

The Role of Internet Penetration in Agricultural Development, Economic Growth and Development Index

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The development of the internet and ICT-based technology (Information and Communication Technology) is currently the main focus of research, especially in the context of agricultural development which is expected to contribute to economic growth and the Human Development Index (HDI). This study aims to map empirical evidence related to internet penetration in the agricultural sector, economic growth, and human development in various countries. The approach used is a systematic literature study, involving 62 reputable journal articles and proceedings indexed by Copus, Web of Science, and published on Google Scholar. The reference selection process goes through a strict series, including the formulation of research questions (RQ), determination of inclusive-exclusive protocols, data extraction, and quality assurance of references recorded in reputable indexes. Extraction through the collection of important information, including the year of publication, main findings, and research results to map research topics and findings as a basis for theoretical and practical insights. The analysis results show that between 2015 and 2025, relevant studies are spread across Europe, Africa, Asia, and Australia, with a wider cross-regional comparison. The findings suggest that internet penetration and ICT use in the agricultural sector can increase productivity, farmer incomes, and community welfare, which in turn contribute to improving HDI and economic growth. Internet and ICT penetration also play an important role in increasing economic growth and human development, especially in developing countries, although the challenge of the digital divide still exists. Therefore, policies that support the development of technology infrastructure and internet access, as well as cross-sector collaboration, are needed to maximize the benefits of technology in promoting sustainability and welfare. The study recommends policy interventions to expand internet and technology access in the agricultural sector, to support economic development and HDI, with special attention to technology equity in developing countries.

Keywords: Internet penetration, digital literacy, Internet of Things (IoT), ICT policy in agriculture, economic growth, human development index, rural-urban digital divide.

INTRODUCTION

The Internet as the main medium in the development of Information and Communication Technology (ICT) has transformed into a major driver of global social and economic change. Along with the development of digital technology, empirical evidence shows the significant impact of internet penetration on economic growth, human development, and efficiency of the agricultural sector, especially in developing countries.

The agricultural sector, which has a major contribution to food security and the national economy, requires special attention to optimally utilize the potential of ICT. The Internet, as a component of ICT, plays a crucial role in accelerating the adoption of innovation, increasing efficiency, and expanding access to information needed for better decision-making. Through internet access, farmers can obtain data related to weather, market prices, the latest agricultural techniques, and information on environmental sustainability that supports more efficient and productive agriculture.

Ilham M., M.Natsir, Gamsir, Lapipi, T. Saili, M.Y. Balaka, Rostin, M.Rahim, Z. Saenong, S. Alwi, A. W. Nusantara and Hasddin. 2025. The Role of Internet Penetration in Agricultural Development, Economic Growth and Development Index. *Journal of Global Innovations in Agricultural Sciences* 13:523-537.

[Received 5 Nov 2024; Accepted 28 Jan 2024; Published 2 Apr 2025]



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However, internet penetration in various regions, especially in rural areas that are the center of agricultural activities, still shows significant inequality. In many developing countries, including Indonesia, although internet penetration has increased nationally, the gap between urban and rural areas remains a major challenge. Rural areas, which mostly depend on the agricultural sector as their main source of income, often struggle to maximize the potential of ICT. This inequality is influenced by various factors, including limited infrastructure, limited accessibility, and low levels of digital skills among rural communities.

In addition, the development of the agricultural sector through internet and ICT penetration is also closely related to economic conditions and the level of human development (Human Development Index/HDI) in a region. Countries with faster economic growth and high HDI tend to have better access to digital infrastructure. Therefore, understanding the relationship between economic growth, HDI, and internet penetration is essential in formulating policies that support equal access to ICT, including in agricultural development.

From an agricultural development perspective, digital literacy is a key factor in facilitating farmers' use of the internet. Without the ability to access and process digital information, the adoption of technologies that can increase agricultural productivity will be hampered. Research by [Nham et al. \(2024\)](#) shows that digitalization drives environmental innovation through precision agriculture technology, increasing the total factor productivity (TFP) of the agricultural sector in Vietnam. In Indonesia, [Sukma et al. \(2024\)](#) noted that farmers who use the internet have 29.6% higher incomes than those who do not, although the uneven distribution of internet infrastructure remains a challenge, especially in Eastern Indonesia.

A study in China by [Zheng et al. \(2022\)](#) found that internet use increased maize yields by 14.25%, with varying impacts depending on age, education, and farm scale. In addition, a literature review by [Rehman et al. \(2022\)](#) and a study by [Suroso et al. \(2022\)](#) confirmed that the role of the internet, including IoT and broadband, has a significant positive impact on agricultural performance, especially in developing countries in Africa, Asia, and Oceania.

Studies by [Khanna and Kaur \(2019\)](#); [Balducci et al. \(2018\)](#) highlight the role of IoT and machine learning in smart agriculture, such as increasing irrigation efficiency, early disease detection, and sensor-based agronomic data management. However, major challenges remain, such as limited internet access in rural areas, the digital divide, and the need for information integration between technology providers, the research sector, and farmers.

In Europe, [De-Clercq et al. \(2023\)](#); [Mayer et al. \(2019\)](#) reported that broadband access, especially in rural areas, can accelerate development in agricultural-based areas. However, the cost of implementing high-speed broadband infrastructure in rural areas remains a challenge. On the other hand, research

by [Mohamed and Nageye \(2022\)](#) in Somalia emphasized that internet usage not only contributes positively to economic growth, but also supports international trade and consumption as the main factors of economic development.

In Africa, [Mapiye et al. \(2023\)](#); [David \(2019\)](#); and [Haftu \(2019\)](#) identified that ICT penetration has a fundamental role in supporting economic growth, especially in the Sub-Saharan region through a panel data approach that strengthens the relationship between digital technology and economic development. This is in line with the findings of [Imasheva and Kramin \(2020\)](#) in Russia, which showed a positive elasticity between broadband internet development and Gross Regional Domestic Product (GRDP). In Indonesia, research by [Imansyah \(2018\)](#) noted that internet penetration is not evenly distributed, with limited access in Java. However, the government's project to expand the network in 57 cities has the potential to increase the role of the internet in national economic growth.

In terms of human development (HDI), internet and ICT penetration provide hope in achieving human resource development goals. Various literatures show that advances in ICT are the main drivers of human development in various parts of the world. Empirical studies show a significant relationship between digital indices and human development, with impacts varying by region, income level, and country development stage. A study by [Laitsou et al. \(2025\)](#) in Europe revealed a positive correlation between the Digital Economy and Society Index (DESI) and HDI. Similar results were found in Asia-Pacific ([Nipo et al., 2023](#)), and Africa ([Nguea, 2023](#)), showing that internet and mobile phone penetration significantly increase HDI.

