

# Cultivating Change: Computational Strategies for Enhancing Adoption of Agricultural Technology in Developing Countries: A Review

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## Abstract

Governments and development organizations have largely embraced agricultural technologies as efficacious strategies to enhance farm output and reduce poverty. Nevertheless, the implementation of these seemingly beneficial technologies continues to be constrained. This research investigates the fundamental determinants that consistently impact the acceptance and utilization of technology in many settings. It is based on an extensive meta-analysis of 367 regression models extracted from scholarly publications. The findings of our research indicate that there is a positive correlation between the adoption of varied agricultural technology and several parameters, including farmer education, household size, landholding size, access to credit, land tenure, availability of extension services, and participation in agricultural organizations. It is worth noting that technologies categorized as enhanced varieties and chemical inputs exhibit a higher likelihood of adoption on larger farms, which raises inquiries regarding their scalability. The significance of agricultural finance is apparent; nonetheless, it is imperative to evaluate the extent to which farmers face credit constraints, rather than only gauging their access to credit. Furthermore, it is worth noting that while extension services may serve as a substitute for formal education when it comes to better varieties, they are more likely to be complementary in the context of natural resource management methods. The issue of land tenure assumes a prominent role in shaping the adoption and implementation of erosion control strategies, especially for technologies that need extensive planning and long-term commitment. However, it is imperative to acknowledge that the factors influencing adoption display significant diversity depending on the technology, cultural setting, and geographical location. Therefore, this study provides mechanism for adoption of agricultural technologies in research and policymakers, highlighting the importance of customizing agricultural technology promotion initiatives to suit specific agricultural and cultural circumstances. Our results not only underscore the importance of tailoring agricultural technology promotion methods to the unique agricultural and cultural conditions of each area but also provide valuable insights for policymakers and adoption researchers.

## Keywords

Agricultural technologies, Adoption, Meta-analysis, Smallholder farms, Technology adoption

## Introduction

The creation and adoption of cutting-edge agricultural technologies have a huge potential to increase production on most small farms, especially in low- and middle-income nations. The world community has acknowledged that agriculture plays a crucial part in achieving several sustainable development objectives, such as eradicating hunger, reducing poverty, and maintaining the environment. The

development of technology aiming at boosting yields, enhancing crop resilience, lowering labor requirements, and encouraging sustainable agricultural practices has received significant funding. Efforts in agricultural research and development have generally been found to be effective, but it's important to realize that the results of these efforts depend on the widespread adoption of new technology. But ever since Ryan and Gross' pioneering 1943 study, which looked at the uneven uptake of hybrid maize in Iowa, experts have worked to understand the many aspects affecting the acceptability of agricultural innovations [1]. By contrasting "adopters" and "non-adopters" within farming communities, adoption studies have been a crucial tool in attempting to understand the motives and restrictions surrounding technology adoption. Despite the abundance of studies on adoption, prior attempts to synthesize results have been constrained in scope, frequently using small sample sizes, and lacking rigorous quantitative meta-analysis in developing world contexts. This research fills up these gaps by doing a thorough meta-analysis of numerous studies on the adoption of agricultural technologies that consider the developing countries [2]. We determine effect sizes for 15 important variables using meta-regression analysis, giving insight on the elements that consistently influence technology adoption. Our findings not only highlight the necessity of adjusting agricultural technology promotion techniques to the distinctive agricultural and cultural contexts of each region but also offer insightful information for policymakers and adoption researchers. Figure 1 shows the overall research structure [3].

The major contribution of this manuscript is summarized as follows: (i) We proposed the extensive meta-analysis of regression models on various technologies that are correlated with adoption of agriculture parameters, (ii) We presented the layouts and all factors of analysis that are impacting the agriculture, and (iii) We analyzed the soil fertility concerns and various impacts on the technology in field of agriculture. The identification of adoption barriers, the function of data-driven decision support, the potential of artificial intelligence and predictive modelling, customization to local contexts, stake-

holder collaboration, and the importance of accessibility and affordability in technology design are some of the main goals of this paper that aim to facilitate the adoption of new technologies, some of them are:

### Identification of adoption barriers

Our analysis reveals that there are a variety of complex adoption barriers in developing nations, including risk aversion, a lack of knowledge, and restricted access to resources. To encourage the adoption of technology, these hurdles must be identified and addressed.

