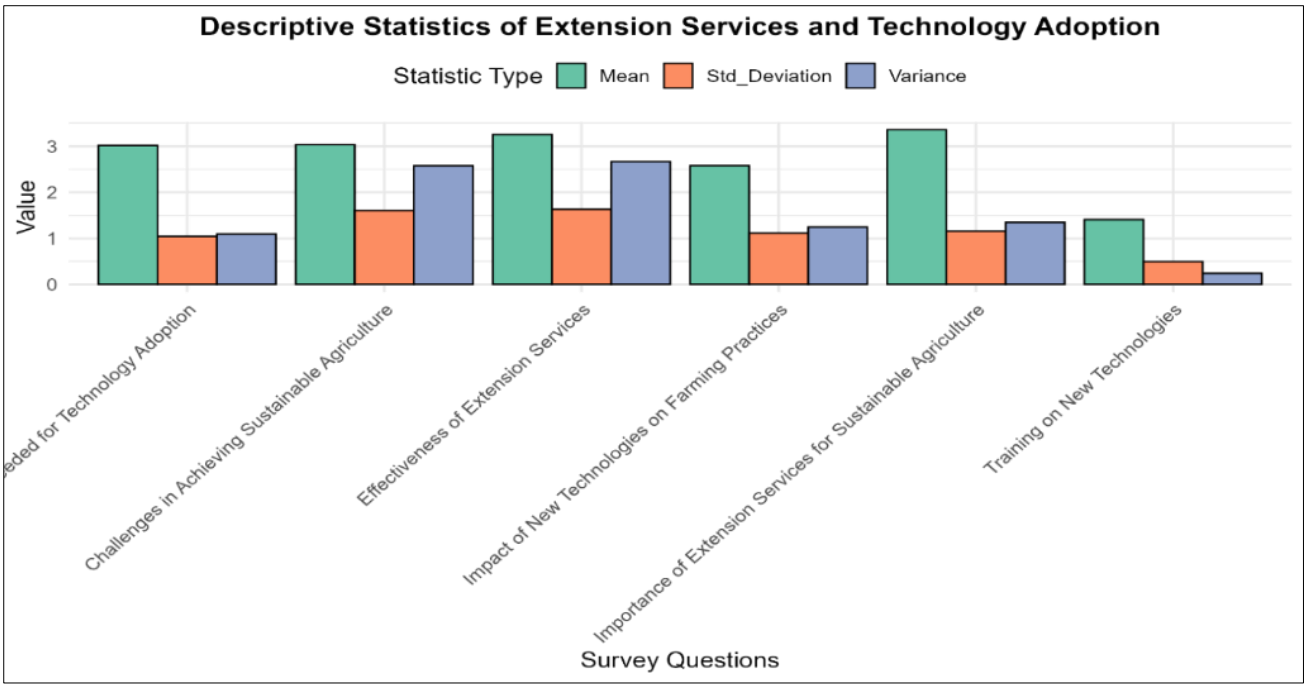

Figure 2: This demographic demonstrates respondents' agricultural extension and technology adaptation

Need for technology adoption respondents demonstrate a pronounced consensus on the necessity of embracing modern technologies, underscoring their pivotal role in advancing sustainable agricultural practices. Challenges in achieving sustainability key impediments, including infrastructural deficiencies and cultural resistance, are prominently highlighted. This observation aligns with previously referenced data, which underscores these barriers as critical obstacles to sustainability. Effectiveness of extension services Although some respondents acknowledge the value of extension services, a significant proportion conveys dissatisfaction, citing deficiencies in accessibility and infrastructural support as major constraints. The impact of technologies on farming practices and the incorporation of innovative tools, such as renewable energy systems and mobile applications, is positively perceived. However, their widespread adoption remains constrained by logistical challenges and insufficient financial resources. Training on new technologies the majority emphasize the imperative of training and capacity development, highlighting the crucial need for disseminating specialized knowledge and practical skills to facilitate technology adaptation effectively.