Studies by [Ježić et al. \(2022\)](#), and [Aksentijević et al. \(2021\)](#) confirm that the impact of ICT on human development is more pronounced in low- and middle-income countries than in developed countries. Studies in developed countries, such as [Bayar et al. \(2023\)](#), show a stronger influence on social aspects. On the other hand, studies such as [Bala \(2024\)](#) highlight that the contribution of ICT to HDI is often driven by improvements in education and health in developing countries, while in developed countries it is more dominant in increasing income.

Overall, better digital literacy among farmers will enable them to leverage the internet to access more accurate and relevant information, which in turn supports better decisions in their agricultural activities. Therefore, improving digital infrastructure and digital literacy is an important step to accelerate the development of the agricultural sector. As a country with great agricultural potential, this can have a significant impact on human development and, more broadly, contribute to economic growth.

Internet and ICT penetration has a close relationship with economic growth, increasing HDI, and its contribution to the development of key sectors, including agriculture. However, challenges in infrastructure development, the digital divide,



and regional disparities need to be addressed to optimize its impact. This study aims to explore empirical evidence on internet penetration, its relationship with economic growth and HDI, and internet use in the agricultural sector. By using a systematic literature study approach, this study is expected to provide strategic insights that can be used by policymakers in formulating more effective policies to accelerate digital transformation in the agricultural sector. The results of this study are expected to provide information for public policies that support the optimization of the role of the internet and ICT in increasing the efficiency, productivity, and sustainability of the agricultural sector, as well as encouraging economic growth and improving the quality of life of the community, especially in rural areas.

MATERIALS AND METHODS

This study applies a literature study or literature review approach. Literature studies sourced from journals and proceedings were conducted using a systematic literature review method, known as a systematic literature review (SLR). Based on studies by [Lim et al. \(2022\)](#); [Luft et al. \(2022\)](#); [Koszyán et al. \(2021\)](#); [Pursell and McRae \(2020\)](#); [Snyder \(2019\)](#); [Cash \(2018\)](#); and [Palmatier et al. \(2018\)](#), a systematic literature review (SLR) is a structured and comprehensive approach to identifying, evaluating, and synthesizing various studies that are relevant to a particular topic or research question. This method follows a clearly defined, transparent, and replicable process, with the aim of minimizing bias and ensuring that findings are based on the best available evidence.

The application of the SLR technique uses secondary data, namely only based on scientific publications in the form of journals and proceedings. By determining these reference criteria, the SLR process can be started, starting from formulating the question topic, to reporting the research results. Summarized from [Chukwuere \(2023\)](#); [Snyder \(2019\)](#); [Palmatier et al. \(2018\)](#); [Galvan and Galvan \(2017\)](#); [Ravitch and Riggan, \(2016\)](#); [Jahan et al. \(2016\)](#); [Boyd and Solarino \(2016\)](#); and [Rodell et al. \(2016\)](#), the SLR stages in the study are described below:

1. Formulate research questions. Formulate research questions or problems by breaking down broad topics into more specific and answerable sub-questions. These questions should guide the entire review process. This process produces key questions or Research Questions (RQ), to limit the material and reach of the analysis topic. The RQ proposed in the study is "The Role of Internet and ICT Penetration; Its Contribution to Agricultural Development, Economic Growth, and the Human Development Index". This RQ is then divided into three to facilitate the search and consistency of the references sought, namely "Internet Penetration in Agricultural Sector Development", "internet penetration on economic

growth", and "internet penetration on the human development index".

2. Develop a Review Protocol. A review protocol is established to define the approach to the review process, including key decisions on journal selection criteria, search strategies (e.g., using Zotero), data extraction, and analysis techniques.
3. Determine Inclusion and Exclusion Criteria. The study defines the following criteria for inclusion and exclusion: Inclusion Criteria: Systematic study design; Publication date within 2015–2025; and International journal articles. Exclusion Criteria: Methodologically problematic studies; Studies outside the defined scope of inclusion criteria; and Irrelevant studies too far removed from the research topic.
4. Systematic Literature Search. A comprehensive search is conducted using databases such as PubMed, Scopus, and Google Scholar to identify relevant studies. Searches are refined to focus on recent publications aligned with the specified RQs, ensuring relevance and consistency in topics.
5. Selection of Literature. Studies are filtered based on the inclusion and exclusion criteria through a thorough review of titles, abstracts, and full texts. The process ensures repeated checks for data quality, focusing on: a) International journals and proceedings; b) Reputable journals indexed in Scopus and other databases like Copernicus; and c) Recent publications (2015–2025). This process resulted in the selection of 62 scientific articles.
6. Data Extraction. Data from selected journals is extracted to gather key information, including publication year, main findings, and research results. The goal is to map research topics and findings as a basis for theoretical and practical insights.
7. Quality Assessment. A quality assessment evaluates the strength and limitations of included studies, minimizing bias and ensuring the robustness of conclusions. This step helps identify both the strengths and weaknesses of the evidence.
8. Data Synthesis. Extracted data is synthesized to answer the research questions. A qualitative synthesis approach is employed, using narrative methods to group studies by themes, results, or methodologies. This process highlights patterns and relationships among the findings.
9. Interpretation and Reporting. Findings are interpreted in the context of the research questions, addressing patterns, inconsistencies, and the strength of evidence. Limitations of the review, including potential methodological biases, are discussed. This step also lays the groundwork for future research directions. Finally, the findings are compiled into a journal manuscript for publication.

The data analysis process uses a qualitative paradigm. Qualitative analysis techniques in systematic literature review



(SLR) research are to conduct synthesis-based analysis (summarizing) of descriptive qualitative research results. The results of the analysis are presented narratively or descriptively to obtain a more in-depth and comprehensive explanation of new evidence.

RESULTS

Through the systematic literature review (SLR) process, a total of 62 scholarly articles were identified, all of which consistently addressed the topic of "Internet and ICT penetration; comparative studies of economic growth, human development index, and their contributions to agricultural development." As shown in Figure 1, among the articles analyzed, the majority of the academic focus was on the influence of internet penetration on the development of the agricultural sector, accounting for 25 articles, or 40.32% of the total.

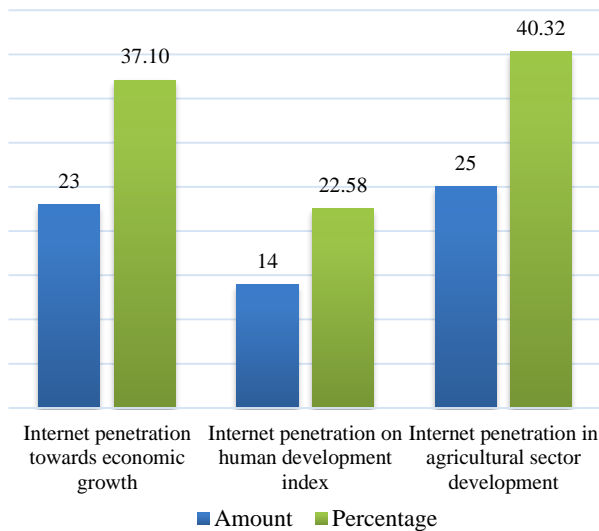


Figure 1. Number of articles according to research question (RQ).

