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# A systematic review of the efficacy of theories used to understand farmers' technology adoption behavior in lower-to-middle-income countries

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## ABSTRACT

A systematic review was conducted to identify the relevant theoretical approaches used to explain farmer technology adoption in low- and middle-income countries (LMICS), and their strengths and weaknesses. Scopus and Web of Science databases were searched. 77 articles were finally included. The analysis was based on the following categorization of the theoretical approaches applied: (1) Diffusion theories, (2) User acceptance theories, (3) Decision-making theories, (4) Personality theories, and (5) Organizational structure theories. The analysis indicated that diffusion theories predicted technology adoption but excluded social determinants. User acceptance theories predicted social determinants of adoption intention but not behaviors. Decision-making theories identified measurement variables related to different adoption behaviors, but did not consider influential psychological factors, (implying that only economic factors affected adoption behavior). Personality theories were sometimes complex, resulting in weak predictability of adoption and behaviors. Organizational structure theories emphasized social structure variables but included variables not relevant to the investigation of specific adoption practices. In conclusion, the predictive and explanatory capability of different theoretical approaches depended on the context of agricultural technology adoption.

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## KEYWORDS

Psychology; economics; theoretical approaches; agricultural technology; low-to-middle-income countries


## Introduction

Agriculture represents an important sector of the economies within low to middle-income countries (LMICS)<sup>1</sup> and contributes to employment and economic growth (Gross Domestic Product [GDP]) (Atangana 2022; Fadeyi, Ariyawardana, and Aziz 2022; Sertoglu, Ugural, and Bekun 2017). In sub-Saharan Africa, the agricultural sector employs about 65 percent of the working population and contributes about 29 percent to the GDP (Feder and Savastano 2017; Gollin 2014). Most agricultural production in LMICS is carried out by smallholder farmers (Gollin 2014), who rely on traditional farm tools (i.e. hoe, cutlass, etc.). In addition, these farmers may be threatened by adverse climatic conditions (Fadeyi, Ariyawardana, and Aziz 2022; Gollin 2014; Kalungu and Leal Filho 2018; Kamara et al. 2019). The aim of this systematic review is to evaluate the predictive and explanatory capability of different theoretical approaches that have been used to predict and

explain farmers' technology adoption behavior in LMICs. Understanding the factors which influence technology adoption behavior by smallholder farmers will contribute to our understanding of how technological innovations can be aligned with preferences, perceived needs, and priorities of farmers, and inform the design of interventions, aimed at facilitating and increasing technology adoption by farmers in LMIC countries. In addition, policy interventions can be developed based on this information which can help to accelerate technology adoption and potentially improve the sustainability of agricultural production practices.

Governments and stakeholders in agriculture have interests in transforming the agricultural sector to be more sustainable. One way of achieving this is through the introduction and implementation of efficient and sustainable production methods (Fadeyi, Ariyawardana, and Aziz 2022; Röttger 2015). For example, through promoting new or improved farming technologies within

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the smallholder farmer agricultural sector (Islam et al. 2018; Lowder, Skoet, and Raney 2016; Poole 2017; Salami, Kamara, and Brixiova 2016). Researchers and policymakers have identified the need to understand ‘how’ and ‘why’ farmers adopt or do not adopt new and potentially transformative agricultural technologies in LMICs.

Research into technology adoption in agriculture has received attention in the literature since the middle of the last century (see (Ryan and Gross 1943) and Griliches (1957)) (Kumar, Engle, and Tucker 2018; Ruzzante, Labarta, and Bilton 2021). Various theories have been developed and evaluated which aim to explain farmers’ adoption of existing and emerging agricultural technologies, including within LMICs (Kabwe, Bigsby, and Cullen 2009; Khandker and Gandhi 2012; Kuehne et al. 2017; Obiero et al. 2019).

Research in this area has used different disciplinary perspectives, in particular drawing on theoretical approaches developed within psychology, sociology and economics, to explain farmers’ adoption of agricultural technologies (Borges, Foletto, and Xavier 2015; Uaiene, Arndt, and Masters 2009). Theories have been developed from those which focus on the characteristics or attributes of the technology to be (adopted) or alternatively on the characteristics or attributes of the technology adopter (Dissanayake et al. 2022; Fadeyi, Ariyawardana, and Aziz 2022; Hillmer 2009; Melesse 2018). Hillmer (2009) and Fadeyi, Ariyawardana, and Aziz (2022) propose that technology adoption-related theories may be classified under five broad categories. These include (1) Diffusion theories, (2) User acceptance theories, (3) Decision-making theories, (4) Personality theories, and (5) Organizational structure theories. ‘Diffusion theories’ focus on how innovative technologies are transferred to different segments of potential adopters (i.e. innovators, early adopters, early majority, late majority, and laggards) via different diffusion mechanisms. ‘User acceptance theories’ predict, if, and how behavioral intentions influence a potential user to adopt innovative technologies. ‘Decision-making theories’ analyze the process an adopter of a new technology may undergo while considering a range of variables, including (perceived) risk, uncertainty, and profitability. ‘Personality theories’ aim to predict how personality characteristics of the adopter influence technology adoption. Finally, ‘Organizational structure theories’ assume that farm characteristics’ (i.e. farm size, farming system type, etc.) can explain a farmer’s adoption of innovative technologies.

Such theoretical approaches may contribute to policy development and implementation, as policies can build upon, and incorporate, information about the drivers of farmer adoption behavior in their design

(Despotović, Rodić, and Caracciolo 2019; Moerkerken et al. 2020).

The aim of this systematic review is to evaluate the various theoretical approaches that have been used in farmers’ adoption behavior in LMICs in relation to their predictive and explanatory capability.

## Our systematic review approach

A systematic literature review was conducted to assess the application of theoretical approaches used in relation to farmers’ adoption behavior towards agricultural technologies in the context of LMICs. Systematic literature reviews are useful for mapping current research and identifying gaps in knowledge that may be relevant for future research. In addition, systematic reviews can assess relevant information and data to answer research questions based on evidence derived from the systematic review while at the same time attempting to minimize biases in the selection of articles (Fadeyi, Ariyawardana, and Aziz 2022; Mallett et al. 2012; Van der Knaap et al. 2008). A systematic review is based on five steps, which include (1) identifying the review question, (2) searching for and identifying relevant research articles, (3) evaluating the identified articles for relevance to the research question, (4) evaluating data or relevant results, and (5) synthesizing and reporting the review findings (see, e.g. Briner and Rousseau (2011); Frewer et al. (2016)).

The systematic review relied on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al. 2009; Page et al. 2021). A set of inclusion and exclusion criteria was applied to select articles for inclusion in the review. The criteria applied were developed to ensure that articles that used theoretical approach to explain agricultural technology adoption by farmers were identified. A critical appraisal was conducted using an appraisal tool (Clark et al. 2016). The Grading of Recommendations Assessments, Development and Evaluation (GRADE) was used to assess the overall quality and strength of evidence in the research presented in the identified articles.

## Search methodology

The research question was: ‘What theoretical approaches have been employed to explain farmers’ adoption of agricultural technologies in LMICs?’. In contrast to advanced economies, or countries that have fewer smallholder farmers, the agricultural sector in LMICs is dominated by smallholder farmers who are characteristically constrained with access to farming resources (Aliber and Hall 2012; Sertoglu, Ugural, and Bekun 2017; Zerssa et al. 2021). Only articles reporting on primary research

involving smallholder farmers in LMIC countries were considered, for inclusion. Further, articles were included if they considered farmer adoption of existing and new agricultural technologies (e.g. mechanical tools, e-services, and improved crop varieties and practices). The review included technologies applied to crop-based agriculture but excluded those applied to livestock. This was because farmer decision-making associated with livestock production was potentially much broader in scope and could include aspects of the 'one-health agenda' regulatory enforcement and animal welfare issues rather than technology adoption *per se*.