### Data-driven decision support

The review emphasizes how crucial real-time information and data analytics are to enabling farmers to make well-informed decisions, allocate resources optimally, and increase production.

### Accessibility and affordability

One of the most important things in encouraging the broad and long-lasting adoption of technology is making sure that it is affordable, accessible, and easy to use.

## Literature Survey

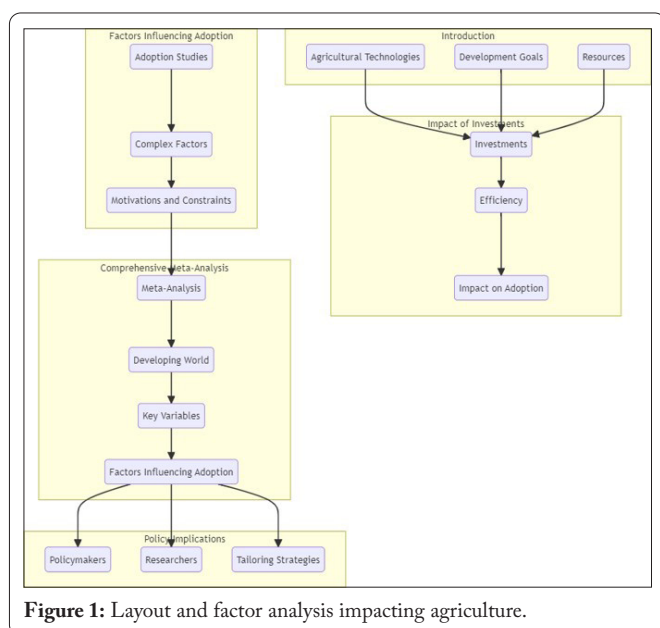
In the field of agricultural research and development, the adoption of agricultural technologies has long been a topic of interest [4]. This review of the literature examines many facets of technology adoption in agriculture and draws conclusions from a variety of research, including those listed in the abstract. For improving farm output, decreasing poverty, and reaching sustainable development goals, agricultural technologies must be adopted. This study will examine the major conclusions and developments in the literature on technology adoption in agriculture, as depicted in figure 2. Figure 2 shows how technology is used to identify soil fertility.

Research and development activities around the world have been primarily focused on the implementation of agricultural technologies. Agricultural technologies have the potential to boost productivity, strengthen resilience to environmental threats, cut labor costs, and advance long-term sustainability [5]. As stated in the abstract, large resources have been devoted to the creation of such technologies, with significant amounts of funding for agricultural research and development worldwide.

Improved agricultural technology adoption was influenced by many factors. Social, economic, institutional, and technological factors are the most cited factors which influence the adoption of improved agricultural technology. Figure 3 shows the theoretical framework.

## Adoption Studies: Understanding the Motivation

Effective technology transmission depends on knowing why some farmers use agricultural innovations while others do not. The goal of adoption studies is to pinpoint the driving forces and restrictions that shape farmers' choices. These studies have been carried out in numerous settings, and the results