The findings reveal that the agricultural sector is one of the most prominent areas benefiting from internet penetration, significantly enhancing productivity and efficiency. This is particularly relevant in the context of the rapid advancements

in information and communication technology (ICT), which have transformed traditional agricultural practices.

Meanwhile, topics related to internet penetration on economic growth (23 articles or 37.10%) also became an important focus. This reflects that researchers see internet penetration as a major driver in accelerating economic development, either through business efficiency, reduced transaction costs, or increased market access. Meanwhile, 14 other articles (22.58%) focused on internet penetration on the human development index (HDI), highlighting how internet penetration can affect the dimensions of education, health, and standard of living. This shows that the internet not only has an economic influence but also plays an important role in improving people's quality of life.

The mapping results of 62 articles analyzed, the researchers are spread across four regions, namely Europe, Africa, Asia, and Australia. The results of the analysis also show their studies in a broader context, namely comparisons between regions and/or according to developed and developing countries. The complete data is presented in Table 1.

Research conducted in Europe during the observation period amounted to 9 articles or 14.52% spread across various years. The years 2023 and 2019 were the years with the most articles contributed from this region. However, the years 2024, 2021, and 2017 did not have any articles contributed, indicating that research from the European region is not so intensive.

In Africa, 15 articles (24.19%) came from this region, showing a relatively consistent distribution over the years. Research contributions from Africa appeared almost every year, although some years, such as 2021, had fewer publications. In particular, 2020 and 2016 recorded higher contributions, with two articles published each year.

The Asian region contributed the largest number of articles, with 22 articles (35.48%) published across the years. This region showed dominance in 2019 and 2020, with each contributing five articles during those years. Despite less productive periods, such as 2024, Asia maintained a substantial share of contributions, reflecting the region's active involvement in research.

Australia, however, produced only one article (1.61%) during the analyzed period, published in 2016. This indicates a lower level of research interest and scientific contributions from this region over the past decade.

Table 1. Distribution of scientific articles by region and year of implementation.

| Region/Area | Year | | | | | | | | | | | Number |
|----------------------------|------|------|------|------|------|------|------|------|------|------|------|--------|
| | 2025 | 2024 | 2023 | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | 2015 | |
| Europe | 1 | | 2 | 1 | | | 1 | 2 | | 1 | 1 | 9 |
| Africa | | | 2 | 1 | | 2 | 2 | 2 | 1 | 3 | 2 | 15 |
| Asia | | 3 | | 1 | | 3 | 3 | 2 | 5 | 2 | 3 | 22 |
| Australia | | | | | | | | | | 1 | | 1 |
| Comparison between regions | | 1 | 1 | 4 | 1 | | 2 | 4 | 2 | | | 15 |
| Total | 1 | 4 | 5 | 7 | 1 | 5 | 8 | 10 | 8 | 7 | 6 | 62 |



In terms of interregional comparisons, 15 articles (24.19%) focused on this theme. These studies focused on specific years, specifically 2022 and 2018, with four articles published in each of these years. The emphasis on interregional comparisons over a specific period indicates an increasing focus on the broader context, particularly in the areas of economic growth, human development, and agricultural development. These findings have important implications, especially for countries engaged in regional cooperation, as they highlight opportunities for complementarity and development of global development strategies. Overall, over the period 2015–2025, the majority of the 62 articles came from Asia, followed by Africa and interregional studies. An infographic summarizing these findings is presented in Figure 2.

The information in Table 1 also shows that the development between years tends to decrease. As presented in Figure 3, the period 2015-2018 saw an increase in the number of articles, the peak occurring in 2018, namely 10 articles or 16.13%.

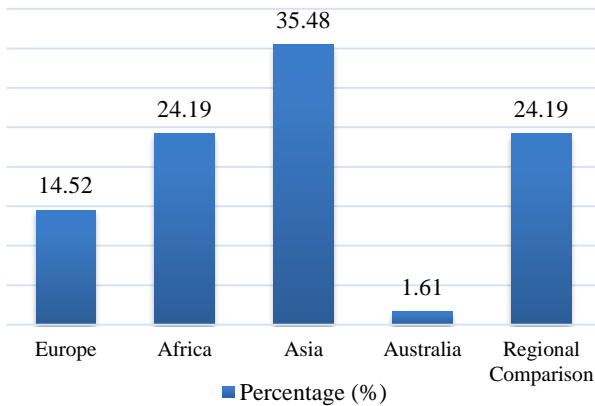


Figure 2. Number of articles by region.

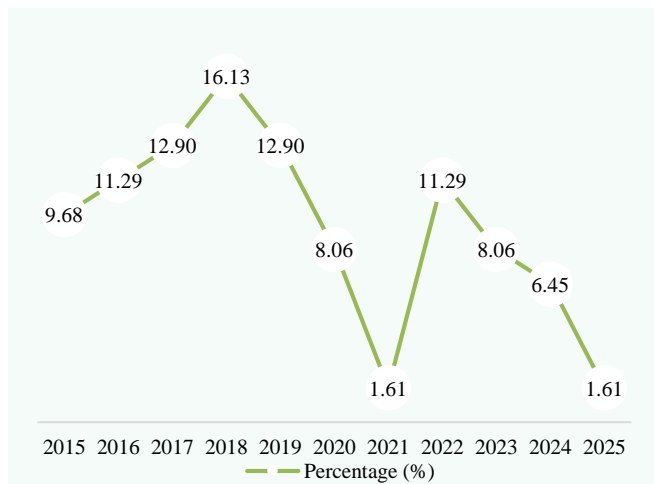


Figure 3. Development of the number of articles in 2015-2025.

Fluctuations in the number of articles published can be attributed to several factors, including socioeconomic conditions, shifts in research focus, and the impact of global events, such as the pandemic. In particular, 2021 and 2025 saw a decline in contributions, which could be indicative of periods of declining interest or delays in research activity. However, despite these variations, there is an overall positive trend in increasing academic interest in the topic. This suggests that the subject is gaining more attention from researchers over time.

Internet Penetration on Agricultural Sector Development: Internet penetration in the development of the agricultural sector has also become a concern for researchers around the world. Quantitatively, internet penetration for the agricultural sector is actually higher than the issue of economic growth and human development (presented in Figure 1). Judging from the distribution of regions, Asia is the highest, namely 15 articles or 60%. This figure is very dominant, compared to other regions in Africa only 4 articles or 16%, Europe only 2 articles or 8%, Australia only 1 article or 4% and comparative studies 3 articles or 13%. Complete information is presented in Table 2 and the infographics are seen in Figure 4.