Only research articles which explicitly stated using a theory or theories to explain farmers' adoption were included. Articles that reported econometric or statistical analytical models but did not address these in the context of a theoretical framework to explain farmers' technology adoption, were excluded. The timeframe of the search ranged from 1960 to 2022. This was because, smallholder farmers in LMICs were introduced to agricultural innovations from the 1960s onwards (e.g. improved crop varieties, fertilizers, and farm implements) (Eliazer Nelson, Ravichandran, and Antony 2019; Evenson and Gollin 2003; Khush 1999). The databases searched included Scopus and Web of Science. These databases contain abstracts and peer-reviewed articles relevant to the systematic review. In addition, these databases emphasize reporting of records from relevant disciplinary journals.

### Search

Specific search terms were used as part of the online search string to identify relevant articles for the review. A combination of the search terms applied included 'technol\*' and 'agric\*' and 'adopt\*'. Additional search terms were 'theor\*' or 'model\*' and 'farm\*' and 'energy\*'. Table 1 summarizes the search terms used and the returned search values. Only peer-reviewed journals were included in the search to ensure the quality of the articles. The results obtained from the search (i.e. article titles and abstracts) were exported into an Endnote library. The researchers conducted the online search between 29 June and 19 September 2022. A total of 36,542 articles were obtained following the initial search.

**Table 1.** Detailed online search string for words starting with the search terms.

Search string applied in the search	
Search term 1	technol* and
Search term 2	agric* and
Search term 3	adopt* and
Search term 4	theor* or model* and
Search term 5	farm* and
Search term 6	energy* or solar* or biomass*

### Inclusion and exclusion criteria

Inclusion and exclusion criteria were developed as part of the screening process. The inclusion criteria were as follows.

- Articles that demonstrated the use of a theoretical approach. It was noted that theoretical approaches may vary between disciplines.
- Articles that reported adopting or using an agricultural technology/ innovation/practice. This criterion included existing and new agricultural technologies.
- Articles focusing on crop-based agriculture were included.
- Articles published on research on agricultural technology adoption only in LMICS were included.

An initial search was conducted by RTK to identify articles. Following the removal of duplicates, an initial screening of titles for relevance to the research question was conducted. Subsequently, RTK and SN, independently evaluated the abstracts of the remaining articles using the inclusion and exclusion criteria to assess further whether the articles aligned with the research question. Abstracts which did not meet the inclusion criteria resulted in the exclusion of the research article. Where disagreement regarding inclusion and exclusion occurred, discussion between the researchers resulted in consensus in all cases. If abstracts were included in the review process at this stage, the full text of the article was downloaded for further assessment.

### Data extraction and synthesis

The articles extracted for review included those which applied quantitative, qualitative, and mixed methodologies. Different dependent variables and assessment methods (parametric, non-parametric and narrative synthesis) were used to explain determinants of technology adoption by farmers in LMICs. Therefore, a meta-analysis was not possible. The data extracted from the included articles were analyzed using a thematic framework. The framework captured the name of the theory, an overview of the theory, the location where data were collected, the advantages and disadvantages of the theory used, and full references of the articles. A summary of data extracted from the articles reviewed is included in ANNEX 1, supplementary files.

### Critical appraisal

The quality of the articles was assessed through the application of a critical appraisal. This was performed

to check for bias and validity. The critical appraisal approach developed by Clark et al. (2016) was adapted to be relevant to the research topic. This approach was relevant due to its applicability in the context of non-healthcare related research. The appraisal enabled evaluation of methodological and interpretive quality in relation to the research aims and design, recruitment of participants, data collection, data analysis, whether ethical approval had been obtained, and the extent to which the discussion of findings was a good interpretation of the results. A 5-point scale was used to measure the risk of bias under each quality criterion, anchored by 1 (very poor) to 5 (very good). Each criterion question for each article was scored from 1 (very poor) to 5 (very good) for each article included. As the different articles applied a variety of research methods, separate appraisal tools were used to assess quantitative and qualitative methodological approaches. Where mixed methods were applied, the assessment was based on each research method separately. A cumulative assessment of quality was made for each article. Subsequently, the Grading of Recommendations Assessments, Development and Evaluation (GRADE) was adapted to assess the overall quality and strength of evidence within each article. A rating structure was used based on four ranks: high, moderate, low, and very low (Guyatt et al. 2011).

Although many articles did not explicitly address ethical considerations (for example, whether an ethics committee had approved the research), this did not result in the exclusion of any article as the overall quality of evidence was satisfactory. A summary of the critical assessment and findings from the review are provided in ANNEX 2, supplementary files.

## Results

### *Characteristics of included articles*

Seventeen thousand, two hundred and eighty-one (17,281) articles were removed because of duplication. Sixteen thousand five hundred seventy-nine (16,579) articles were excluded after screening the articles' titles, where it was decided that the articles were not relevant to the research question. Two thousand four hundred sixty-four (2464) articles were retrieved for eligibility assessment. Three hundred fifty-three (353) articles were excluded as data reported were collected outside LMICs. One hundred thirty-two (132) articles were excluded due to the non-crop-based agricultural context of the research. One thousand six hundred thirty-four articles (1634) were excluded due to the unexplicit use of a theory. Two hundred sixty-eight (268) articles were