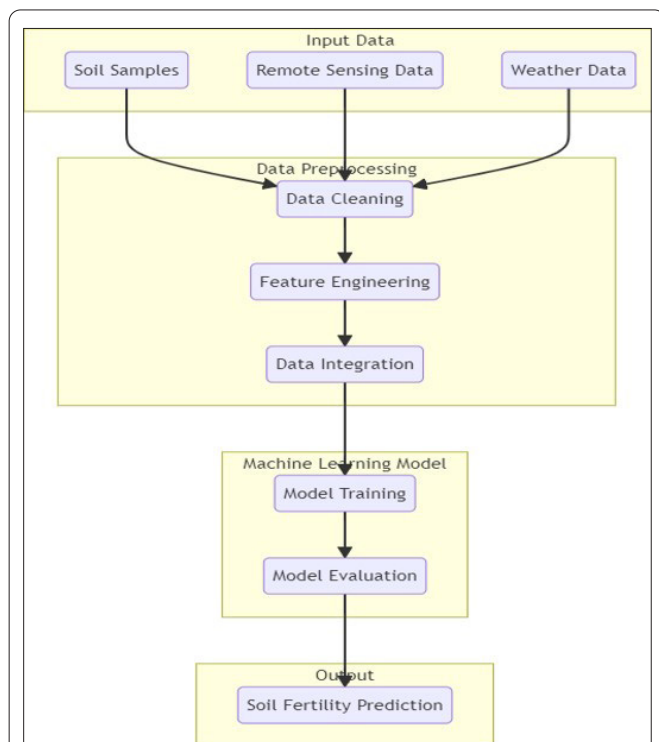


Figure 2: Soil fertility in concern to impact of technology on agricultural.

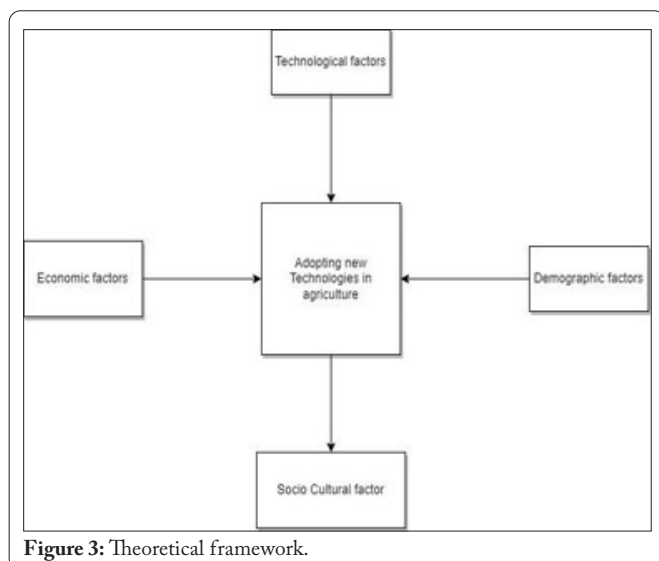


Figure 3: Theoretical framework.

offer insightful information about the dynamics of technology adoption [6]. Factors influencing adoption are stated below.

The abstract outlines several elements that have often shown up as influences on the adoption of technology. These variables include the level of farmer education, household size, size of landholdings, availability of financing, tenure of the land, availability of extension services, and participation in agricultural organizations. Each of these elements contributes in a different way to the adoption landscape [7].

### Farmer education

The introduction of technology has consistently shown a strong beneficial association with education. Farmers who have had formal education are typically more open to novel concepts and better able to comprehend the possible advantages of implementing cutting-edge techniques [8].

### Household size

The size of the household can influence adoption choices. Greater labor availability for implementing new technology may make larger households more receptive to alterations in farming methods.

### Land size

A farmer's landholding size has an impact on which technologies are adopted. For instance, the abstract mentions that larger farms are more likely to embrace superior varieties and chemical inputs, implying scalability concerns for these technologies [9].

### Access to credit

Credit for agriculture has a big impact on adoption. However, it is crucial to distinguish between credit availability and credit limitations because the latter is a better indicator of adoption.

### Land tenure

Different types of land tenure can promote or prevent the adoption of new technologies. Farmers may feel more confident investing in long-term, resource-intensive technologies if they have secure land tenure [10]. Accessibility to extension services can close knowledge gaps and speed up acceptance. It's interesting to note that depending on the technology under consideration, the relationship between education and extension services can change. Membership in agricultural organizations can give farmers access to knowledge and group support, which has a favorable impact on adoption rates [11].

## Technology Categories and Adoption Patterns

The categorization of agricultural technologies into improved varieties and chemical inputs is mentioned in the abstract. Designing targeted interventions requires a thorough understanding of how various technologies are adopted.

### Improved varieties

According to the abstract, larger farms adopt improved varieties more quickly. This finding calls into question the ability to scale such technologies and the demand for specialized methods [12].

### Chemical components

The adoption of chemical inputs appears to be influenced by farm size, much like improved varieties are. This emphasizes how crucial it is to take farm-specific characteristics into account when promoting these technologies [13].