4. CONCLUSİON

This study highlights the critical link between agricultural extension services, innovation strategies, and sustainable agriculture in Somalia. Despite a generally positive perception of these efforts in promoting sustainable practices, substantial gaps persist in areas such as knowledge acquisition, financial resources, climate variability, political instability, and training programs. Utilizing a descriptive research design, data from 211 participants across seven Somali regions revealed significant institutional challenges, including policy deficits, governance issues, and capacity-building gaps. Resistance to change, cultural barriers, and inadequate supportive policies further hinder the adoption of sustainable practices. The analysis underscores the male-dominated nature of the agricultural sector, with many participants having at least primary or secondary education. However, the variability in extension service support leads to inconsistent farmer experiences, undermining the widespread adoption of sustainable methods. Addressing these challenges requires strengthening extension services, fostering innovation, and ensuring resources are equitably distributed. The study recommends:

- Invest in programs to enhance extension workers' skills in sustainable agriculture.
- Build irrigation systems, storage facilities, and transportation networks to reduce vulnerability to climate variability.
- Foster collaboration between government agencies, NGOs, and private entities to pool resources and expertise.
- Implement policies supporting sustainable agriculture, offering incentives for environmentally friendly practices, and addressing political instability.
- Promote research to develop locally adapted technologies and innovative solutions.
- Tailor extension services and innovations to meet the specific needs of diverse Somali regions effectively.

5. Author Statement

The authors confirm their contribution to the paper as follows: study conception and design, data

collection, analysis, and interpretation of results: Mohamed Mursal Ibrahim, Mohamud Ali Ibrahim, Mohamed Said, Shuaib Abdullahi Siad, and Hassan Nuur Ismaan; draft manuscript preparation and literature discussion: Mohamed Mursal Ibrahim, Mohamud Ali Ibrahim, and Shuaib Abdullahi Siad. All authors reviewed the results and approved the final version of the manuscript.

6. Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

- Abdullahi, A. A., & Arısoy, H. (2022). Agricultural structure in Somalia. *Eurasian Journal of Agricultural Economics (EJAE)*, *2*(1), 1-14
- Abubakar, A., Gambo, J., & Umar, S. (2021). An overview of the effects of some agricultural policies in Nigeria, 1960-2020. *Nigerian Agricultural Journal*, *52*(3), 151-162. http://www.ajol.info/index.php/naj.
- Amadu, F. O., McNamara, P. E., & Miller, D. C. (2020). Understanding the adoption of climate-smart agriculture: A farm-level typology with empirical evidence from southern Malawi. *World Development*, *126*, 104692.
- Andersson, M., Axelsson, T., & Palacio, A. (2021). Resilience to economic shrinking in an emerging economy: the role of social capabilities in Indonesia, 1950–2015. *Journal of Institutional Economics*, *17*(3), 509–526. doi:10.1017/S1744137420000624.
- Antwi-Agyei, P., Stringer, L. C. (2021). Improving the effectiveness of agricultural extension services in supporting farmers to adapt to climate change: Insights from northeastern Ghana. *Climate Risk Management*, *32*, 100304. https://doi.org/10.1016/j.crm.2021.100304.
- Atalba, O. (2016). The agricultural extension in Turkey. *Bulgarian Journal of Agricultural Science*, *22*(1), 151–157. Retrieved from https://agrojournal.org/01-26.pdf.
- Blakeney, M. (2022). Agricultural innovation and sustainable development. *Sustainability*, *14*(5). MDPI. https://doi.org/10.3390/su14052698.
- Chowdhury, A. H., Hambly Odame, H., Leeuwis, C. (2014). Transforming the roles of a public extension agency to strengthen innovation: Lessons from Bangladesh's National Agricultural Extension Project. *Journal of Agricultural Education and Extension*, *20*(1), 7–25. https://doi.org/10.1080/1389224X.2013.803990.
- Dallimer, M., Tinch, D., Acs, S., Hanley, N., Southall, H. R., Gaston, K. J., & Armsworth, P. R. (2009). 100 years of change: Examining agricultural trends, habitat change, and stakeholder perceptions through the 20th century. *Journal of Applied Ecology*, *46*(2), 334-343. https://doi.org/10.1111/j.1365-2664.2009.01619.x.
- Darnhofer, I., Bellon, S., Dedieu, B., & Milestad, R. (2010). Adaptiveness to enhance the sustainability of farming systems: A review. *Agronomy for Sustainable Development*, *30*(3), 545–555. https://doi.org/10.1051/agro/2009053.
- Devereux, S. (2010). Better marginalized than incorporated? Pastoralist livelihoods in Somali Region, Ethiopia. *European Journal of Development Research*, *22*(5), 678–695. https://doi.org/10.1057/ejdr.2010.29.
- Eidt, C. M., Hickey, G. M., & Curtis, M. A. (2012). Knowledge integration and the adoption of new agricultural technologies: Kenyan perspectives. *Food Security*, *4*(3), 355–367. https://doi.org/10.1007/s12571-012-0175-2.
- Evenson, R. E., Gardner, B., Huffman, W., Anderson, J., Roe, T., Kislev, Y., Ruttan, V., & Evenson, R. E. (2000). Economic impacts of agricultural research and extension. In B. L. Gardner & G. C. Rausser (Eds.), *Handbook of Agricultural Economics* (pp. 1-84). Elsevier Science.
- FAREH Abdulkadir Mohammed, B. (2011). Opportunities and challenges in implementing poverty reduction strategy in pastoral communities: A case study from the Somali Regional State of Ethiopia.
- Hassan, B. A. (2014). An assessment of the socio-economic and ecological impacts of environmental changes on rural livelihood: A study across Addado, Buhodle and Northern Galkaayo of Central and Northern Somalia. *Agriculture, Forestry and Fisheries*, *3*(4), 279. https://doi.org/10.11648/j.aff.20140304.20.
- Jankowska, A. (2021). Regional diversification of the use of agricultural production potential in the EU candidate and the Eastern Partnership countries. *PLoS ONE*, *16*(10), e0257490. https://doi.org/10.1371/journal.pone.0257490
- Jimale, A. D., Abdullahi, M. O., Ahmed, Y. A., & Nageye, A. Y. (2023). Towards sustainable farming in Somalia: Integrating IoT for improved resource management. *SSRG International Journal of Electrical and Electronics Engineering*, *10*(9), 95-101. https://doi.org/10.14445/23488379/IJEEE-V10I9P109
- Kader, A. A. (2). Increasing food availability by reducing postharvest losses of fresh produce. *In V International Postharvest Symposium 682*, 2169-2176. Retrieved from https://ucanr.edu/datastoreFiles/234-528.pdf
- Kaur, K., & Kaur, P. (2015). Direct-seeded rice for sustainable agriculture in Punjab. *Indian Journal of Economics and Development*, *11*(1), 71. https://doi.org/10.5958/2322-0430.2015.00008.6.
- Kaur, K., & Kaur, P. (2018). Agricultural extension approaches to enhance the knowledge of farmers – A review. *International Journal of Current Microbiology and Applied Sciences*, *7*(2), 2367–2376.