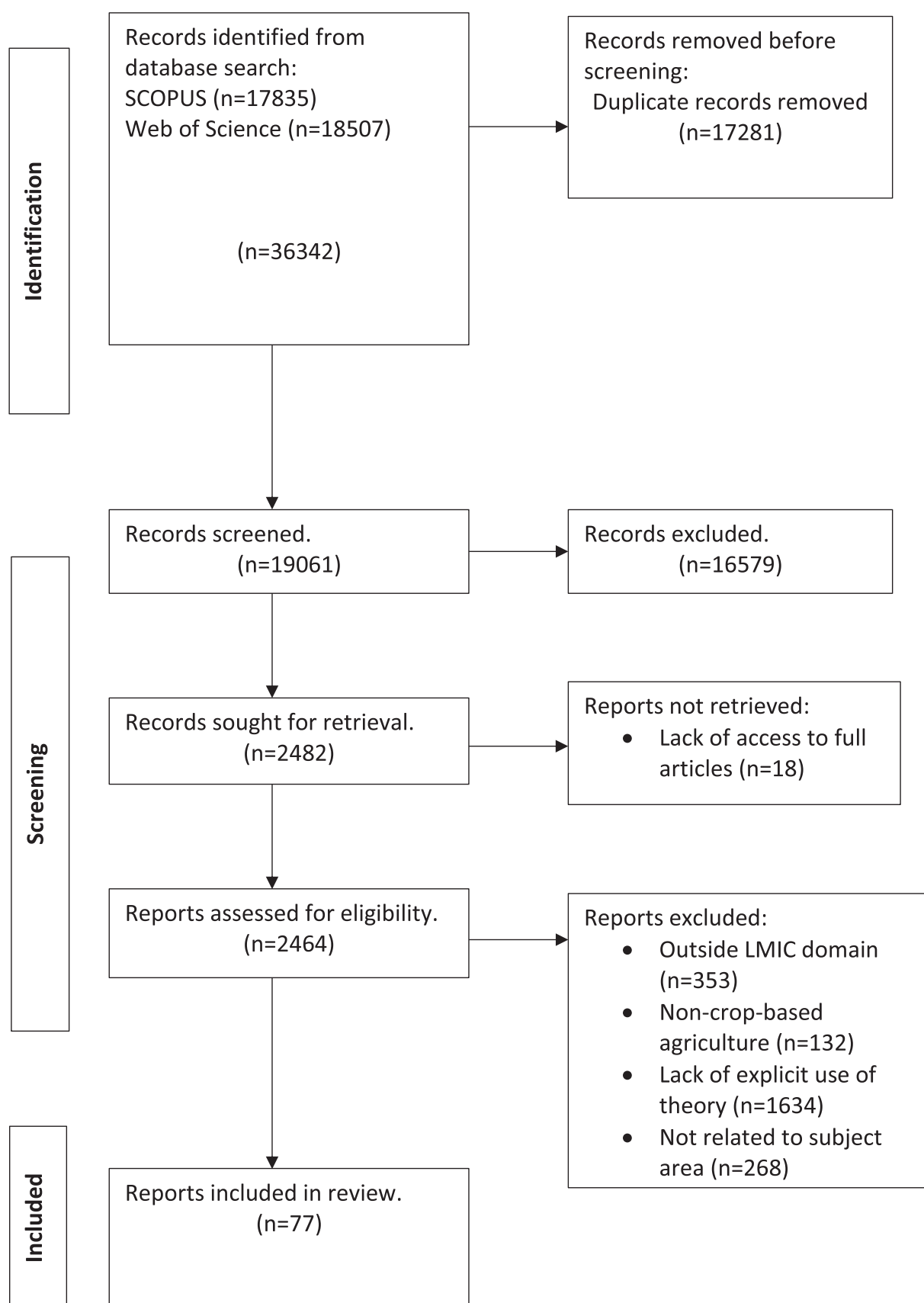
excluded for non-relevance to the research question. A total of 77 articles were selected for inclusion in the review. Figure 1 represents the PRISMA flow diagram depicting the articles' selection process.

The articles selected for inclusion in the systematic review ( $n=77$ ) had publication dates ranging from 2006 to 2022 when the search was discontinued. Most articles were published in 2022 ( $n=18$ ). The years 2006, 2007, 2009, 2012 and 2013 had the least publications ( $n=1$ ) (Figure 3). The articles were published in a broad range of journals. Heliyon ( $n=6$ ) and Water International ( $n=4$ ) were found to have published more than 1 article. Cogent Economics and Finance, Cogent Food and Agriculture, and the European Journal of Development Research each had publications. Most of the articles ( $n=62$ ) assessed farmer technology adoption in sub-Saharan Africa [Ethiopia ( $n=10$ ), Ghana ( $n=10$ ), and Kenya ( $n=8$ )]. Outside of sub-Saharan Africa, most articles assessed farmer technology adoption in Iran ( $n=9$ ) and Bangladesh ( $n=3$ ) (Figures 2 and 3).

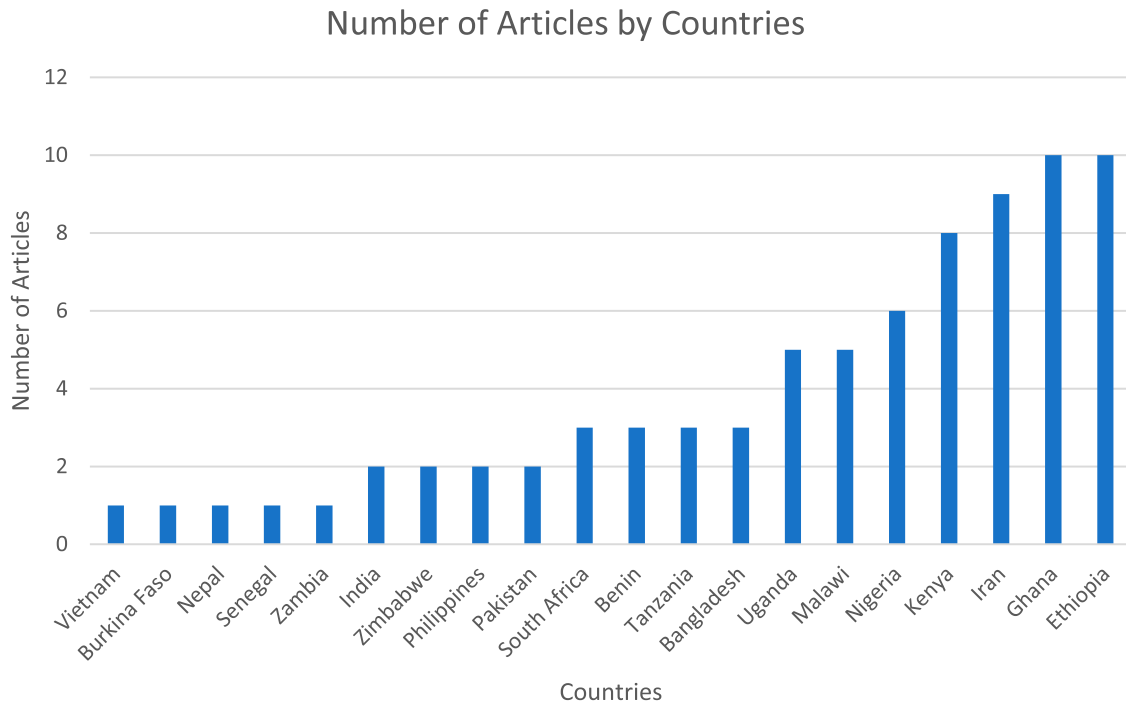
A total of ( $n=24$ ) theories were found to have been applied in the articles included in the systematic review (ANNEX 1). The Diffusion of Innovation Theory ( $n=12$ ) and Random Utility Theory ( $n=12$ ) were the most frequently applied, followed by the Technology Acceptance Model ( $n=11$ ) and the Expected Utility Theory ( $n=11$ ). Theories such as the Decomposed Theory of Planned Behavior and Consumption Value Theory were used only once. Most articles ( $n=25$ ) focused on the farmer's adoption of sustainable soil and water conservation practices, followed by articles on the farmer's adoption of improved crop varieties ( $n=15$ ).

## Discussion

The results returned articles published after 2006. This is potentially because articles published before this date used observational, applied economic analysis rather than using theoretical approaches to explain technology adoption among farmers. The analysis indicated that the Diffusion of Innovation Theory ( $n=12$ ) and Random Utility Theory ( $n=12$ ) were the most frequently applied. Diffusion theories primarily focused on how innovative technologies were introduced to prospective adopters at different temporal scales (i.e. which farmers initially adopted the technology, and which followed by adopting the technology later in the diffusion of innovation process). The Diffusion of Innovation Theory was used to explain the transfer and adoption of agricultural technologies between farmers. According to Rogers (2003), the Diffusion of Innovation Theory



