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Evaluating the Meaningful Participation of Smart Villages in Industry 4.0 Ecosystems in Sub-Saharan Africa

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Abstract:

The study seeks to examine, through a literature review, the level of participation and impact of smart villages in Sub-Saharan Africa. The smart village initiative has the potential to alleviate poverty in rural areas and reduce the rural-urban migration challenge in sub-Saharan Africa. Given that Africa has the world's fastest-growing youth population. A total of 29 articles were included in this study following the PRISMA inclusion and exclusion criteria. The study observed that a few smart village initiatives had been implemented in Sub-Saharan Africa. Emphasis is mostly on climate-smart agriculture aimed at alleviating rural poverty and adaptation to climate change. There are challenges in implementing the smart village initiatives, such as a lack of supportive policies, poor infrastructure, lack of electricity, technologies and finances. The success of climate-smart agriculture is necessary for the transition to smart villages, as agriculture is the backbone of most villages in SSA. Collaborations between universities, technology owners and villagers are essential for the successful implementation of smart villages in SSA.

Keywords:

Smart Villages, Smart Agriculture, Climate Change, Rural-urban Migration, Sub-saharan Africa

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Introduction

The rural-urban divide is a socioeconomic chasm marked by disparities in income, technology access, education, and standards of living. These disparities have resulted in the rural population facing higher poverty and limited access to health, education and employment opportunities. The perpetuating inequalities often result in the rural-urban migration of the younger population and the marginalisation of the remaining population (Emerllahu & Bogataj, 2024). The migration of youth in pursuit of better opportunities results in skills and youth population drain in rural areas, driving unsustainable urbanisation in developing countries and creating pressure on urban infrastructure, often resulting in informal settlements (Selod & Shilpi, 2021). For example, in Africa, droughts due to climate change are the major cause of the rural-urban migration, with 50% of the African population expected to be in cities by 2030 (Awumbila, 2015; Kabuya et al., 2024). Whilst in Asia, rural-urban migration is a result of the rising sea level (Selod & Shilpi, 2021).

The rural-urban divide, combined with the digital divide in the 21st century, affects the development and modernisation of remote villages. The rural population in Sub-Saharan Africa (SSA) is less likely to have digital skills, own digital devices or have an internet connection in comparison to their urban counterparts. This lack of benefit from globalisation and technological change in villages often forces the skilled and educated young people to migrate to cities for economic benefit (Eurofound, 2023). Thus, leaving the rural area with little hope for economic and social development. Addressing the urban-rural disparity through the establishment of smart villages is crucial for achieving balanced, sustainable societies. Smart villages are rural communities that leverage Industry 4.0 technologies such as the Internet of Things, renewable energy and smart agricultural practices to improve the lifestyles, sustainability and economic opportunities of the rural population. Smart villages built on the concept of resilience and the intrinsic quality of rural life can lead to the reduction of rural-urban migration and sustainable development (Kalinowski et al., 2022; Pérez-delHoyo & Mora, 2019). The establishment of smart villages in SSA has the potential of leading to sustainable village development and being a panacea to the rural-urban divide challenges. The elimination of these challenges through the smart villages concept facilitates opportunities for economic development, innovation and social inclusion in rural areas.

Though the definition of rural communities varies from country to country, most rural areas are affected by similar challenges such as climate change, demographic shifts and the advent and use of technology in agriculture and everyday life (Bokun & Nazarko, 2023). In most countries, rural areas cover the vast lands of the country, yet they remain excluded from most development processes. For example, in Poland the rural population accounts for around 40% of the population (Kalinowski et al., 2022). Economic and social disparities exist between rural and urban populations, yet equipping the rural

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population with digital skills and technologies could reduce developmental differences. Gerli et al. (2022) concluded that smart villages are seen as the rural versions of smart cities or an innovative strategy for rural development. Yet, rurality and sustainable development are unique features in the smart village concept. For instance, smart villages have the potential to eradicate poverty, inequalities and environmental challenges in villages.

For the successful implementation of smart villages, there is a need for an interdisciplinary approach and inclusion of village-specific conditions such as community participation, leadership, infrastructure development and innovation (Susilowati et al., 2025). Innovative technology that addresses and solves existing local needs in Industry 4.0 can enhance the competitive advantage of a village. Through the smart village concept, the potential of the area and that of its inhabitants can be exposed and strengthened through the justified use of new technologies. Thus, smart development is the true essence of the smart village concept (Bokun & Nazarko, 2023). To achieve smart development, the smart village concept should be highly flexible and geographically sensitive. For example, a smart village concept in a Zimbabwean village should vary from that of a Polish village after considering the needs, potential, resource availability and other characteristics of each village. In the UK, smart water, smart energy, smart healthcare, smart education and smart water were the key smart village strategies for the country (Renukappa et al., 2024). Despite the potential benefits, Renukappa et al. (2024) highlighted the hindrances associated with smart village implementation, such as the lack of collaborative efforts among stakeholders, lack of finances, scant knowledge on smart villages and the absence of clear implementation strategies for sustainable smart villages.