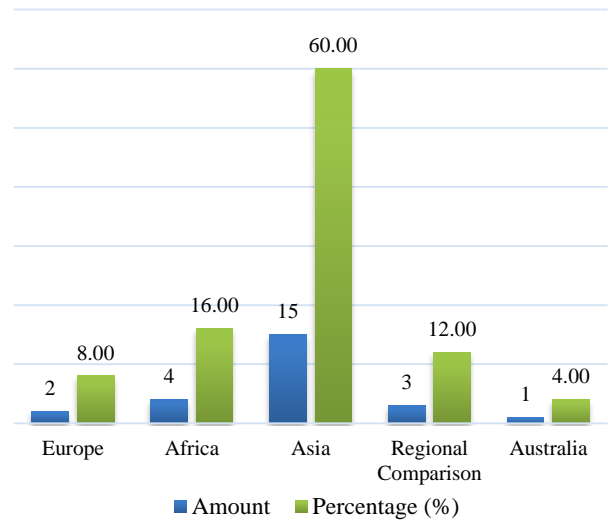


Figure 4. Number of articles by region.

As shown in Figure 4, Asia leads the distribution of research topics, accounting for 60% (15 articles) of the total. There are four main reasons behind this superiority, as reflected in the background review and the sources of research cited in each journal or proceeding. The *first* reason is the high interest in agriculture, economics, and natural resources issues in Asia. The agricultural sector plays a vital role in many Asian countries, and there is a growing need to sustainably improve agricultural output.

The second factor contributing to this trend is the availability of research data and resources. Many countries in Asia,



Table 2. Distribution of scientific articles on internet penetration in the development of the agricultural sector.

| Region/Area | Year | | | | | | | | | | Number | |
|----------------------------|------|------|------|------|------|------|------|------|------|------|--------|------|
| | 2025 | 2024 | 2023 | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | | 2015 |
| Europe | | | | | | | | 1 | | 1 | | 2 |
| Africa | | | 1 | | | 1 | | 1 | | | 1 | 4 |
| Asia | | 3 | | 1 | | 1 | 1 | 1 | 4 | 1 | 3 | 15 |
| Australia | | | | | | | | | | 1 | | 1 |
| Comparison between regions | | | | 2 | | | 1 | | | | | 3 |
| Total | | 3 | 1 | 3 | | 2 | 2 | 3 | 4 | 3 | 4 | 25 |

Source: Nham *et al.* (2024); Sukma *et al.* (2024); Sheng and Liu (2024); Mapiye *et al.* (2023); Zheng *et al.* (2022); Rehman *et al.* (2022); Suroso *et al.* (2022); Ma and Wang (2020); Kour and Arora (2020); Khanna and Kaur (2019); Khan *et al.* (2019); Kiambi (2018); Balducci *et al.* (2018); Hamad *et al.* (2018); Biradarand and Shabadi (2017); Roselin and Jawahar (2017); Pandithurai *et al.* (2017); Rekha *et al.* (2017); Jayaraman *et al.* (2016); Bauer *et al.* (2016); Patil and Thorat (2016); Arkeman *et al.* (2015); Ojha *et al.* (2015); Irungu *et al.* (2015); Heang and Khan (2015)

especially those in Southeast and South Asia, have relatively better access to data and resources for research in agriculture and related fields compared to other regions. A third contributing factor is the relevance of the region's agricultural challenges, including climate change, food security, and the need for increased agricultural productivity. These critical issues require extensive research, which helps explain the higher concentration of studies in this area. Lastly, international funding and collaboration also play a significant role. Asia hosts numerous leading research institutions and universities, which often conduct studies funded by global financial support, driving further research output in the region.

The results of the aggregation of research topics and findings, summarized six (6) points that are the researcher's contribution in explaining internet penetration to agricultural development.

Innovation and digitalization in agriculture: That Vietnam, China, India, and Australia are building a new paradigm regarding the application of digital technologies such as the Internet of Things (IoT), machine learning, and sensors to improve agricultural efficiency. In Vietnam, China, and India, the focus is on the use of IoT and sensor-based systems to improve agricultural yields and sustainability (smart agriculture, precision agriculture). Australia and Italy focus on the experience and application of machine learning and

internet platforms for smart agriculture that can improve the decision-making process in agriculture.

The role of the internet in the agricultural sector: Indonesia, China, and Pakistan explore how the internet can enhance agricultural productivity, with examples including the use of the internet for marketing, managing green financial data, and applying smart agricultural technologies. In China, research focuses on the effect of internet usage on wheat productivity and rural income, as well as the role of the internet in promoting sustainable agricultural practices. Meanwhile, studies in Africa and Sudan highlight how ICT can improve access to crucial information for small-scale farmers, thereby boosting agricultural income.

Leveraging technology to improve agriculture in water-stressed regions: China examines the impact of digital technologies in managing green finance innovations, with a focus on improving agriculture in water-stressed regions of Asia. This is important for regions with limited water availability challenges.

Technology challenges and potential in agriculture in Africa: Sub-Saharan Africa and Kenya demonstrate the potential of Information and Communication Technologies (ICT) in disseminating agricultural information and attracting youth to more profitable agriculture sectors. Africa in general also highlights how the Internet of Things (IoT) can be used in precision agriculture and agricultural data management.

Table 3. Distribution of scientific articles on internet penetration and economic growth.

| Region/Area | Year | | | | | | | | | | Number | |
|----------------------------|------|------|------|------|------|------|------|------|------|------|--------|------|
| | 2025 | 2024 | 2023 | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | | 2015 |
| Europe | | | 1 | 1 | | | 1 | 1 | | | 1 | 5 |
| Africa | | | | 1 | | 1 | 2 | | 1 | 2 | 1 | 8 |
| Asia | | | | | | 2 | | 1 | 1 | 1 | | 5 |
| Comparison between regions | | | | | | | | 4 | 1 | | | 5 |
| Total | | | 1 | 2 | | 3 | 3 | 6 | 3 | 3 | 2 | 23 |

Source: De-Clercq *et al.* (2023); Mohamed and Nageye (2022); Wahab *et al.* (2020); Imasheva and Kramin (2020); Li *et al.* (2020); Oladipo and Wynand (2020); Mayer *et al.* (2019); David (2019); Haftu (2019); Imansyah (2018); Edquist *et al.* (2018); Bahar (2018); Latif *et al.* (2018); Toader *et al.* (2018); Maurseth (2018); Keho (2017); Ghosh (2017); Vu (2017); Salahuddin and Gow (2016); Borena and Negash (2016); Kumar *et al.* (2016); Minges (2015); Wamboye *et al.* (2015)



The role of digital systems and platforms in smart agriculture: India highlights the application of various IoT and sensor technologies in smart agriculture, including wireless sensor systems used for monitoring soil and crops, as well as utilizing IoT to identify plant diseases.

The impact of the internet on the development of the agricultural industry: China also discusses how internet marketing can help in the development of the agricultural industry, highlighting case studies linking digital marketing and agriculture.