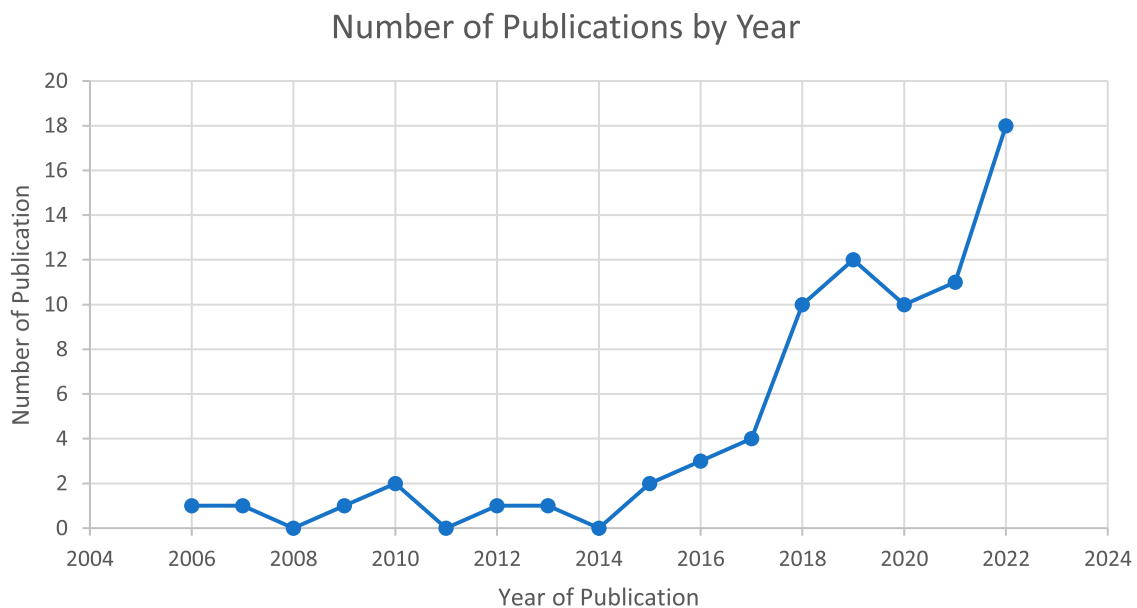
**Figure 1.** PRISMA Flow Diagram. Source: Authors' construct (2022).



**Figure 2.** The number of review articles by countries included in the review.

examines the process an innovation must undergo to determine adoption. This follows five main phases: knowledge about the innovation, persuasion, decision to adopt or not, implementation of the innovation, and confirmation of adoption. In addition, adoption practices are evaluated against 5 criteria including (1) Perceived relative advantage (compared to those offered by existing technologies), (2) Compatibility (the extent to which new technology fits with existing

cultural norms, attitudes, and beliefs), (3) Complexity (the extent to which the technology under consideration is easy to understand and use by the potential end-users), (4) Trialability (the extent to which technology can be accessed and ‘tried out’ by potential end-users), and (5) Observability (the extent to which a potential end-user has the opportunity to observe the successful application of the technology by others). Examples of the application of the Diffusion of Innovation Theory



**Figure 3.** The number of articles published per year included in the review.

include Kamwamba-Mtethiwa et al. (2021), who used it to explain the diffusion of small-scale irrigation pumps among farmers in Malawi. Similarly, Kondo et al. (2020) used the theory to examine the various dissemination strategies and factors determining farmers' adoption of improved cassava varieties in Ghana.

The results suggest the Diffusion of Innovation Theory has a wide-ranging assumption structure because of its inclusive framework (Cafer and Rikoon 2018; Chinseu, Dougill, and Stringer 2019; Kwade et al. 2019). The 'face validity' of the theory, which explicitly considers technology adoption, may account for the theory's frequent application within the articles identified (Dadzie et al. 2022; Goswami, Choudhury, and Saikia 2012; Jha, Kaechele, and Sieber 2019; Kwade et al. 2019; Mihretie, Abebe, and Misganaw 2022; Nyairo et al. 2022). A strength of the theory is its generalizability and applicability across many sectors and contexts because it encapsulates a broad range of potentially influential variables and constructs (Dibra 2015). Nonetheless, the theory may be limited in its explanatory capability as it does not address societal factors such as social support and individual farmers' access to resources (MacVaugh and Schiavone 2010).

The results indicate that user acceptance theories have good explanatory power in relation to providing explanations of how behavioral intentions influence technology adoption. Various theories, including the Theory of Planned Behavior, the Decomposed Theory of Planned Behavior, and the Technology Acceptance Model, have been used to investigate how farmers' behavioral intentions resulted in the adoption of agricultural technologies. For example, Landmann, Lagerkvist, and Otter (2021) used the Theory of Planned Behavior to explore the factors influencing Indian smallholder farmers' intention to adopt smartphones to generate agricultural knowledge. Zeweld, Van Huylbroeck, Tesfay, and Speelman (2017) used the Decomposed Theory of Planned Behavior to investigate smallholder farmers' intentions to adopt sustainable agriculture practices in Ethiopia. Nwokoye et al. (2019) used the Technology Acceptance Model to investigate the determinants of information communication technology (ICT) adoption among rice in Ebonyi State, Nigeria.

Although user acceptance theories originate from within social psychology, each theory has distinct assumptions explaining the effect of intentions on adoption behaviors (Fadeyi, Ariyawardana, and Aziz 2022; Lai 2017). For example, the Theory of Planned Behavior suggests that an individual's behavior can be predicted when an intention is developed based on the influence of three main psychological constructs: attitude, subjective norms, and perceived behavioral

control (Ajzen 1991). In the case of technology acceptance, attitude is formed based on beliefs about a technology, subjective norms measure beliefs about others' attitude towards that technology and perceived behavioral control assess beliefs held by an individual regarding their ability to perform a behavior, (in this case adopt the technology under consideration) (Ajzen 1991). These theoretical approaches assume adoption behavior is influenced by behavioral intentions, which in turn are influenced by perceived subjective norms and perceived behavioral control of an individual's ability to engage in technology adoption behaviors (Alomary and Woollard 2015). However, unlike diffusion theories, acceptance theories assume that an individual's intention to perform a behavior, will lead to that behavior being performed, although the latter has infrequently been measured in the articles included in this review. In addition, the different factors that constitute or contribute to an individual's beliefs are not adequately addressed (Bagozzi 1981; Taylor and Todd 1995a).

As an extension of the Theory of Planned Behavior, the Decomposed Theory of Planned Behavior deconstructs the unidimensional constructs presented in the Theory of Planned Behavior into perceived usefulness, perceived ease of use, compatibility, the role of peer and superior influences, self-efficacy, technology-facilitating conditions, and resource-facilitating conditions (Taylor and Todd 1995a). Thus, the Decomposed Theory of Planned Behavior may offer advantages if the research aims to analyze the relationship between specific variables included within the belief construct (Nyasulu and Dominic Chawinga 2019; Taylor and Todd 1995b). In the case of the Technology Acceptance Model, two main factors (perceived usefulness and perceived ease of use) are assumed to be adequate to explaining technology adoption by farmers (Davis 1989). This theory has been demonstrated to be reliable in research predicting technology adoption behavior (Bagheri et al. 2021; Contillo and Tiongco 2019; Nwokoye et al. 2019). Despite the theory's good face validity and straightforward assumption structure (Ajibade 2018; King and He 2006), the theory does not incorporate social factors in the prediction of farmers' adoption behavior. Technology adoption may also be linked to cultural factors such as values, norms, and interpersonal relations (Eidt, Pant, and Hickey 2020; Huyer 2016; Rola-Rubzen et al. 2020; Tanko and Ismaila 2021). These factors may influence behavioral intentions to adopt technologies and as such should be accounted for in the theoretical approach and associated models being applied in research.