Given the potential of smart villages in eradicating the rural-urban divide through innovative technologies. The study seeks to evaluate the impact of smart village initiatives on village livelihood in Sub-Saharan Africa. The study also seeks to uncover the impact and effectiveness of this concept in SSA, given that these African countries face unique developmental and economic challenges. Additionally, the study seeks to understand how the use of Industry 4.0 technologies through the smart village initiative can be used to reduce the rural-urban divide. A scoping literature review was conducted from Scopus-indexed journals, reports and newspaper articles on various smart village initiatives in Sub-Saharan Africa.

Smart Villages

The concept of smart villages was introduced by the European Union in 2017 to facilitate the development of remote and depopulated regions in Europe through the exploitation of Industry 4.0 technologies and smart innovations (Kalinowski et al., 2022). In Europe, the smart village concept is closely aligned with the EU's long-term vision of ensuring that digital transformation benefits all regions, including rural areas, as well as achieving carbon neutrality by 2050 (Emerllahu & Bogataj, 2024). The

concept is equally influenced by the Sustainable Development Goals (SDGs), especially SDG11, which encourages the use of smart technology solutions in rural communities to achieve sustainable cities and villages with improved standards of living. Sustainable villages often leverage sustainable power, renewable energy, smart innovative technology and smart agricultural practices that increase productivity in drought-prone areas with minimal environmental impact (Kasinathan et al., 2022; Sampetoding et al., 2024).

The establishment of smart villages is aimed at achieving sustainable development and preserving the ability of future generations to achieve theirs. This notion is rooted in the Brundtland report of 1987. The smart village concept has the potential to economically and socially empower villagers while protecting the environment for future generations through the use of smart technologies and smart agricultural practices (Hoerber, 2026). The achievement of sustainable development in smart villages depends on social capital and community participation. Dembogurski et al. (2026) and Susilowati et al. (2025) observed that multi-stakeholder community participation in the village design and formulation stage was important for the successful implementation of smart villages. However, smart villages are a new concept that lacks instruments for monitoring progress and faces challenges in the implementation and adoption of technologies (Dembogurski et al., 2026).

Smart villages leverage the Internet of Things (IoT), artificial intelligence, information and communication technology and other Industry 4.0 technologies to bridge the rural-urban divide and enhance the quality of life for villagers. Rural communities are usually marginalised and struggle with poverty, climate change, lack of infrastructure, technological backwardness, environmental degradation and lack of other basic amenities for survival. Successful smart village implementation will result in villagers overcoming these developmental, social, economic and environmental challenges (Junaidi et al., 2025). Community participation and technological integration are essential in smart village implementation.

Local economic governance and technological adoption for smart village sustainability in Sub-Saharan Africa

Digital technologies are facilitators of sustainable economic progress and are reshaping the sustainability strategies of societies. Industry 4.0 technologies have the potential to improve environmental law efficacy, transparency and enforcement. For instance, digital technologies can be embedded into policy and legal design to enhance accessibility and efficiency and improve data driven decision-making in the creation of smart villages. Digitally empowered policies significantly improve productivity, maximise environmental taxation and enhance green innovation (Zhang & Bilawal Khaskheli, 2025). Additionally, digital technologies can be used to connect economic growth with environmental degradation. Sensors and satellite images can be used to track water quality, forest cover and air pollution. While blockchain technology can be used to enforce transparency on supply chains

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and the prevention of environmental fraud by both firms and primary producers. Green innovation and circular economy strategies are disruptive ideas that require a novel regulatory approach that matches the pace of technologies and sustainability requirements. The European Union introduced the European Green Deal in a bid to achieve carbon neutrality by using Industry 4.0 technologies to create renewable energy, promote circular economy practices and sustainable farming.