Internet Penetration on Economic Growth: As the result of the analysis, articles discussing “internet penetration towards economic growth” are 23 articles. As seen in Table 3, the largest number of articles were conducted in Africa, followed by Europe, Asia and comparative studies between regions. Research in Africa was the highest, namely 8 articles (2015–2022), with the most in 2016 and 2019. The most articles were published in 2018 (6 articles), followed by 2020, 2019, 2017 and 2016 each (3 articles). Then there was a trend of increase and fluctuation, but the distribution of articles tended to be spread across the years with peak activity in 2017–2020, and thereafter decreased (the infographic is presented in Figure 5).

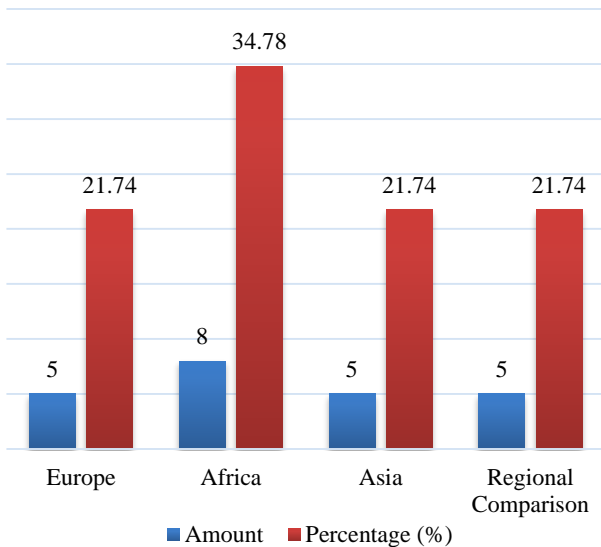


Figure 5. Number of articles by region.

Africa is the region most frequently focused on research on internet penetration and economic growth, with a steady trend of research activity from 2015 to 2022. Research peaked in 2020, likely influenced by the COVID-19 pandemic that increased attention to digitalization and its impact on the economy. Meanwhile, Europe and Asia have a relatively balanced number of articles, with a tendency to focus on in-depth studies, although the distribution is less even. Cross-regional research was mostly conducted in 2015 and 2016, with a decline in intensity thereafter.

The research focus in Europe (including France and Russia) can be classified into five main themes, which generally address the digital divide between regions. These themes, as outlined in studies by De-Clercq *et al.* (2023); Imasheva and Kramin (2020); Mayer *et al.* (2019); Toader *et al.* (2018); Minges (2015), include:

1. Urban-Rural Digital Divide; this examines the disparity in broadband access between urban and rural areas in Europe. This gap has a direct impact on economic growth, especially in rural areas that have limited access to digital infrastructure.
2. The Impact of Broadband Internet on Regional Economic Growth; highlights how broadband access affects economic growth in different regions of Russia, with a focus on the different regional impacts depending on the level of technology penetration.
3. Reassessing the Broadband-Economic Relationship; reassesses the relationship between broadband technology adoption and economic growth in Europe, highlighting the importance of policies supporting digital access as part of economic development strategies.
4. ICT Infrastructure and Economic Growth in the European Union; this examines the impact of information and communications technology infrastructure on economic growth, focusing on the contribution of ICT infrastructure to the economies of EU countries, with an empirical approach to analyzing the benefits of investing in information technology.
5. Exploring the Broadband-Economic Relationship; explores the relationship between broadband access and economic growth in a holistic manner, providing insights into how this technology drives productivity and development.

Researchers from Africa during 2015-2025 generally focused on six main friends that were widely discussed. As reported by Mohamed and Nageye (2022); Oladipo and Wynand (2020); David (2019); Haftu (2019); Salahuddin and Gow (2016); and Wamboye *et al.* (2015) the six friends are:

1. The Relationship between Internet Use and Economic Growth; highlights how internet use and investment by local telecommunications companies, such as Hormuud Telecom, have played a significant role in driving economic growth in Somalia.
2. Information and Communication Technology (ICT) Penetration as an Economic Driver; examines how ICT penetration rates have become a key driver of economic development in the African region, highlighting the potential of technology to reduce development gaps.
3. Telecommunications Operations to Support Economic Growth; discusses the critical role of the telecommunications sector in accelerating economic development and creating greater connectivity in Africa.
4. ICT and Economic Growth in Sub-Saharan Africa; uses a panel data approach to evaluate the relationship



between ICT adoption and economic growth in Sub-Saharan African countries, showing a significant positive correlation.

5. Internet Use, Trade Openness, and Economic Development; analyzes the impact of internet use, financial sector development, and trade openness on South Africa's economic growth using a time series approach.
6. Technology Adoption and Growth in Sub-Saharan Africa: focuses on the adoption of new technologies in Sub-Saharan African countries, highlighting the importance of technology access to drive innovation and sustainable economic growth.

The focus of the research theme in Asia is directed at five (5) things that simultaneously reflect the significant contribution of researchers in maximizing the role of internet penetration for the economy, especially in Southeast Asia and Indonesia, China, and India. The five themes are (Wahab *et al.*, 2020; Li *et al.*, 2020; Imansyah, 2018; Vu, 2017; and Kumar *et al.*, 2016):

1. Internet Use and the Economy; uses panel data analysis to evaluate the relationship between the number of internet users and economic growth in Southeast Asian countries. The results show a significant positive effect of digital technology adoption on the regional economy;
2. Internet, Population Scale, and Economic Growth in China; explains how widespread internet access in China's major cities, in the context of a large population, contributes to the country's rapid economic growth.
3. The Impact of Internet Penetration on the Indonesian Economy; focuses on how internet penetration affects Indonesia's economic growth, with an emphasis on the role of the internet in supporting the productive sector and inclusiveness of development.
4. ICT Diffusion and Production in ASEAN; discusses the diffusion patterns of information and communication technologies (ICT) in ASEAN countries, assesses the resulting economic performance, and provides policy guidance to enhance regional competitiveness.
5. The Impact of ICT on Output per Worker; evaluates the impact of information and communication technologies on labor productivity in China, showing that investment in technology has contributed significantly to labor efficiency.

The focus of the researcher's discussion for the comparative study case between regions on five (five) points as reported by Edquist *et al.* (2018); Bahar (2018); Latif *et al.* (2018); Maurseth (2018); and Ghosh (2017). The friends in question are:

1. Pentingnya Jaringan Pita Lebar Seluler untuk Pembangunan Ekonomi Global; menyoroti peran jaringan pita lebar seluler sebagai infrastruktur penting yang mendukung pembangunan ekonomi global, terutama di era digital. Penelitian menekankan kontribusi

signifikan teknologi ini terhadap produktivitas ekonomi lintas kawasan.