- Kerubo, O. I. P. (2021). *Agricultural output and economic growth in Kenya: A causality test* Master's thesis, University of Nairobi, School of Economics. University of Nairobi. http://erepository.uonbi.ac.ke/handle/11295/161116
- Le Sage, A., & Majid, N. (2002). The livelihoods gap: Responding to the economic dynamics of vulnerability in Somalia. *Disasters, 26*(1), 10–27. https://doi.org/10.1111/1467-7717.00188.
- Lubell, M., Hillis, V., & Hoffman, M. (2011). Innovation, cooperation, and the perceived benefits and costs of sustainable agriculture practices. *Ecology and Society*, *16*(4). https://doi.org/10.5751/ES-04389-160423.
- Lwoga, E. T., Ngulube, P., & Stilwell, C. (2010). Sustainable indigenous knowledge for sustainable agricultural development in developing countries: Knowledge management approaches in the social context. *International Information and Library Review*, *42*(3), 174–185. https://doi.org/10.1080/10572317.2010.10762862.
- Marie, M., Yirga, F., Haile, M., & Tquabo, F. (2020). Farmers' choices and factors affecting adoption of climate change adaptation strategies: Evidence from northwestern Ethiopia. *Heliyon*, *6*(4), e03867. https://doi.org/10.1016/j.heliyon.2020.e03867
- Mohamud, A. I., Mohamed, Y. A., & Mohamed, S. A. (2023). The link between animal welfare and sustainable development: Lessons for Somalia. Veterinary Sciences: *Research and Reviews, 9*(2). https://doi.org/10.17582/journal.vsrr/2023/9.2.132.151.
- Mustapit, Subekti, S., Sunartomo, A. F., & Rokhani. (2019). Achieving sustainable agriculture through enhancing agricultural extension institutions. IOP Conference Series: *Earth and Environmental Science, 250*(1). https://doi.org/10.1088/1755-1315/250/1/012011.
- Negera, M., Alemu, T., Hagos, F., & Haileslassie, A. (2022). Determinants of adoption of climate-smart agricultural practices among farmers in Bale-Eco region, Ethiopia. *Heliyon, 8*(7). https://doi.org/10.1016/j.heliyon.2022.e09824.
- Özçatalbaş, O., Imran, M. (2017). The role of agricultural extension and agricultural education for sustainability. ResearchGate. https://www.researchgate.net/publication/323748046.
- Pandey, V., Mittal, R., & Sharma, P. (2017). Documentation and application of indigenous traditional knowledge (ITK) for sustainable agricultural development. *Asian Journal of Agricultural Extension, Economics & Sociology, 15*(3), 1–9. https://doi.org/10.9734/ajaees/2017/31481.
- Pender, J., Gebremedhin, B., Benin, S., & Ehui, S. (2001). Strategies for sustainable agricultural development in the Ethiopian highlands. *American Journal of Agricultural Economics, 83*(5), 1231-1240. https://www.jstor.org/stable/1244813
- Rosenzweig, C., & Tubiello, F. N. (2007). Adaptation and mitigation strategies in agriculture: An analysis of potential synergies. *Mitigation and Adaptation Strategies for Global Change, 12*(5), 855–873. https://doi.org/10.1007/s11027-007-9103-8
- Sahoo, M., Ghosh, S., & Rout, S. K. (2024). How can agricultural innovation and extension systems be effective in delivering agro-advisories? *Current Science*, *127*(11), 1279–1286. https://doi.org/10.18520/cs/v127/i11/1279-1286.
- Samatar, A. I. (1985). In Somalia the predatory state and the peasantry: Reflections on rural development policy. *Development and Change, 32*(3). https://about.jstor.org/terms.
- Savran, F., Demiryürek, K., Özçatalba, O., Akin, A., & Boz, Đ. (2011). The agricultural extension system and practices in Turkey. *Scientific Research and Essays*, *6*(8), 1831–1838. https://doi.org/10.5897/SRE10.908.
- Sekhar, M., Rastogi, M., Rajesh, C. M., Saikanth, D. R. K., Rout, S., Kumar, S., & Patel, A. K. (2024). Exploring traditional agricultural techniques integrated with modern farming for a sustainable future: A review. *Journal of Scientific Research and Reports*, *30*(3), 185–198. https://doi.org/10.9734/jsrr/2024/v30i31871.
- Sennuga, O. S. (2021). Agricultural extension theories and practice in Sub-Saharan Africa: A critical review. *The Journal of Agricultural Science*. https://doi.org/10.5281/zenodo.4587438.
- Sharma, R., Peshin, R., Khar, S., & Ishar, A. K. (2014). Agriculture innovation system approach for sustainable agriculture development: A review. [Manuscript submitted for publication].
- Sheikdon, A. A. (2020). An analysis of the contribution of agriculture sector to the Somali economy. *International Journal of Economics & Management Sciences, 9*(1), 1–3.
- Wakweya, R. B. (2023). Challenges and prospects of adopting climate-smart agricultural practices and technologies: Implications for food security. *Journal of Agriculture and Food Research, 14*, 100698.
- Weber, M. T., Staatz, J. M., Holtzman, J. S., Crawford, E. W., & Bernsten, R. H. (1988). Informing Food Security Decisions in Africa: *Empirical Analysis and Policy Dialogue, 70*(5).
- Yurtkuran, S. (2021). The effect of agriculture, renewable energy production, and globalization on CO2 emissions in Turkey: A bootstrap ARDL approach. *Renewable Energy*, *171*, 1236-1245. https://doi.org/10.1016/j.renene.2021.03.009.