Technological adoption in smart villages will stimulate local economic development through reshaping and supporting digital entrepreneurship and attracting new private investments. Digital technologies can transform villages into robust economic clusters, such as the Campinas high-technology cluster, renowned for its strong link between research institutes and industry (Mago & van der Merwe, 2023). The use of Industry 4.0 technologies such as mobile apps and digital town halls effectively reduces the gap between municipalities and villagers and results in increased civic participation. However, Industry 4.0 adoption's impact on village economic development is hampered by a lack of region-wide policies to govern the smart village initiatives. Policies that support village economic development vary from country to country depending on the country's vision and priorities. This, in turn, has forced non-governmental organisations to be on the forefront of the smart village initiative in Sub-Saharan Africa. The smart village initiative has the potential to lead to interterritorial collaborations and promote robust rural-urban socio-cultural relationships (Fernández, 2026).

Methodology

The study used a qualitative approach, which enabled the study to have depth in understanding the complex subject of sustainable smart villages in Sub-Saharan Africa. Data was collected from carefully selected publicly available data sources such as published articles, reports, online publications and newspaper articles. Google Scholar, Science Direct, and online newspaper articles were used to collect data for this study. The study used news as a data source because of accessibility, representativeness, and timeliness, given that there is limited research on smart villages in sub-Saharan Africa (Filipe & Duarte, 2026). Online news enabled the study to continuously collect data on the phenomena over time and enabled the study to gather the sentiments of society on the smart village concept. The following key search words were used to start and select the articles to use in the study: 'Sub-Saharan Africa and smart villages', 'Sub-Saharan Africa and smart agriculture', and 'Africa and smart villages'. An additional search was conducted on Google in search of smart village initiatives in Africa. This Google search led to newspaper articles, reports and blog posts on smart village initiatives in Sub-Saharan Africa. The search inclusion criteria were influenced by the following: a mention of any smart village in Sub-Saharan Africa, the impact of the smart village initiative on villagers' livelihood and the challenges in implementing the smart village initiative in Sub-Saharan Africa. A total of 23 articles, 6 reports and news articles were

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identified, collected and analysed for the study. The article selection process is summarised in Figure 1 below.