2. Difusi TIK, R&D, dan Pertumbuhan Ekonomi; menggunakan pendekatan data panel dinamis untuk mengevaluasi pengaruh difusi teknologi informasi dan komunikasi (TIK) serta intensitas penelitian dan pengembangan (R&D) terhadap pertumbuhan ekonomi di berbagai negara. Penelitian ini menemukan korelasi positif yang signifikan antara investasi dalam TIK dan R&D dengan peningkatan produktivitas ekonomi.
3. Dinamika TIK, Investasi Asing Langsung, Globalisasi, dan Pertumbuhan Ekonomi; menganalisis hubungan antara difusi TIK, arus investasi asing langsung (FDI), dan globalisasi terhadap pertumbuhan ekonomi global. Hasilnya menunjukkan bahwa interaksi antara teknologi dan FDI mempercepat integrasi ekonomi global.
4. Dampak Internet terhadap Pertumbuhan Ekonomi - Studi Lintas Negara; membahas bukti empiris dari berbagai negara tentang pengaruh internet terhadap pertumbuhan ekonomi. Hasil penelitian menunjukkan dampak yang bervariasi tergantung pada tingkat pembangunan ekonomi dan adopsi teknologi di setiap negara.
5. Broadband Penetration and Its Role in Economic Policy: This research examines the link between broadband penetration and economic growth, with a focus on the role of government policies in fostering technology adoption. It highlights the importance of having a supportive regulatory environment to ensure accessibility to technology and drive sustainable economic development.

The keywords that are the focus of research in each region are shown in Figure 6 below,

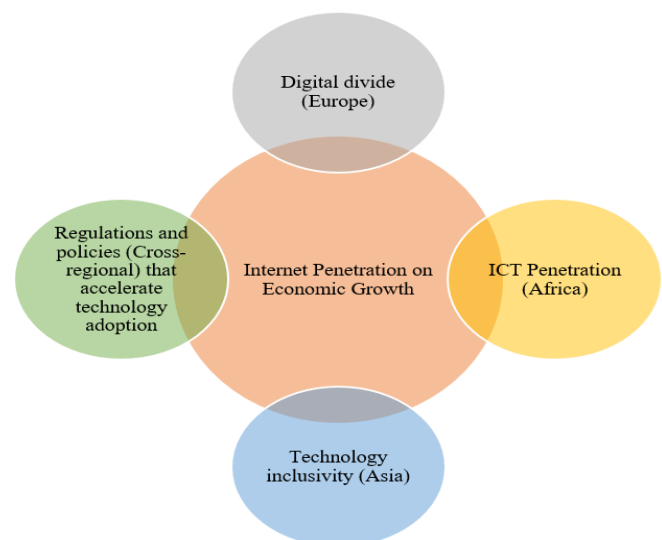


Figure 6. Key Focus of internet penetration on economic growth.



Table 4. Distribution of scientific articles on internet penetration and human development.

| Region/Area | Year | | | | | | | | | | Number | |
|----------------------------|------|------|------|------|------|------|------|------|------|------|--------|------|
| | 2025 | 2024 | 2023 | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | | 2015 |
| Europe | 1 | | 1 | | | | | | | | | 2 |
| Africa | | | 1 | | | | | 1 | | 1 | | 3 |
| Asia | | | | | | | 2 | | | | | 2 |
| Comparison between regions | | 1 | 1 | 2 | 1 | | 1 | | 1 | | | 7 |
| Total | 1 | 1 | 3 | 2 | 1 | | 3 | 1 | 1 | 1 | | 14 |

Source: [Laitsou et al. \(2025\)](#); [Bala \(2024\)](#); [Nguea \(2023\)](#); [Bayar et al. \(2023\)](#); [Nipo et al. \(2023\)](#); [Ježić et al. \(2022\)](#); [Zelenkov and Lashkevich \(2022\)](#); [Aksentijević et al. \(2021\)](#); [Hoz-Rosales et al. \(2019\)](#); [Iqbal et al. \(2019\)](#); [Gupta et al. \(2019\)](#); [Asongu and Nwachukw \(2018\)](#); [Lee et al. \(2017\)](#); [Asongu and Nwachukw \(2016\)](#)

Internet penetration on human development: As the results of the analysis, articles discussing "internet penetration on economic growth" were 14 articles. The distribution data during the observation period is shown in Table 4. Research discussing this topic was not carried out so intensively, for example in Europe only in 2025 and 2023. Overall, the published articles showed a fluctuating pattern, with the highest peak in 2019 and 2023.

Of the total articles published, comparative studies between regions are the highest. As seen in Figure 7, half of the total journals (7 or 50%) articles are comparative studies, followed by Africa with 3 or 21.43% and Europe and Asia with 14.29% each.

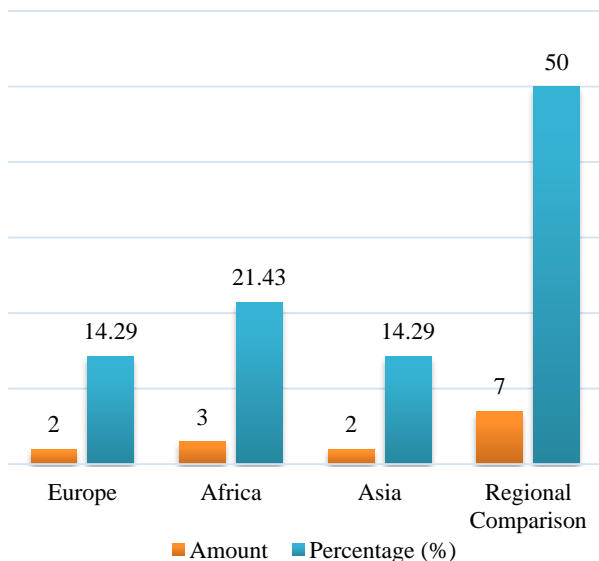


Figure 7. Number of articles by region.

Researchers across different regions have discussed several key issues regarding human development and ICT. In Europe, especially within the European Union, studies have highlighted a positive relationship between digitalization and human well-being. These studies show that the integration of human capital and technology plays a crucial role in impacting the Human Development Index (HDI).

Additionally, ICT penetration has been identified as having a beneficial effect on human development, particularly in the transition economies within the EU. In Africa, research indicates that ICT significantly contributes to human development, with a focus on advancements in education and healthcare in developing nations. Furthermore, factors such as the quality of education and mobile phone accessibility in Sub-Saharan Africa have been recognized as key elements driving inclusive development across the region.

Researchers in Asia agree that ICT contributes significantly to human development, especially in South and Southeast Asia (ASEAN). Specifically, in Asia-Pacific, it is asserted that ICT, electricity access, and governance affect human development, with varying impacts across countries' income levels.

Finally, several regions of the world (comparative studies) led researchers to deepen the role of mobile broadband projects in supporting human development in developing countries, while internet bandwidth is more influential in developed countries. The second issue raised is that ICTs make a positive contribution to human development in developing countries, especially at the individual level. Third, ICTs have a significant impact in low-middle income countries, with a small impact in high-income countries. Fourth, the use of ICTs by individuals, businesses, and governments contributes to human development. Fifth, the spread of ICTs plays a significant role in human progress globally, with impacts varying by type of technology and country income.