### Adoption of technology in different environments

The acknowledgement that adoption determinants differ greatly depending on technology, cultural context, and geography is a key takeaway from the abstract. This emphasizes the requirement for technology promotion strategies that are context-specific [14]. In conclusion, the adoption of technology in agriculture is a complex phenomenon that is influenced by many different variables. The abstract highlights the need for context-specific approaches and offers insightful information

on the major adoption factors. It emphasizes how crucial it is to take farm-specific traits, technology types, and regional contexts into account when developing strategies to promote agricultural technologies. In the end, achieving sustainable agricultural development and addressing global challenges related to food security and poverty reduction depend on understanding and promoting technology adoption [15]. The comparative analysis of the literature is given in [table 1](#).

## Problem Definition

The issue at hand concerns the successful adoption of cutting-edge agricultural technologies in low- and middle-income nations. Although there have been significant investments made in agricultural research and development, it is still difficult to get these technologies adopted widely. Although this issue is complex, it can be divided into the following major parts:

### Low adoption rates

Small-scale farmers in developing nations are not adopting innovative agricultural technologies like better crop varieties and sustainable farming practices at the desired rate. This results in lost chances to boost agricultural productivity [25].

### Hunger and poverty

Agriculture is a key sector for achieving sustainable development goals related to reducing poverty and eradicating hunger. In these areas, the issue of low technological adoption contributes to enduring poverty and food insecurity.

### Resource allocation

Considerable resources are devoted to the creation of agricultural technologies, and it is crucial to make sure that these expenditures result in noticeable effects by gaining widespread acceptance.

### Factors of complexity

A variety of complex interrelated factors, such as economic, social, cultural, and environmental variables, play a role in the adoption of agricultural innovations. It's essential to comprehend these elements when developing successful adoption

strategies. Even though adoption studies already exist, there is a need to thoroughly synthesize results, particularly in the context of the developing world. Previous efforts frequently had a narrow focus or lacked formal quantitative analysis [16].

### Contextual adaptation

To promote the adoption of new technologies, strategies must be modified to consider the distinctive agricultural and cultural contexts of each region. An all-encompassing strategy is insufficient. The problem definition emphasizes the difficulty in encouraging the use of agricultural technology as a means of achieving sustainable development objectives. It emphasizes the necessity of a thorough comprehension of the elements influencing adoption and the customization of strategies to contexts. For low- and middle-income countries to increase agricultural productivity, reduce poverty, and guarantee food security, this issue must be resolved [26].

## Recommendations

A multifaceted strategy involving policymakers, researchers, and development organizations is needed to address the issue of the low adoption of innovative agricultural technologies in low- and middle-income countries. Here are some important suggestions based on the problem definition:

### Context-sensitive tactics

Recognize that factors affecting adoption vary greatly depending on geography, culture, and technology [27, 13]. Develop agricultural technology promotion strategies that are specific to the regional requirements and difficulties. An all-encompassing strategy is unlikely to be successful. Spend money on research. Allocate funds to carry out thorough adoption studies that take a wide range of factors into account. Concentrate on comprehending the complicated factors that affect the uptake of technology in particular areas. Rigid research methods, such as quantitative meta-analysis, should be used in this study.

### Improve extension and education services

Promote access to extension services and farmer education. These services are essential in promoting the adoption

**Table 1:** Comparative analysis of literature survey.

Article title	Main focus
Machine learning approaches for soil aggregate stability [16]	Predicting soil aggregate stability using machine learning methods
Optimizing available phosphorus in calcareous soils [17]	Phosphorus retention and immobilization in calcareous soils
An AI solution for soil fertility and crop friendliness detection and monitoring [18]	Using AI and IoT for soil fertility and crop friendliness detection
IoT based soil nutrition and plant disease detection system for smart agriculture [19]	IoT-based system for soil nutrition and plant disease detection
Concurrent use of active and passive microwave remote sensing data for monitoring of rice crop [20]	Using microwave remote sensing for monitoring rice crop
Evolution of IoT and its significant impact in the field of precision agriculture [21]	The role of IoT in precision agriculture
Sensing, smart, and sustainable technologies for agri-food 4.0 [22]	Development of sensing, smart, and sustainable technologies for agri-food 4.0
The future of digital agriculture: Technologies and opportunities [23]	Technological advances in digital agriculture
Impact of agricultural innovation adoption: A meta-analysis [24]	Meta-analysis of the impact of agricultural innovation adoption

of agricultural technologies, particularly those connected to enhanced crop varieties and environmentally friendly farming methods [28]. The availability of agricultural credit should be ensured for farmers. It's not just a matter of whether credit is available; it's also a matter of whether farmers are credit constrained. Taking credit restrictions into account can help adoption.