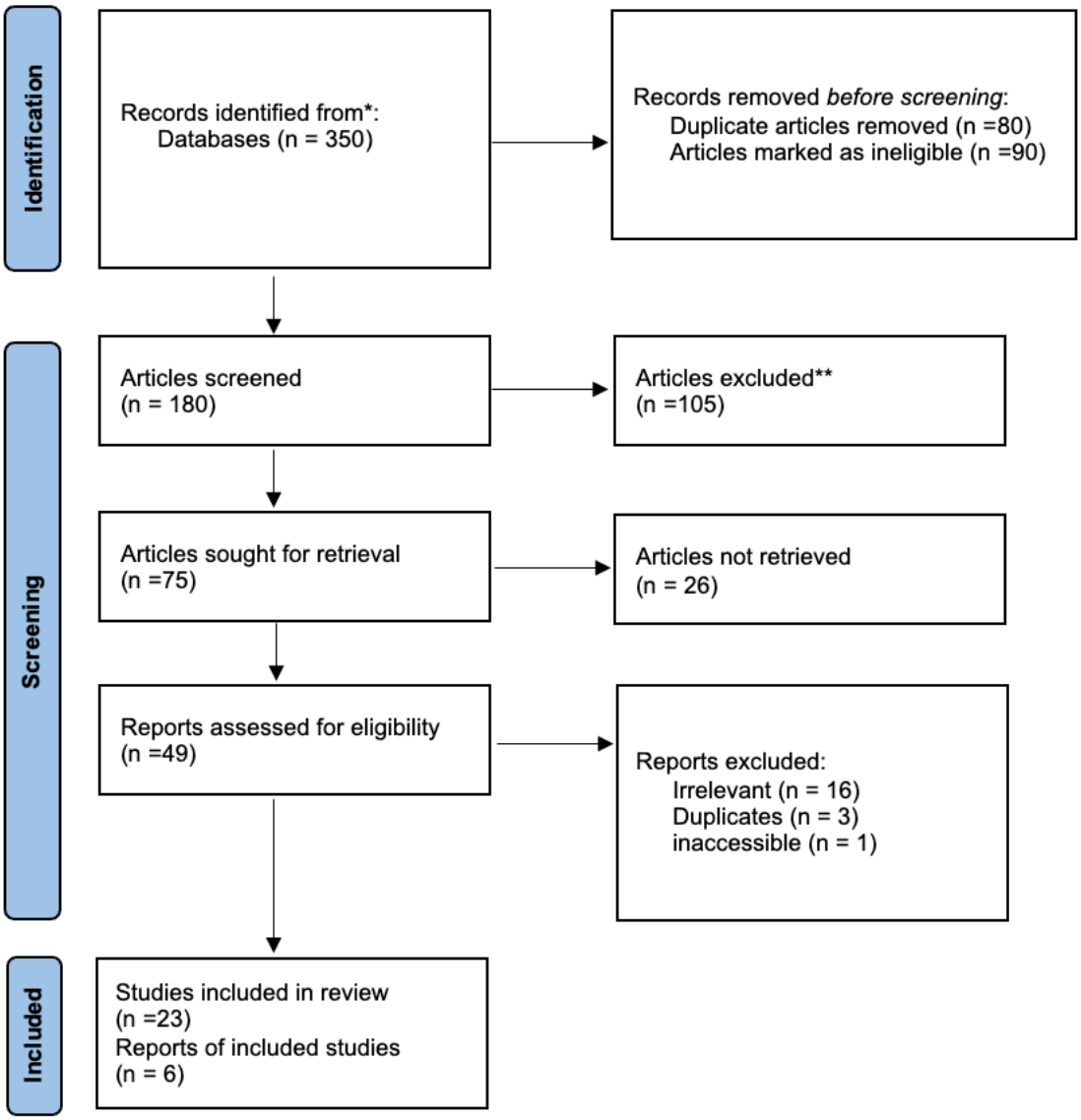

Figure 1: Step-by-step process for selecting articles

Findings

The importance of smart villages in Sub-Saharan Africa

The smart village concept has the potential to improve the standards of living in rural communities globally, though the concept is still poorly deployed in most developing countries (Kabuya et al., 2024). This is worsened by the unique challenges that affect rural areas, such as geographic isolation, poverty,

dispersed populations and limited resources. Additionally, most Sub-Saharan African countries are committing most of their resources towards achieving smart cities and enhancing technological connectivity in cities, consequently, leaving the villages lagging behind (Heap & Hirmer, 2020). By following such traditional models of development, it will take a long time for rural areas to achieve parity of development (Holmes & Thomas, 2015). If this skewed development approach in favour of smart city initiatives is left unchecked, it can worsen the rural-urban divide in SSA and other developing countries (Heap & Hirmer, 2020; Lakshmanan et al., 2022). The quality of life in smart cities is dependent on the success of smart villages.

Smart villages can improve food security and enhance the sustainable growth of rural enterprises (Heap & Hirmer, 2020). Renewable energy sources, mobile phone technology and internet access are pillars in community-led development of rural areas. These three pillars can lead to the integration of education, the health care system, environmental protection and food security within villages. Smart villages also boost access to information through technological use and thus can help SSA achieve sustainable development goals, such as the eradication of poverty, reducing inequalities, access to clean water and ensuring good health in rural areas (Heap & Hirmer, 2020; Kabuya et al., 2024). Internet access is expected to enable the mitigation of rural population decline. For example, in Poland, rural areas with poor access to the internet faced the highest population decline.

Capitalising on Sub-Saharan Africa's natural resources and agriculture is vital for successful smart village implementation and sustainable local development (Heap & Hirmer, 2020). Currently, the arable farmlands are either underutilised or producing below optimal capacity due to the persistent climate change-induced erratic weather patterns. Investment in smart agricultural technology, such as data-driven agriculture and precision farming, can assist rural farmers in making better-informed decisions on crop and animal management and efficient utilisation of land, water and pesticides (Aggarwal et al., 2018; Kabuya et al., 2024). The use of renewable energy sources can equally alleviate deforestation challenges in African villages. Smart agriculture technology is important in the creation of resilient and sustainable food production systems. However, to achieve successful smart agriculture implementation, there is a need for the interaction of technology owners, government policy and the consideration of the local socioeconomic and cultural conditions (Aggarwal et al., 2018).

Villages in African countries are viewed as lacking economic opportunities and the glitz and glamour of modern cities by the younger generation. The rural-urban migration by young people, in turn, robs the economic and social potential of villages and increases strain on the cities' infrastructure (Kabuya et al., 2024). Smart villages in Sub-Saharan Africa, hence, aim to improve the quality of life for the rural population as well as alleviate the challenges of urban overpopulation. Thus, the successful smart village initiatives can lead to the stabilisation of climate change, reduction of carbon footprints and increased use of eco-friendly practices in villages. This initiative, moreover, can result in improved quality of

education, access to digital resources and renewable energy sources in villages and, therefore, curb the rural-urban migration. These improvements in villages will naturally stimulate entrepreneurship and boost local businesses through increased local commerce and employment creation. Furthermore, there is preservation of local culture and trades in successful smart villages (Kabuya et al., 2024).