Decision-making theories address the range of economic factors underlying farmer adoption behaviors. It is

assumed that perceptions of (economic) risks, uncertainties, and profitability associated with a technology are associated with adoption decision. Expected utility, Utility Maximization, and Random Utility theories have been applied to explain farmers' decisions to adopt new technology (Anang and Zakariah 2022; Dadzie et al. 2022; Danso-Abbeam, Dagunga, and Ehiakpor 2019; Meda et al. 2018). For example, Danso-Abbeam, Dagunga, and Ehiakpor (2019) used the Utility Maximization Theory to assess farmers' decision to adopt zai soil fertility technology in the Upper East Region of Ghana. According to the Expected Utility Theory, an adoption behavior is associated with (perceived) risk and uncertainty associated with the adoption decision, such that an individual is likely to adopt a technology if the expected utility from the new technology surpasses the old or existing technology (Mongin 1998). The strength of these theoretical approaches is their capacity to capture the potential rating of an individual's expected utility according to the expected benefit to be obtained following the decision. However, psychological constructs, which may also be relevant to the prediction of adoption behavior, are not considered. For example, Utility Maximization Theory assumes that adoption behaviors are performed to gain the highest level of satisfaction (i.e. fulfilment) from the technology being adopted (Curwen 1976). However, in contrast to psychological constructs, the variables are easily measured, and the results from different research activities are often comparable. Random Utility Theory assumes that an individual may consecutively adopt a particular technology, and where a different technology is chosen may be attributed to unspecified factors (random factors) (Cascetta and Cascetta 2001). The strength of this theory is its potential to increase accuracy of predictions in the context of the rationality of choice (Hess, Daly, and Batley 2018). However, the theory's assumption that adoption behavior is always rational because an individual can choose to adopt a particular technology for a range of different reasons represents a weakness in the theory's predictive capacity. For example, a broad range of socioeconomic factors (e.g. farm size, capital, farmer experience, etc) have been used to explain farmer technology adoption (Anang and Zakariah 2022; Baiyegunhi, Akinbosoye, and Bello 2022; Sunny et al. 2022).

Personality theories generally assume that the adopter's personality influences technology adoption. For example, Self-Determination Theory and Peterson and Seligman's Theory of Character Strength were applied to investigate whether personality factors influence farmers' adoption of agricultural technologies (Bukchin and Kerret 2020; Jambo et al. 2019). For example,

Jambo et al. (2019) used Self-Determination Theory to examine farmers motivation to adopt sustainable intensification practices in Tanzania and Malawi. Self-Determination Theory explains how psychological factors such as autonomy, competence, and relatedness can influence technology adoption decisions (Adams, Little, and Ryan 2017; Deci and Ryan 2004). These theories have been used across different sectors and interpreted within different disciplinary contexts. However, they have been considered to be overly multifaceted and complex, which reduce their predictive capacity. Peterson and Seligman's Theory of Character Strength proposes that the personal character of an adopter (i.e. creativity, curiosity, bravery, etc.) can predict the adoption of a technology (Park and Peterson 2008; Peterson and Seligman 2004). The assumption underpinning the theory is that it is the potential adopter's personality which predicts adoption, rather than external or economic factors. However, the theory's explanation of adoption behavior may be limited due to its primary focus on the adopter's personality with no consideration of external variables that can affect behaviors, or for experiential factors such as personality states (as opposed to traits).

Organizational structure theories have also been used to investigate technology adoption among farmers in LMICs. For example, (Meda et al. 2018) used Institutional Theory to assess drivers of farmers' adoption of conventional, organic and genetically modified cotton in Burkina Faso. Typically, these theories assume farm characteristics explain farmers' technology adoption. They rely on characteristic farm structures, including farm size, farming system type, policies, and programmes, to explain an adoption behavior. For example, Institutional Theory has been used to examine farmers' adoption of agricultural technologies (Meda et al. 2018), and assumes that rules and norms develop a social structure and influence technology adoption behavior (Amenta and Ramsey 2010). The theories strength is in understanding how a social structure influences behavior in relation to decision-making. However, in contrast to personality theories, the influencing role of individual traits is not addressed. Furthermore, social structure variables that may not be relevant to the adoption process in a specific context are included in the theoretical approach.

Overall, the results from the review suggest connectivity across a broad range of factors which potentially influence technology adoption. Some research articles used a combined theoretical approach to explain adoption behaviors (Dadzie et al. 2022; Momvandi et al. 2018; Musungwini, van Zyl, and Kroeze 2022). This indicates the need for the application of an integrated theoretical approach which assumes that an individual action (in

this case, adoption behavior) results from interrelated factors such as norms, physical activities, mental activities, technology use, knowledge, and meanings, and imply that technology adoption can be complex given the diversity in the factors or variables that are influential (Fadeyi, Ariyawardana, and Aziz 2022; Garforth and Usher 1997; Meijer et al. 2015; Morris et al. 2012). Combining theories from different perspectives or disciplines is an approach which can potentially explain farmers' adoption behavior while avoiding explanatory gaps (Borges, Foletto, and Xavier 2015; Uaiene, Arndt, and Masters 2009).

In summary, the systematic review identified various theoretical approaches which have been used to understand farmer technology adoption in LMIC countries: diffusion theories, user acceptance theories, decision-making theories, personality theories and organizational structure theories were identified (see also (Fadeyi, Ariyawardana, and Aziz 2022; Hillmer 2009; Melesse 2018)).

The strength of diffusion theories was their predictive and explanatory capability in relation to both an adoption intention and adoption. However, these theories lacked consideration of possible influential social factors. User acceptance theories predicted adoption intention but did not consider adoption (although this could be added to the model where adoption behavior is observable). These theories have good predictive and explanatory capability in relation to adoption behavior because of their consideration of social determinants (e.g. subjective norms). Decision-making theories did not address psychological factors influencing technology adoption, assuming that only economic factors predicted adoption behaviors. However, all these theories had strengths in that the variables that determined an adoption behavior could be easily measured.

Personality theories were found to have broad applicability to various technology adoption decisions but are complex and may result in weak predictive and explanatory capability. Although organizational structure theories considered a range of social structure variables, some of these were not always relevant to investigation of a particular technology adoption context. Overall, combining theoretical approaches, may deliver better predictive and explanatory capability than mono-disciplinary approaches adopted within either psychology or economics (Venkatesh et al. 2003). A scientific comparison of comparable outcome measures is needed to support this interpretation. Applying an integrated theory to minimize explanatory gaps and broaden the perspective of explaining an adoption behavior may be appropriate in future research.

## Limitations

The systematic review excluded research articles considering livestock farming. While combining theoretical approaches may provide a useful basis for understanding and predicting farmers technology adoption behaviors in LMICs, in relation to crops, other drivers of decision-making may be relevant in relation to livestock (e.g. legislation in relation to prevention of antimicrobial resistance) (AMR); (Hudson et al. 2017) or transmission of zoonotic diseases; (Magouras et al. 2020). Regulatory drivers of adoption of new technologies may interact with farmer attitudes, intentions and behaviors (Bogueva and Marinova 2020), for example in the case of zoonotic disease transmission.

The results are only applicable to LMICs, as resource-rich countries were excluded from the research question. Conducting a comparative analysis of theory application in farmer technology adoption studies in LMICS and non-LMICS may provide information about the global generalization of different theoretical approaches.

## Conclusion

Theoretical perspectives to predict or explain farmers' adoption behaviors should consider the context or focus of the research. The categorization of theories suggests that influential contextual factors may depend on the (perceived) characteristics of the technology being considered as well as farmer and farm characteristics. Predicting and explaining farmers' adoption behavior depends on understanding the research context and applying the most suitable theoretical approach to the specific research question asked. Combining theoretical perspectives may provide a useful basis for understanding and predicting farmers' technology adoption behaviors in LMICs.