### **Land tenure security**

Laws that guarantee stable land tenure can promote the use of natural resource management strategies. When it comes to the adoption of technologies with long planning horizons, land tenure plays a significant role [29]. Promoting a range of technologies understands the value of various agricultural technologies that go beyond high-yielding varieties. Promote the adoption of technologies that enhance resiliency, sustainability, and minimal environmental impact.

### **Inter-sector cooperation**

Encourage cooperation between development organizations, policymakers, and agricultural research institutions. Co-ordination of efforts can result in more successful technology adoption and dissemination [30].

### **Continual monitoring and evaluation**

Put in place procedures for evaluating adoption programs on a continuous basis. Assess the effects of interventions frequently to make sure they are having the desired effects. Promote the exchange of knowledge and best practices between nations and regions. Strategies for adoption that have been successful, and lessons learned in one setting may be useful in another.

### **Making decisions with inclusion**

Include farmers and local communities in the decision-making process for implementing new technology. Their opinions and suggestions can help with the creation of more efficient tactics [31].

### **Long-term perspective**

Be aware that the effects of adopting agricultural technology may not be felt right away and may call for a longer-term viewpoint. It frequently takes time for sustainable modifications to farming methods to take place [32].

### **Adaptive management**

Be receptive to new management strategies. To ensure that adoption strategies are as effective as possible, make necessary adjustments as new data and information become available.

### **Resource allocation**

Make sure that funds for agricultural research and development are effectively allocated to the techniques and ideas that have the best chances of becoming widely used and having beneficial effects.

These suggestions stress the significance of a nuanced and context-specific strategy for encouraging the adoption of agricultural technology. It is possible to increase agricultural productivity, lower poverty, and contribute to food security in

low- and middle-income countries by addressing the complex problems outlined in the problem definition and putting these recommendations into practice [33].

## **Conclusion**

To achieve sustainable development, low- and middle-income countries must adopt cutting-edge agricultural technologies that have the potential to increase productivity, combat poverty, and guarantee food security. However, achieving widespread adoption is a complex, multifaceted challenge. The issue of low technology adoption rates has been examined in this paper, along with suggestions for solutions. A one-size-fits-all strategy for promoting technology is insufficient. Technology, cultural setting, and geographic location all have a significant impact on adoption factors. As a result, specific strategies that consider regional conditions and constraints are crucial. To create and implement adoption programs that are tailored to specific contexts, policymakers, researchers, and development organizations must work together.

It is essential to invest in research that carefully considers the variables affecting technology adoption. To understand adoption more thoroughly, rigorous methodologies should be used, such as quantitative meta-analysis. Adoption is greatly facilitated by education, extension services, credit availability, and secure land tenure, all of which should be given priority in intervention strategies. To ensure sustainability, resilience, and environmental stewardship, a variety of agricultural technologies, beyond high-yielding varieties, should be promoted. Successful adoption programs must incorporate cross-sector cooperation, ongoing monitoring and evaluation, and inclusive decision-making procedures. It is crucial to understand that adopting agricultural technology may not have an immediate impact and that a long-term perspective is needed. It is important to adopt adaptive management strategies that enable strategy modification in response to new information and insights. In summary, overcoming the issue of the low adoption of novel agricultural technologies is essential for achieving sustainable development goals. We can unlock the potential of agricultural technologies to transform farming practices, lessen poverty, and guarantee food security in low- and middle-income countries by putting the suggestions made in this paper into practice and adopting a nuanced, context-specific approach. This project needs commitment, teamwork, and a dedication to the long-term health of farming communities and the world food system. Implementing the recommendations outlined in this paper and embracing a nuanced, situation-specific strategy. This undertaking requires dedication, collaboration, and a steadfast commitment to the sustained well-being of agricultural communities and the global food system.

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None.

## **Conflict of Interest**

None.

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