Electricity and access to digital technology and infrastructure are important for the implementation of smart villages in Sub-Saharan Africa. However, before smart villages can be implemented in Sub-Saharan African countries, there is a need to address basic human challenges such as access to clean drinking water, sustainable food security, internet access and clean energy sources. Given that Africa has the youngest and fastest-growing population in the world, with between 60 and 70 per cent of the population under the age of 30. Addressing these basic human challenges and the adoption of smart villages is paramount for a sustainable future in Sub-Saharan Africa.

Effectiveness of Smart Villages in Sub-Saharan Africa

Smart villages are important for the well-being and development of a society. However, the smart village initiative research is scarce in Africa, and education is a foundational cornerstone for successful smart village implementation in Sub-Saharan Africa (Kabuya et al., 2024). The successful governance of smart villages hinges on the interaction of technological, social, environmental and economic pillars. Despite the potential of achieving sustainable rural development through smart village adoption, the effectiveness of the concept has not been tested to measure its acceptance, adoption and sustainability. The lack of implementation strategies, the lack of collaboration among various stakeholders and the absence of financial resources are some of the challenges hindering the establishment of efficient smart villages in Sub-Saharan Africa (Renukappa et al., 2024). Hadian & Wibowo (2026) and Hadian et al. (2025) concluded that village leadership, technological literacy, community participation and technological infrastructure were critical instruments for an effective and sustainable smart village.

Agriculture is the backbone of most villages in Sub-Saharan Africa, with approximately 65% of the population's livelihood depending on agriculture (Djoumessi, 2022). Yet, there has been serious land degradation, deforestation and erratic weather patterns due to climate change in most sub-Saharan African villages. Consequently, the success of smart villages depends on the successful implementation of climate-smart agriculture. The introduction of climate-smart technologies and climate-smart agriculture practices could improve food production and increase income and resilience for smallholder farmers. For example, the Zimbabwean government introduced the Pfumvudza conservation agriculture programme, solar-powered irrigation schemes and reintroduced climate-smart drought-tolerant seeds such as sorghum and millet to enhance resilience in climate-smart villages (World Bank, 2019). The industry 4.0 technologies, such as sensors, are used for water optimisation and crop health monitoring. Solar-powered irrigation systems ensure sustainable agriculture in drought-prone and arid areas.

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Access to the internet, technology and financial services through mobile money services enhances access to financial services, markets to sell produce profitably and farming information in smart villages (FAO, 2023). Additionally, the smart village initiatives offer unique opportunities to the youthful population in Africa, which constitutes 70% of users in the digital agriculture ecosystem (FAO, 2023). Thus, digital agriculture could lead to greater profitability, sustainability and food security.

Smart village initiatives in Sub-Saharan Africa

There are a few documented smart village initiatives recorded in Sub-Saharan Africa. There is a high probability that a lot may be happening on the ground without being documented. The Food and Agriculture Organisation (FAO) has been at the forefront of carrying out the smart village initiatives across Sub-Saharan Africa. The Digital Village Initiative (DVI) is aimed at addressing socio-economic challenges such as poverty, socio-economic inequalities and hunger (FAO, 2023). The smart village pilot project is being carried out in 9 countries, namely Ghana, Kenya, Malawi, Niger, Senegal, Nigeria, Zimbabwe and Liberia. These initiatives assist farmers by reducing their farming knowledge gaps, adjusting to climate change and improving productivity using digital agri-advisory apps. Additionally, the smart village initiative is expected to result in greater access to financial and commodity markets (FAO, 2023). The success of smart villages in these nine countries depends on the integration of DVI with local village development priorities, continuous improvement of the local agrifood systems, sustainable and affordable rural digital connectivity, digital agriculture awareness, capacity building, engagement with youth and women, support of complementary rural transformation services, embedding sustainability in the design of digital agriculture services and nurturing existing supportive partnership ecosystems such as civil society organisations and farmer organisations (FAO, 2023; Isinkaye et al., 2026).