DISCUSSION

Internet penetration on agricultural sector development:

Internet penetration and the use of Information and Communication Technology (ICT) in the agricultural sector have been shown to have a significant impact on the Human Development Index (HDI), especially in developing countries. Digitalization not only accelerates innovation in precision agriculture, but also plays a significant role in increasing productivity, efficiency, and environmental sustainability.

According to [Nham et al. \(2024\)](#), advances in environmental monitoring technology and precision agriculture have



contributed to an increase in total factor productivity (TFP) in the agricultural sector. The use of digital tools and data analysis allows farmers to maximize agricultural efficiency and yields, while maintaining environmental sustainability. Digitalization in the agricultural sector shows that continued investment in digital infrastructure is essential to drive growth and innovation in this sector.

[Sukma et al. \(2024\)](#) reported that self-employed farmers who used the internet experienced a 29.6% increase in agricultural income compared to farmers who did not use the internet. The use of the internet had varying impacts depending on the agricultural subsector, with the largest increases seen in the livestock and food crops subsectors. The study also highlighted the challenges of limited internet infrastructure in eastern Indonesia, which if addressed, could improve farmers' access to technology and information that could potentially increase their incomes.

The importance of mobile and web-based applications, such as Esoko, iCow, WeFarm, and DigiFarm, has also been seen in many developing countries as a tool for disseminating agricultural information. While these applications can expand access to information and services for farmers, [Mapiye et al. \(2023\)](#) noted that there is still a lack of comprehensive reviews of these applications, despite their great potential for improving the productivity and welfare of farmers, especially smallholder farmers.

[Zheng et al. \(2022\)](#) confirmed that internet use had a significant positive impact on crop yields, with corn yields increasing by 14.25% for farmers who accessed the internet. This impact was greater for young farmers, those with low levels of education, and those living in developing rural areas. These findings suggest that the internet can accelerate the adoption of agricultural technologies, which in turn improves farmer productivity and welfare.

[Rehman et al. \(2022\)](#) stated that the Internet of Things (IoT) has become an integral part of smart farming, providing significant benefits in crop management, irrigation, disease detection, and overall farm management. IoT technology allows farmers to control agricultural activities remotely, saving time, and increasing yields. The use of sensors to monitor soil and crop conditions has been shown to reduce resource use and increase efficiency, ultimately contributing to environmental sustainability. IoT technology is also used in agricultural monitoring systems such as AGRO-TECH and SmartFarmNet, which enable farmers to manage their farms automatically by providing personalized recommendations based on the data collected ([Pandithurai et al., 2017](#); [Jayaraman et al., 2016](#)). Thus, IoT plays a significant role in reducing manual efforts, saving time, and increasing agricultural yields, which in turn improves the Human Development Index.

However, [Kiambi \(2018\)](#) noted challenges in accessing Information and Communication Technology (ICT) in rural areas, where many farmers still struggle to utilize this

technology. Therefore, it is important for governments and policymakers to develop policies that support the development of ICT infrastructure in rural areas and the integration of agricultural technologies, in order to improve productivity and human development.

The use of the internet, fixed broadband subscription access, and secure internet servers have been shown to have a significant positive impact on the performance of the agricultural sector, especially in developing countries. In Africa, Asia, and Oceania, the internet plays a major role in increasing agricultural productivity ([Suroso et al., 2022](#)), which shows that the role of the internet is more important in developing countries, contributing to increasing farmers' income and welfare.

Internet penetration on economic growth: Internet penetration on economic growth shows mixed results, depending on the region and its characteristics. [De-Clercq et al. \(2023\)](#) found that the expansion of low-speed broadband access has a significant effect on economic growth per capita, both in urban and rural areas. However, the impact is weaker in rural areas that face more infrastructure-related challenges. In contrast, high-speed broadband only shows a significant relationship with economic growth in rural areas, with no significant impact in urban areas. This study confirms the importance of fast internet access as an economic driver, especially in areas that were previously digitally isolated. However, the expansion of connectivity in rural areas with high technology has not been fully profitable in terms of costs, although there is an increase in returns to scale as coverage increases.

Further research shows that increasing internet penetration through broadband projects can have a significant impact on GDP per capita. For example, a 10 percent increase in broadband access can increase GDP per capita by USD 13,036, or around USD 1,000 per person, reflecting the great potential of digital infrastructure investment for the economy ([Minges, 2015](#)).

In developing countries, such as Somalia, research by [Mohamed and Nageye \(2022\)](#) shows that internet usage has a significant positive contribution to economic growth. This study highlights the importance of consumption and international trade driven by internet access, which accelerates the country's economic growth. The internet, in this case, serves as an important channel to access global markets.

In Southeast Asia, [Wahab et al. \(2020\)](#) found that increasing internet usage has a significant positive impact on economic growth, with countries in the region benefiting from internet penetration in increasing their economic competitiveness. In China, [Li et al. \(2020\)](#) noted that widespread internet usage in large cities plays a major role in driving economic growth, especially due to the need for connectivity to support various industrial sectors.



Research in Russia also shows that broadband internet development in the region has a positive elasticity to gross regional product (GDP), meaning that the more developed the digital infrastructure, the higher its contribution to economic growth (Imasheva and Kramin, 2020).

Furthermore, there is a two-way causality between information and communication technology (ICT) and economic growth. Bahar (2018) shows that ICT diffusion contributes to an increase in the share of R&D personnel in total employment, although it does not directly affect the income allocated to R&D. This finding suggests that countries with advanced economies, such as those in the OECD, need to strengthen ICT development not only to drive economic growth but also to support the growth of the R&D sector.

In Indonesia, research by Imansyah (2018) shows that internet penetration has not had a significant impact on the economy as a whole, given its distribution is still limited to certain regions, especially in Java Island, with Jakarta as its center. However, a government project that aims to connect 57 cities in Indonesia by the end of 2018 is expected to encourage equal access to the internet, which in turn will increase the positive impact on the Indonesian economy.

Overall, internet penetration has a significant impact on economic growth, although the impact varies depending on the level of access, speed, and spread of technology in different regions. Developing countries can experience great benefits, especially in connecting rural areas with digital infrastructure, while developed countries can leverage ICT to improve their global economic competitiveness.

Internet penetration on human development: Internet penetration and Information and Communication Technology (ICT) have a significant relationship with the Human Development Index (HDI), which includes dimensions of health, education, and income. Empirical evidence is obtained that there is a positive and significant relationship between the Digital Economy and Society Index and HDI (Laitsou *et al.*, 2025; Aksentijević *et al.*, 2021). This shows that the more digital access develops, the better human development will be, especially in improving people's quality of life through access to information and economic opportunities. Human capital and Digital Technology Integration (IDT) also play an important role in improving HDI, with significant contributions to overall community welfare. Furthermore, the classification of countries based on HDI and DESI shows a strong interaction between these indicators, illustrating the reciprocal influence between the level of technological development and human development. Countries with high HDI levels tend to have better internet and information technology access, which in turn improves human development indicators, such as education and health.