## Note

1. According to the World Bank, Low-income countries are economies with a Gross National Income (GNI) per capita of \$1,045 or less. Lower Middle-Income Countries are economies with GNI per capita of more than \$1,045 but less than \$4,125 (<https://datahelpdesk.worldbank.org/knowledgebase/articles/906519>, 13/02/2023, 16:08).

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## References

- Adams, N., T. D. Little, and R. M. Ryan. 2017. "Self-Determination Theory." In *Development of Self-Determination Through the Life-Course*, edited by M. L. Wehmeyer, K. A. Shogren and T. D. Little and S. J. Lopez, 47–54. Springer Science and Business Media. doi:10.1007/978-94-024-1042-6\_4.
- Ajibade, P. 2018. "Technology Acceptance Model Limitations and Criticisms: Exploring the Practical Applications and use in Technology-Related Studies, Mixed-Method, and Qualitative Researches." *Library Philosophy and Practice* 9. doi:0000-0002-8608-8378.
- Ajzen, I. 1991. "The Theory of Planned Behavior." *Organizational Behavior and Human Decision Processes* 50 (2): 179–211.
- Aliber, M., and R. Hall. 2012. "Support for Smallholder Farmers in South Africa: Challenges of Scale and Strategy." *Development Southern Africa* 29 (4): 548–562.
- Alomary, A., and J. Woollard. 2015. How is Technology Accepted by users? A Review of Technology Acceptance Models and Theories.
- Amenta, E., and K. M. Ramsey. 2010. "Institutional Theory." In *Handbook of Politics. Handbooks of Sociology and Social Research*, edited by K. T. Leicht and J. C. Jenkins, 15–39. New York, NY: Springer. doi:10.1007/978-0-387-68930-2\_2
- Anang, B. T., and A. Zakariah. 2022. "Socioeconomic Drivers of Inoculant Technology and Chemical Fertilizer Utilization among Soybean Farmers in the Tolon District of Ghana." *Heliyon* 8 (6): e09583.
- Atangana, E. 2022. "With the Continuing Increase in Sub-Saharan African Countries, Will Sustainable Development of Goal 1 Ever Be Achieved by 2030?" *Sustainability* 14 (16): 10304.
- Bagheri, A., A. Bondori, M. S. Allahyari, and J. Surujlal. 2021. "Use of Biologic Inputs among Cereal Farmers: Application of Technology Acceptance Model." *Environment, Development and Sustainability* 23 (4): 5165–5181.
- Bagozzi, R. P. 1981. "Attitudes, Intentions, and Behavior: A Test of Some key Hypotheses." *Journal of Personality and Social Psychology* 41 (4): 607.
- Baiyegunhi, L., F. Akinbosoye, and L. Bello. 2022. "Welfare Impact of Improved Maize Varieties Adoption and Crop Diversification Practices among Smallholder Maize Farmers in Ogun State, Nigeria." *Heliyon* 8 (5): e09338.
- Bogueva, D., and D. Marinova. 2020. "Influencing Dietary Changes in a Zoonotic Disease Crisis." *Movement and Nutrition in Health and Disease* (4): 70–72.
- Borges, J. A. R., L. Foletto, and V. T. Xavier. 2015. "An Interdisciplinary Framework to Study Farmers Decisions on Adoption of Innovation: Insights from Expected Utility Theory and Theory of Planned Behavior." *African Journal of Agricultural Research* 10 (29): 2814–2825.
- Briner, R. B., and D. M. Rousseau. 2011. "Evidence-based I–O Psychology: Not There yet." *Industrial and Organizational Psychology* 4 (1): 3–22.
- Bukchin, S., and D. Kerret. 2020. "Character Strengths and Sustainable Technology Adoption by Smallholder Farmers." *Heliyon* 6 (8): e04694.
- Cafar, A. M., and J. S. Rikoon. 2018. "Adoption of new Technologies by Smallholder Farmers: The Contributions of Extension, Research Institutes, Cooperatives, and Access to Cash for Improving tef Production in Ethiopia." *Agriculture and Human Values* 35 (3): 685–699.
- Cascetta, E., and E. Cascetta. 2001. "Random Utility Theory." *Transportation Systems Engineering: Theory and Methods* (49): 95–173.
- Chinseu, E., A. Dougill, and L. Stringer. 2019. "Why do Smallholder Farmers dis-Adopt Conservation Agriculture?" *Insights from Malawi. Land Degradation and Development* 30 (5): 533–543.
- Clark, B., G. B. Stewart, L. A. Panzone, I. Kyriazakis, and L. J. Frewer. 2016. "A Systematic Review of Public Attitudes, Perceptions and Behaviours Towards Production Diseases Associated with Farm Animal Welfare." *Journal of Agricultural & Environmental Ethics* 29 (3): 455–478.
- Contillo, G., and M. Tiongco. 2019. *Determinants of Adoption of the Rice Crop Manager System among Farmers in Pangasinan, Philippines*.
- Curwen, P. 1976. "Utility Maximisation." In *The Theory of the Firm*, 127–134. London: Palgrave Macmillan. doi:10.1007/978-1-349-15645-0\_19
- Dadzie, S. K. N., J. Ndebugri, E. W. Inkoom, and S. Akuamoah-Boateng. 2022. "Social Networking and Risk Attitudes Nexus: Implication for Technology Adoption among Smallholder Cassava Farmers in Ghana." *Agriculture and Food Security* 11 (1): 1.
- Danso-Abbeam, G., G. Dagunga, and D. S. Ehiakpor. 2019. "Adoption of Zai Technology for Soil Fertility Management: Evidence from Upper East Region, Ghana." *Journal of Economic Structures* 8 (1): 1.
- Davis, F. D. 1989. "Perceived Usefulness, Perceived Ease of use, and User Acceptance of Information Technology." *MIS Quarterly* 13 (3): 319–340.
- Deci, E. L., and R. M. Ryan. 2004. *Handbook of Self-Determination Research*. Rochester, NY: University Rochester Press.
- Despotović, J., V. Rodić, and F. Caracciolo. 2019. "Factors Affecting Farmers' Adoption of Integrated Pest Management in Serbia: An Application of the Theory of Planned Behavior." *Journal of Cleaner Production* 228:1196–1205.
- Dibra, M. 2015. "Rogers Theory on Diffusion of Innovation-the Most Appropriate Theoretical Model in the Study of Factors Influencing the Integration of Sustainability in Tourism Businesses." *Procedia-Social and Behavioral Sciences* 195:1453–1462.
- Dissanayake, C., W. Jayathilake, H. Wickramasuriya, U. Dissanayake, K. Kopyawattage, and W. Wasala. 2022. "Theories and Models of Technology Adoption in Agricultural Sector." *Human Behavior and Emerging Technologies* 2022: 1–15.
- Eidt, C. M., L. P. Pant, and G. M. Hickey. 2020. "Platform, Participation, and Power: How Dominant and Minority Stakeholders Shape Agricultural Innovation." *Sustainability* 12 (2): 461.
- Eliazer Nelson, A. R. L., K. Ravichandran, and U. Antony. 2019. "The Impact of the Green Revolution on Indigenous Crops of India." *Journal of Ethnic Foods* 6 (1): 1–10.
- Evenson, R. E., and D. Gollin. 2003. "Assessing the Impact of the Green Revolution, 1960 to 2000." *Science* 300 (5620): 758–762.
- Fadeyi, O. A., A. Ariyawardana, and A. A. Aziz. 2022. Factors Influencing Technology Adoption Among Smallholder Farmers: A Systematic Review in Africa.
- Feder, G., and S. Savastano. 2017. "Modern Agricultural Technology Adoption in sub-Saharan Africa: A Four-Country Analysis." In *Agriculture and Rural Development in*