The integration of indigenous knowledge and technological advancement is crucial in achieving sustainable rural development in Sub-Saharan African countries. Isinkaye et al. (2026) proposed an indigenous knowledge-focused smart village framework where indigenous knowledge is included in the development of digital technologies. Indigenous knowledge practices play a central role in the management of human existence, and this knowledge is essential for the survival of Indigenous people. For example, indigenous knowledge has long supported sustainable conservation of local species and ecosystem biodiversity through restrictions based on taboos and myths. Such initiatives could result in the achievement of sustainable governance and increased adoption and acceptance of the smart village initiatives (Isinkaye et al., 2026; Sirayi, 2023). In South Africa, through a collaboration among Northwest University, Nyandeni Local Municipality and the Department of Science, Technology and Innovations, a pioneering indigenous knowledge-led smart village was created. The Nyandeni smart village was the country's first step towards rural regeneration using a community-driven development approach (Department of Science, Technology and Innovation, 2025). The inclusion of culture and indigenous knowledge at the inception stage of smart village planning enables the achievement of sustainable

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development (Sirayi, 2023). Bridging the divide among technology, indigenous knowledge, ecological issues and social realities enables smart technologies to address the unique needs of the local communities.

Smart technologies are being used to address health challenges in Sub-Saharan Africa. For example, Internet of Things-powered medical systems are used to collect medical data in South Africa, and Zipline drones are used to deliver medical supplies in remote villages in Rwanda (Isinkaye et al., 2026). The smart health care systems have reduced costs, enhanced access and efficiency in health delivery. However, for the successful implementation of the smart village initiatives, there is a need to engage and sensitise the community to overcome resistance. Community leaders must be engaged from conception to implementation as they play a significant role in African communities. Additionally, there is a need for continuous awareness campaigns highlighting the benefits of smart technologies in rural communities (Isinkaye et al., 2026).

Zambia officially opened its first smart village in the Namwala district in 2024 via a partnership with Huawei (Huawei, 2024). Through this initiative, the village now has access to a mini solar grid powering the local school, clinic and teachers' residential homes. Additionally, a wireless communication tower was constructed in the district to reduce network deployment costs by 50%. Also, an additional 100 similar smart villages are expected to be constructed in Zambia (Huawei, 2024). This strategic partnership is expected to give access to the internet, electricity and healthcare to around 400 000 villagers and create approximately 5 000 new jobs. Despite the potential benefits highlighted in the memorandum of understanding, the smart village initiative is not one-size-fits-all. There is a need for the project implementers to be knowledge-smart, which entails understanding the unique needs of each village, learning what works in one smart village and adopting the concept in another village with similar situations. For instance, the Climate Change, Agriculture and Food Security (CCAFS) organisation had to proactively make farmers from Lawra-Jirapa, a Ghanaian smart village, visit Yatenga smart village in Burkina Faso to learn crop and farming management techniques aimed at tackling similar anticipated climatic conditions in the future.

In South Africa, Gwakwani village was transformed from being a village without basic amenities such as clean water, electricity and reliable cell phone reception to a smart village through a collaboration between the local community, the University of Johannesburg and technology providers (Brand South Africa, 2025). The transformation involved replacing the diesel water pumping system with a solar-powered borehole water pumping system connected to a network of taps and tanks. Drip irrigation systems were installed to improve the supply of fresh vegetables in the village and beyond. Through the initiative, self-sustenance and entrepreneurship were further introduced through a solar-powered bakery. This resulted in employment creation and the availability of fresh bread for the community. The

education system was enhanced through the creation of a solar-powered creche where a television was installed to ensure that local children were raised as global citizens from their formative years.

Sub-Saharan African countries have also made significant strides towards electrification. This is a key variable in smart village implementation. For instance, Kenya increased its electrification rate from 33% in 2010 to 76% by 2022 due to investment in solar energy, improved solar policies and the involvement of the private sector. The Rwandan government initiated the mini-grid expansion, and the South African government introduced the renewable energy auctions, both of which have resulted in solar energy expansion (Gyani & Chandel, 2025). Despite the improved electrification in some SSA countries, there is a need to incorporate smart energy systems and harness wind energy to enhance clean energy generation (Gyani & Chandel, 2025).

The Farmer Fields School (FFS) in Uganda resulted in the empowerment of smallholder farmers with sustainable agricultural practices such as organic farming, the introduction of drought-resistant crops, effective irrigation systems and integrated pest management systems (African Union Commission, 2020; Mfitumukiza et al., 2017). Mfitumukiza et al. (2017) further observed that FFS farmers were more resilient due to being equipped with adaptive agriculture skills which rely on information sharing among farmers and less on external inputs. This culture of information sharing has fostered a culture of self-reliance and community support in the Terago and Kiboga districts (African Union Commission, 2020; Strong et al., 2023). Additionally, there is also improved financial literacy and entrepreneurship among the FFS participant farmers due to increased profits from farming activities.