Researchers propose various policies and strategies aimed at harnessing the opportunities of digitalization to support human development. According to Bala (2024), this includes wider adoption of technology, improved digital infrastructure,

and more equitable access to technology across regions. These policies can make a significant contribution to the overall well-being of society, by leveraging ICT as a tool for economic development and improving the quality of life.

Bala (2024);Nguea (2023) continued, the impact of ICT on human development is highly dependent on the country's development stage and the telecommunications services available. In developing countries, especially in Africa and Asia, mobile broadband plays a major role in driving human development, with a focus on improving health and education. In contrast, in developed countries, increasing internet bandwidth contributes more to people's incomes, along with more evenly distributed technological advances across sectors.

Conversion factors (CF) that measure the impact of ICT on human development show different results between developing and developed countries. In developing countries, ICT contributes more to individual-level HDI, especially in improving quality of life, access to health, and education. Meanwhile, in developed countries, the impact (Zelenkov and Lashkevich, 2022). ICT focuses more on social conversion, such as strengthening the social sector, better public policies, and increasing economic productivity. The spread of ICT is a determinant of human progress at the global level, with impacts varying depending on the type of technology and the income level of the country. Low- to middle-income countries tend to feel a more significant impact from ICT adoption in improving health, education, and income indices. Conversely, high-income countries tend to see a smaller impact on human development indicators, because ICT infrastructure and education are more developed.

Finally, this study provides useful insights for policymakers to pay more attention to aspects of trade openness, financial development, energy consumption, and democracy, if ICT is used as a tool to promote more inclusive human development. The role of strong internet and ICT penetration in explaining the improvement of human development, then developing countries get more direct benefits in health and education aspects, while developed countries feel more impacts on income and economic productivity. Therefore, policies that support more equitable internet access and ICT development can improve the quality of life and social equality, promoting more inclusive and sustainable economic growth.

Conclusion: Over the past decade, the topic of internet penetration in agriculture, economic growth, and human development has received increasing academic attention. Research conducted in global regions, especially Asia and Africa, shows that ICT plays a significant role in driving development in these sectors, although challenges and fluctuations in research interest need to be considered.

Internet penetration on economic growth in four regions (Europe, Africa, and Asia) and across regions shows that digital technologies, especially internet access and ICT, have



a significant impact on economic growth. The focus of research in each region highlights unique contexts and challenges, such as the digital divide in Europe, ICT penetration in Africa, technology inclusiveness in Asia, and cross-regional regulations and policies that accelerate technology adoption.

Internet and ICT penetration play a key role in human development across regions, with a more significant impact in developing and low-middle income countries, and are influenced by factors such as internet access, education quality, and governance.

Overall, internet penetration and ICT use in the agricultural sector have been shown to increase productivity, farmer incomes, and community welfare, which directly contribute to the improvement of the Human Development Index (HDI) and economic growth. IoT and web-based applications have great potential in supporting smart agriculture and environmental sustainability. However, to maximize this potential, policies are needed that support more equitable internet access, infrastructure development, and a technology-based approach that prioritizes public-private sector collaboration.

Theoretical Implications: The findings show that internet penetration and use of Information and Communication Technologies (ICT) have significant impacts on economic growth, human development, and the agricultural sector. The findings emphasize that high-speed internet access in rural areas can accelerate economic growth and improve human development, especially through improvements in education, health, and income. In developing countries, internet penetration increases agricultural productivity, while in developed countries, the impact is more pronounced in increasing R&D and economic productivity.

The study also reveals that ICT can be a major driver in the agricultural sector, as evidenced by smart farming applications and Internet of Things (IoT) technologies that improve efficiency and sustainability. However, there are challenges in terms of technology access in rural areas that require policies to improve infrastructure and equitable digital access.

Practical Implications (Policy): Overall, these findings suggest that policies that support ICT development and wider internet access can support human development and economic growth, with a focus on inclusiveness and equity of technology across regions, especially in developing countries.

Research Limitations: It is recognized that, with the literature study approach, it certainly has limitations. In terms of context, this study only summarizes findings from previous studies without adjusting to the specific characteristics of a region or sector, so the results may be less relevant to certain contexts. The next limitation is that this study does not

involve primary data or direct experiments to test or validate the findings from the referred literature. Another limitation is that this study tends to focus on general trends without investigating deeper causal relationships or specific factors that influence the success of ICT implementation, and its findings are too generalizing the impact of internet and ICT penetration, without exploring in detail the differences between countries or regions with varying levels of development.

Suggestions: Based on the identified limitations, the study offers the following recommendations: a) Future research could gather primary data from specific regions or sectors to assess the direct impact of ICT on economic, human, and agricultural development; b) Further studies should investigate the impact of internet penetration in rural areas or developing countries, addressing unique challenges such as limited infrastructure; c) Longitudinal research is needed to understand how internet and ICT penetration influence economic growth, human development, and the agricultural sector over time; d) A comprehensive approach should be adopted by integrating technological, economic, and social perspectives to evaluate the overall effects of internet penetration, including its impact on social and gender inequalities; and e) Comparative studies between developed and developing countries could help identify variations in the effectiveness of internet penetration across different sectors.

Author Contributions: All authors contributed together from the start of the research to the presentation of the publication manuscript. Author Muh. Ilham as the main contributor, was fully involved in all research processes until the publication of the journal. Authors Muh. Natsir, Gamsir, Lapipi, Takdir Saili, Muh. Yani Balaka, Rostin, Manat Rahim, Zainuddin Saenong, Saemu Alwi, and Ambo Wonua Nusantara contributed in the conceptual, checking the validity of the data, interpretation of the analysis results to, assessment of the feasibility of the research results to be published in a reputable journal.

Conflict of interest: The contents of this manuscript are free from conflicts of interest, both among fellow authors and with external parties. All authors have read and approved the entire contents of the manuscript.

Acknowledgements: The research was purely on the author's initiative so it did not involve other parties (respondents and informants). Thus, no special recognition was given.

Funding: This research is not related to sponsors as research funders.

Ethical statement: The content of the manuscript is free from potential ethical violations, such as plagiarism and data manipulation.



Availability of data and material: Data is openly available in repositories so that it can be read by all parties

Consent to participate: The author has approved the contents of the manuscript for publication as stated in the author's statement.

Consent for publication: The author has approved the contents of the manuscript for publication as stated in the author's statement.

SDGs addressed: Decent Work and Economic Growth, Industry, Innovation and Infrastructure, Reduced Inequality, and Partnership for the Goals.

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