- a Globalizing World: Challenges and Opportunities*, edited by P. Pintail and G. Feder, 11–25. London: Routledge.
- Frewer, L. J., A. Fischer, M. Brennan, D. Bánáti, R. Lion, R. M. Meertens, G. Rowe, et al. 2016. "Risk/Benefit Communication About Food—a Systematic Review of the Literature." *Critical Reviews in Food Science and Nutrition* 56 (10): 1728–1745.
- Garforth, C., and R. Usher. 1997. "Promotion and Uptake Pathways for Research Output: A Review of Analytical Frameworks and Communication Channels." *Agricultural Systems* 55 (2): 301–322.
- Gollin, D. 2014. *Smallholder Agriculture in Africa: An Overview and Implications for Policy* IIED Working Paper IIED. London [Google Scholar].
- Goswami, K., H. K. Choudhury, and J. Saikia. 2012. "Factors Influencing Farmers' Adoption of Slash and Burn Agriculture in North East India." *Forest Policy and Economics* 15:146–151.
- Griliches, Z. 1957. "Hybrid Corn: An Exploration in the Economics of Technological Change." *Econometrica* 25 (4): 501–522.
- Guyatt, G., A. D. Oxman, E. A. Akl, R. Kunz, G. Vist, J. Brozek, S. Norris, et al. 2011. "GRADE Guidelines: 1. Introduction—GRADE Evidence Profiles and Summary of Findings Tables." *Journal of Clinical Epidemiology* 64 (4): 383–394.
- Hess, S., A. Daly, and R. Batley. 2018. "Revisiting Consistency with Random Utility Maximisation: Theory and Implications for Practical Work." *Theory and Decision* 84 (2): 181–204.
- Hillmer, U. 2009. "Existing Theories Considering Technology Adoption." In *Technology Acceptance in Mechatronics: The Influence of Identity on Technology Acceptance*, edited by C. Jesse and N. Schweitzer, 9–28. Wiesbaden: GWV Fachverlage GmbH.
- Hudson, J. A., L. J. Frewer, G. Jones, P. A. Brereton, M. J. Whittingham, and G. Stewart. 2017. "The Agri-Food Chain and Antimicrobial Resistance: A Review." *Trends in Food Science & Technology* 69: 131–147.
- Huyer, S. 2016. "Closing the Gender gap in Agriculture." In Vol. 20, 105–116. New Delhi, India: SAGE Publications Sage India.
- Islam, A., P. Ushchev, Y. Zenou, and X. Zhang. 2018. *The Value of Information in Technology Adoption: Theory and Evidence from Bangladesh*.
- Jambo, I. J., J. C. J. Groot, K. Descheemaeker, M. Bekunda, and P. Tittonell. 2019. "Motivations for the use of Sustainable Intensification Practices among Smallholder Farmers in Tanzania and Malawi." *Njas-Wageningen Journal of Life Sciences* 89 (1).
- Jha, S., H. Kaechele, and S. Sieber. 2019. "Factors Influencing the Adoption of Water Conservation Technologies by Smallholder Farmer Households in Tanzania." *Water (Switzerland)* 11: 2640.
- Kabwe, G., H. R. Bigsby, and R. Cullen. 2009. *Factors Influencing Adoption of Agroforestry among Smallholder Farmers in Zambia*.
- Kalungu, J. W., and W. Leal Filho. 2018. "Adoption of Appropriate Technologies among Smallholder Farmers in Kenya." *Climate and Development* 10 (1): 84–96.
- Kamara, A., A. Conteh, E. R. Rhodes, and R. A. Cooke. 2019. "The Relevance of Smallholder Farming to African Agricultural Growth and Development." *African Journal of Food, Agriculture, Nutrition and Development* 19 (1): 14043–14065.
- Kamwamba-Mtethiwa, J., K. Wiyo, J. Knox, and K. Weatherhead. 2021. "Diffusion of Small-Scale Pumped Irrigation Technologies and Their Association with Farmer-led Irrigation Development in Malawi." *Water International* 46 (3): 397–416.
- Khandker, V., and V. P. Gandhi. 2012. *Introduction of New Technologies in Agriculture: A Study of the Challenges in the Adoption of Hybrid Rice in India*.
- Khush, G. S. 1999. "Green Revolution: Preparing for the 21st Century." *Genome* 42 (4): 646–655.
- King, W. R., and J. He. 2006. "A Meta-Analysis of the Technology Acceptance Model." *Information & Management* 43 (6): 740–755.
- Kondo, K., O. Cacho, E. Fleming, R. A. Villano, and B. O. Asante. 2020. "Dissemination Strategies and the Adoption of Improved Agricultural Technologies: The Case of Improved Cassava Varieties in Ghana." *Technology in Society* 63: 101408.
- Kuehne, G., R. Llewellyn, D. J. Pannell, R. Wilkinson, P. Dolling, J. Ouzman, and M. Ewing. 2017. "Predicting Farmer Uptake of New Agricultural Practices: A Tool for Research, Extension and Policy." *Agricultural Systems* 156:115–125.
- Kumar, G., C. Engle, and C. Tucker. 2018. "Factors Driving Aquaculture Technology Adoption." *Journal of the World Aquaculture Society* 49 (3): 447–476.
- Kwade, P. C., B. K. Lugu, S. Lukman, C. E. Quist, and J. Chu. 2019. "Farmers' Attitude Towards the use of Genetically Modified Crop Technology in Southern Ghana: The Mediating Role of Risk Perception." *Aims Agriculture and Food* 4 (3): 833–853.
- Lai, P. 2017. "The Literature Review of Technology Adoption Models and Theories for the Novelty Technology." *JISTEM-Journal of Information Systems and Technology Management* 14 (1): 21–38.
- Landmann, D., C. J. Lagerkvist, and V. Otter. 2021. "Determinants of Small-Scale Farmers' Intention to Use Smartphones for Generating Agricultural Knowledge in Developing Countries: Evidence from Rural India." *The European Journal of Development Research* 33 (6): 1435–1454.
- Lowder, S. K., J. Skoet, and T. Raney. 2016. "The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide." *World Development* 87:16–29.
- Meijer, S. S., D. Catacutan, O. C. Ajayi, G. W. Sileshi, and M. Nieuwenhuis. 2015. "The Role of Knowledge, Attitudes and Perceptions in the Uptake of Agricultural and Agroforestry Innovations Among Smallholder Farmers in Sub-Saharan Africa." *International Journal of Agricultural Sustainability* 13 (1): 40–54.
- MacVaugh, J., and F. Schiavone. 2010. "Limits to the Diffusion of Innovation: A Literature Review and Integrative Model." *European Journal of Innovation Management* 13 (2): 197–221.
- Magouras, I., V. J. Brookes, F. Jori, A. Martin, D. U. Pfeiffer, and S. Dürr. 2020. "Emerging Zoonotic Diseases: Should we Rethink the Animal–Human Interface?" *Frontiers in Veterinary Science* 7:582743.
- Mallett, R., J. Hagen-Zanker, R. Slater, and M. Duvendack. 2012. "The Benefits and Challenges of Using Systematic Reviews in International Development Research." *Journal of Development Effectiveness* 4 (3): 445–455.
- Meda, Y. J. M., I. S. Egyir, P. Zohonogo, J. B. D. Jatoo, and C. Atewamba. 2018. "Institutional Factors and Farmers' Adoption of Conventional, Organic and Genetically Modified Cotton in Burkina Faso." *International Journal of Agricultural Sustainability* 16 (1): 40–53.