The climate-smart village initiative in Tanzania has resulted in the enhancement of soil carbon sequestration, which helps in improving soil health and reducing the Tanzanian carbon footprint. For instance, climate-smart villages in Tanzania have carbon stocks ranging between 70% and 86% when compared with non-climate-smart villages (Ambaw et al., 2020). The climate-smart villages incorporate indigenous knowledge and scientific research in the development of resilient farming systems (Njogu et al., 2024). The inclusion of community members in the decision-making process ensures that the interventions are inclusive and address the local needs (Kirina et al., 2022; Njogu et al., 2024).

Impact of Smart Village initiatives in Sub-Saharan Africa

Rural communities in SSA rely on natural resources such as trees for firewood, as 75% of the population is without access to electricity (Gyani & Chandel, 2025). Yet, electricity is important for the establishment of smart villages. Improving access to smart electricity grids can positively impact the socio-economic development of remote areas and assist in the establishment of smart villages (Gyani & Chandel, 2025). Smart grids powered by solar energy and wind energy can provide clean, efficient and reliable electricity in rural villages (Maghraoui et al., 2026). Access to renewable energy and mobile technology forms the backbone of smart village implementation in SSA. This pairing enables access to vital services such as

digital payments and smart agriculture. The availability of clean energy and mobile connectivity can lead to local villagers' economic empowerment and environmental sustainability.

Smart village initiatives introduce the benefits of digital technologies to village dwellers. For example, farmers have access to real-time weather forecasts, agronomic advice and market information. Farmers have access to loans and mobile money services. Access to solar power could lead to sustainable food preservation through the creation of cold storage hubs where farmers can store their produce when market prices are not favourable. This is important as village farmers have traditionally been short changed or sold their produce to unscrupulous middlemen in fear of perishable produce rotting. The mobile technology enables farmers to access better farm produce markets. Through the interaction of mobile technology and renewable energy, farmers have ample time to implement value addition to their farm produce. Despite these potential benefits, smart village initiatives are often overshadowed by smart city initiatives, as remote and rural areas are often undermined despite their role in achieving sustainable development. This bias has resulted in less research output on the subject area, especially in Sub-Saharan Africa (Radoine et al., 2026). Thus, supportive policies, continued investment and collaborations with private players will enable the achievement of an Industry 4.0 powered smart village by 2063.

Smallholder farmers are empowered with knowledge and skills to carry out sustainable agriculture. Farmer training programmes and information sharing among farmers encourage farmers to experiment with new techniques in agroforestry, conservation farming, and water harvesting. Such initiatives encourage farmers to make informed decisions and enhance climate resilience. Climate-smart agriculture has also led to food security and improved economic capacity among smallholder farmers (Quarshie et al., 2023). For example, in East Africa, the climate-smart agriculture initiatives have led to the introduction of climate-resilient crop varieties and pest-resistant animal varieties, such as the hard Mashona cattle breed (Gebremedhin et al., 2025).

Challenges in Smart Village Implementation

Villages in Sub-Saharan Africa are affected by a lack of infrastructure, and where infrastructure exists, it is usually outdated or dilapidated (Mashau & Kroeze, 2023). New technological infrastructure is equally expensive to acquire and is sourced from other countries. These infrastructural challenges often result in a lack of reliable internet connectivity. This makes it challenging to adopt the modern digital technologies essential for smart villages.

There is a shortage of a technologically skilled population in rural areas. The lack of people with knowledge and skills to operate and manage modern technologies hinders the smart village initiative (Mashau & Kroeze, 2023). This digital illiteracy, coupled with limited access to technology and language barriers, hinders the adoption of technologies essential in smart village initiatives in Sub-Saharan Africa.

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This is further worsened by a lack of finances for the acquisition, training and development of villagers on technology use and an absence of homegrown innovative technologies that are cheaper and easier to understand for the local population. There is a need for active participation in the creation of technologies by African countries in the 4th industrial revolution to solve local challenges, instead of relying on the consumption of technology from other countries, as in previous industrial revolutions.

There is a lack of sustainable energy supply in most villages. Most of the rural population does not have access to electricity, which makes it challenging to use modern technology daily. Stable electricity or a renewable energy power supply is foundational in the establishment of smart villages. This is further worsened by a lack of financial resources to fund the smart village initiatives. Most villagers are generally poor and cannot afford to buy smart agricultural equipment or financially contribute towards the acquisition of 4IR infrastructure (Mashau & Kroeze, 2023). Additionally, it's expensive to operate and maintain the smart technology infrastructure in remote and sparsely populated areas.

There is a lack of alignment between the smart village initiatives and local village needs. This misalignment usually happens due to failure in considering local needs in the planning stages. Understanding the unique challenges and needs of each village is important before implementing a smart village initiative. The sustainability and continuity of smart villages depend on the local villagers. Thus, it is imperative to include the local views, indigenous knowledge, local leaders and local businesspeople in the planning and implementation of the initiative. For example, in Iran, Barati et al. (2026) observed that community members had low trust in climate-smart businesses as a solution to climate change challenges affecting the community.

The lack of control over technology brings data and privacy concerns. Data and privacy concerns are some of the challenges that come with active smart village initiatives. Unless local investments are made to counter such foundational challenges, data privacy concerns will continue to hound most Sub-Saharan African countries.

Sub-Saharan Africa is currently battling widespread poverty and climate-induced droughts and floods. This climate change is threatening food security and worsening the poverty situation. Additionally, there is income inequality and poor health delivery systems, with the rural population on the receiving end of these challenges (Gebremedhin et al., 2025). These socio-economic challenges are forcing the younger populations to leave villages in search of greener pastures. This leaves the villages with elderly and female populations, making it challenging to adopt the smart village initiative.

Institutional policy barriers are also affecting the smart village initiative in Sub-Saharan Africa. For example, there are only seven countries with mini-electricity grid regulatory frameworks in Sub-Saharan Africa, while thirteen countries have mini-grids without any regulatory frameworks. This lack of policy and regulatory frameworks is significantly discouraging private equity investors (Gyani & Chandel,

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2025). In East Africa, institutional barriers have affected the scalability of sustainable climate-smart agriculture programmes (Gebremedhin et al., 2025).

Smallholder farmers in SSA are affected by a myriad of socio-economic challenges, such as a lack of resources and access to finance. This is further worsened by poor political and governance issues, which result in a lack of policies that support smart village initiatives. The lack of clear policies negatively affects the scalability of smart village initiatives. For example, a lack of smart village policies often results in a lack of coordinated efforts among government agencies and other stakeholders, which often results in systemic inefficiencies (Gebremedhin et al., 2025).

Conclusions

The smart village concept is still in the implementation stages in Sub-Saharan Africa, with the climate-smart agriculture programme at the forefront. This could be attributed to the urgent need to eradicate poverty and adjust to climate change in Sub-Saharan Africa. The success of the smart agriculture initiative will pave the way to smart villages in Sub-Saharan Africa. The existing initiatives are mostly driven by humanitarian organisations and are closely aligned with addressing climate change challenges. Government departments and humanitarian organisations need to work together and share information to avoid duplication of processes and facilitate the continuity of the programmes. There is a need for policies that support the smart village initiative in Sub-Saharan countries. The existence of supportive policies will attract private investors. Collaborations between universities, technology providers, and community participation will go a long way in the establishment of smart villages. The smart village initiative has the potential to improve livelihoods in villages and reduce rural-urban migration. Despite the potential benefits of smart village implementation, challenges such as lack of infrastructure, skills gaps, digital divides, lack of electricity and internet still affect most Sub-Saharan African countries.

Recommendations

Since agriculture is the anchor of most African villages, implementing climate-smart agricultural systems is the first step towards achieving smart villages. Smart agricultural systems such as water conservation, smart irrigation systems, smart seeds, mechanisation and environmental conservation are essential in achieving food security. Access to affordable modern farming equipment and conservative smart farming practices will improve the economic situation of villagers. Local leadership has a central role in reshaping and influencing smart agriculture in villages through incorporating indigenous and local knowledge.

Collaboration and information sharing among various stakeholders, such as the government departments, local leadership, local youth and technology providers, are paramount for the establishment of smart villages. There is a need to customise technology to address the local

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challenges. In the same light, giving access to modern technology to youth in villages and training them on the correct use of technology in solving local challenges would assist in achieving local sustainable development and retaining the young population in the villages. Such training will give purpose and create employment opportunities for youth in their communities and reduce the rural-urban migration of youth. This retention of the skilled youthful population in villages is paramount for a successful smart village.

Funding local innovation hubs and supporting local inventions is important in smart village initiatives. Supporting local technological innovations financially enables the continuous improvement of ideas and products. However, for this to be effective, there is a need for collaborations between Sub-Saharan African countries and established technology providers for the training of the youthful population in the development and correct use of the technology. It's easier and more efficient to build on the foundation of existing technology.

Addressing the socio-economic and institutional inequalities within villages will enable the successful implementation of smart villages. For example, internet access is a basic requirement for successful smart village initiatives. Internet access enhances the social, economic and institutional functioning of the villages. The functioning of the village will improve due to easy access to readily available information, improved quality in decision-making and access to financial and produce markets.

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