- Melesse, B. 2018. "A Review on Factors Affecting Adoption of Agricultural new Technologies in Ethiopia." *Journal of Agricultural Science and Food Research* 9 (3): 1–4.
- Mihretie, A. A., A. Abebe, and G. S. Misganaw. 2022. "Adoption of Tef (*Eragrostis Tef*) Production Technology Packages in Northwest Ethiopia." *Cogent Economics & Finance* 10 (1): 2013587.
- Moerkerken, A., J. Blasch, P. Van Beukering, and E. Van Well. 2020. "A New Approach to Explain Farmers' Adoption of Climate Change Mitigation Measures." *Climatic Change* 159 (1): 141–161.
- Moher, D., A. Liberati, J. Tetzlaff, and D. G. Altman. 2009. "Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement." *Journal of Clinical Epidemiology* 62 (1006e): 1012.
- Momvandi, A., M. O. Najafabadi, J. F. Hosseini, and F. Lashgarara. 2018. "The Identification of Factors Affecting the Use of Pressurized Irrigation Systems by Farmers in Iran." *Water* 10:1532.
- Mongin, P. 1998. Expected utility theory.
- Morris, J., M. Marzano, N. Dandy, and L. O'Brien. 2012. *Theories and Models of Behaviour and Behaviour Change*. Surrey: Forest Research.
- Musungwini, S., I. van Zyl, and J. H. Kroeze. 2022. "The Perceptions of Smallholder Farmers on the Use of Mobile Technology: A Naturalistic Inquiry in Zimbabwe." In *Future of Information and Communication Conference*, 530–544. Cham: Springer International Publishing.
- Nwokoye, E. S., A. Oyim, S. K. Dimnwobi, and C. S. Ekesiobi. 2019. "Socioeconomic Determinants of Information and Communication Technology Adoption among Rice Farmers in Ebonyi State." *Nigeria. Nigerian Journal of Economic and Social Studies* 61 (3): 367–397.
- Nyairo, N. M., L. Pfeiffer, A. Spaulding, and M. Russell. 2022. "Farmers' Attitudes and Perceptions of Adoption of Agricultural Innovations in Kenya: A Mixed Methods Analysis." *Journal of Agriculture and Rural Development in the Tropics and Subtropics* 123 (1): 147–160.
- Nyasulu, C., and W. Dominic Chawinga. 2019. "Using the Decomposed Theory of Planned Behaviour to Understand University Students' Adoption of WhatsApp in Learning." *E-Learning and Digital Media* 16 (5): 413–429.
- Obiero, K. O., H. Waidbacher, B. O. Nyawanda, J. M. Munguti, J. O. Manyala, and B. Kaunda-Arara. 2019. "Predicting Uptake of Aquaculture Technologies among Smallholder Fish Farmers in Kenya." *Aquaculture International* 27 (6): 1689–1707.
- Page, M. J., J. E. McKenzie, P. M. Bossuyt, I. Boutron, T. C. Hoffmann, C. D. Mulrow, L. Shamseer, et al. 2021. "The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews." *Systematic Reviews* 10 (1): 1–11.
- Park, N., and C. Peterson. 2008. "The Cultivation of Character Strengths." In *Teaching for Wisdom: Cross-cultural Perspectives on Fostering Wisdom* 4, 59–77. Dordrecht: Springer Netherlands.
- Peterson, C., and M. E. Seligman. 2004. *Character Strengths and Virtues: A Handbook and Classification*. Vol. 1. New York: Oxford University Press.
- Poole, N. 2017. *Smallholder Agriculture and Market Participation*. Rome: Food and Agriculture Organization of the United Nations (FAO).
- Rogers, E. M. 2003. *Diffusion of Innovations*. New York: Simon and Schuster.
- Rola-Rubzen, M. F., T. Paris, J. Hawkins, and B. Sapkota. 2020. "Improving Gender Participation in Agricultural Technology Adoption in Asia: From Rhetoric to Practical Action." *Applied Economic Perspectives and Policy* 42 (1): 113–125.
- Röttger, D. 2015. *Agricultural Finance for Smallholder Farmers: Rethinking Traditional Microfinance Risk and Cost Management Approaches*. Vol. 11. Stuttgart: Columbia University Press.
- Ruzzante, S., R. Labarta, and A. Bilton. 2021. "Adoption of Agricultural Technology in the Developing World: A Meta-Analysis of the Empirical Literature." *World Development* 146:105599.
- Ryan, B., and N. C. Gross. 1943. "The Diffusion of Hybrid Seed Corn in two Iowa Communities." *Rural Sociology* 8 (1): 15.
- Salami, A., A. Kamara, and Z. Brixiova. 2016. Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities: African Development Bank Tunis, Tunisia. In.
- Sertoglu, K., S. Ugral, and F. V. Bekun. 2017. "The Contribution of Agricultural Sector on Economic Growth of Nigeria." *International Journal of Economics and Financial Issues* 7 (1): 547–552.
- Sunny, F. A., L. Fu, M. S. Rahman, and Z. Huang. 2022. "Determinants and Impact of Solar Irrigation Facility (SIF) Adoption: A Case Study in Northern Bangladesh." *Energies* 15 (7): 2460.
- Tanko, M., and S. Ismaila. 2021. "How Culture and Religion Influence the Agriculture Technology gap in Northern Ghana." *World Development Perspectives* 22:100301.
- Taylor, S., and P. Todd. 1995a. "Decomposition and Crossover Effects in the Theory of Planned Behavior: A Study of Consumer Adoption Intentions." *International Journal of Research in Marketing* 12 (2): 137–155.
- Taylor, S., and P. Todd. 1995b. "Understanding Information Technology Usage: A Test of Competing Models." *Information Systems Research* 6 (2): 144–176.
- Uaiene, R. N., C. Arndt, and W. Masters. 2009. "Determinants of Agricultural Technology Adoption in Mozambique." In *10th African Crop Science Conference Proceedings*, Maputo, Mozambique, 10–13, October 2011. African Crop Science Society.
- Van der Knaap, L. M., F. L. Leeuw, S. Bogaerts, and L. T. Nijssen. 2008. "Combining Campbell Standards and the Realist Evaluation Approach: The Best of two Worlds?" *American Journal of Evaluation* 29 (1): 48–57.
- Venkatesh, V., M. G. Morris, G. B. Davis, and F. D. Davis. 2003. "User Acceptance of Information Technology: Toward a Unified View." *MIS Quarterly* 27 (3): 425–478.
- Zerssa, G., D. Feyssa, D.-G. Kim, and B. Eichler-Löbermann. 2021. "Challenges of Smallholder Farming in Ethiopia and Opportunities by Adopting Climate-Smart Agriculture." *Agriculture* 11 (3): 192.
- Zeweld, W., G. Van Huylbroeck, G. Tesfay, and S. Speelman. 2017. "Smallholder Farmers' Behavioural Intentions Towards Sustainable Agricultural Practices." *Journal of Environmental Management* 187:71–81. <https://doi.org/10.1016/j.jenvman.2016.11.014>