Barriers to Sustainable Farming Practices

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Research has a critical role in supporting the implementation of farming practices that are appropriate for meeting food and climate security for a growing global population. Notwithstanding progress towards more sustainable agricultural production, the rate of change varies across and within regions and is, overall, too slow. Understanding what is and is not working at the implementation level and, critically, providing justified explanations on outcomes, is an important contribution of the literature. It is suggested that a greater application of theory in adoption research could increase the contribution of the literature.

Keywords: adoption ; farming ; sustainability ; theory ; barriers ; conservation ; agriculture

1. Introduction

The ever rising global demand for food driven by population growth and higher individual consumption, has traditionally been met by increasing agricultural production outputs through extension of agricultural land, increasing the frequency of soil tillage, and/or the intensification of inputs such as pesticides and chemical fertilizers[1]. However, this is not sustainable with these practices reducing bio-diversity and enhancing environmental degradation. Agricultural production in many regions is already caught in a vicious cycle whereby environmental degradation caused by the externalities of traditional agriculture further exacerbates production levels and livelihoods[1][2]. With the world population predicted to reach nearly 10 billion people by the year 2050, future food security is inextricably linked to the reduction and reversal of negative environmental impacts from agricultural practices on land and water resources.

Several of the United Nations (UN) 2030 Sustainable Development Goals (SDGs) are specifically dedicated to responsible food production and consumption, the protection and rehabilitation of land and water resources, and reversal of climate change. Implementation of climate adaptation and mitigation options in agricultural production is not progressing at the scale required to meet global targets[2][3]. Furthermore, implementation remains uneven with differences observed across environmental, social, economic, legislative, regulatory, political and cultural contexts at national, regional, and local levels[2][3].

2. Rationale

Research has a critical role in supporting sustainable agriculture not only through the development of technologies, but by producing evidence on what is and is not working at the adoption level and, critically, by providing justified explanations on outcomes. In particular, systematic or narrative reviews of the adoption literature are a means of making sense of large amounts of information by exploring themes and commonalities in the evidence base for a specific topic[4]. Several reviews [5][6][7][8][9][10] of the adoption literature have sought to identify factors and their role in farming practice change, although results are not unequivocal. Rather, reviews have generally found that consistency across studies diminishes as the focus moves from overarching themes in practice change to the roles of specific factors. For example, the evidence suggests that a core theme explaining adoption of a conservation practice is the extent to which the practice is perceived by individuals to allow them to better achieve their goals[5]. However, the identification of issues and variables that consistently explain or predict individual perceptions has been more elusive[6][7][8][9][10].

An aspect of adoption research that until recently received limited attention in reviews of the literature is the use of theory. When theory has been included as a study characteristic, reviews have found a frequent lack of theoretical precision in measures of behavioural constructs, which in the absence of a unified approach could be a key cause of observed mixed and/or inconclusive results[7]. It has also been observed that empirical evidence from quantitative and qualitative studies often corresponds to key aspects and mechanisms of practice change incorporated in social and behavioural theories, although studies may not be theoretically framed, or use of theory is not fully reported or theory is applied selectively[6][7][8][9][10].

Against this background, it is suggested that there is scope for increasing the application of theory in adoption research, both at the individual study level and the review level. Theory is a set of interrelated concepts, definitions, and propositions that is a means of 'reason-giving' for events or situations, by specifying relations among variables[11][12][13][14]. At the individual study level, theory provides an a priori set of principles that serve as conceptual and analytic frameworks for examining the phenomena under investigation[11][15]. Research that is theoretically informed is more amenable to replication, as it is makes use of a common language of articulated constructs and processes [9]. Identification of theoretically derived mechanisms of action (i.e. mediators) enables researchers to determine why initiatives (e.g., programs, projects, interventions) have succeeded or failed relative to hypotheses [9][15][16][17]. As a 'dynamic entity' whose value depends on its application and refinement based on empirical findings, theories may be optimised or discarded as additional evidence emerges[15][17]. Finally, based on recent applications of communication and psychology concepts in policy studies, it is suggested that theory offers a viable storytelling and framing technique to support processing and appraisal of research findings by policy and decision-makers [12].

In this context, this research sought to understand and qualify the extent of theory use in research on barriers to sustainable farming practice change, and addressed the following research question: What theories have been used in the literature to identify and understand elements that prevent, discourage, or otherwise deter farmers from adopting sustainable farming practices?

3. Review methodology

This research is part of of a wider project that included a systematic literature review that had identified 75 studies conducted between 2014 and 2018 that focused on barriers to sustainable farming practice change. Studies located within the systematic literature review that reported theory or construct use were assessed to identify the theoretical underpinnings of research on barriers to practice change.

To this end, all articles were searched for the following terms: theor*; framework; model; construct; concept. The search term *theor* followed by an asterisk * permits words with different endings to be identified by the research team. Those articles that did not include any clear mention of theory based on the set terms (e.g. model etc) were excluded from further review. The remaining 57 articles were then analysed to examine use of theory where reported in the available studies. Based on levels of theory use as qualified by Glanz and Bishop[13], studies were categorised as: 1) informed by theory; 2) applied theory; 3) tested theory; 4) built/created theory.

Articles (n=39) that reported studies categorised as *Informed by theory* were excluded from further analysis as the aim of this study was to explore the practical role of theory as an explanatory device in empirical research. A distinction was made between building or creating theory and we excluded articles (n = 2) reporting studies for *Creating theory* and retained those reporting studies that *built on or expanded* on theory. The rationale for the latter exclusion was to focus on the role of widely tested theories within practice change adoption literature to date.

4. Results

4.1. Farming sector and target practice

The application of criteria for theory use resulted in the identification of 16 articles that qualified for addressing the research question for this review (see Table 1). Studies examined the adoption of sustainable practices in several agricultural sectors in countries across all continents. The largest group of studies examined crop farming (n = 12); agricultural areas included in other studies were aquaculture [18], horticulture[19], viticulture[20], palm oil cultivation[21], and agroforestry[22].

The most frequently included sustainable farming practices in crop farming were minimal tillage, permanent soil cover, crop rotation, crop mixing, improved seed varieties, water conservation, and ecological pest control. The participation in initiatives designed to support adoption and implementation of sustainable crop farming practices were also examined [20] [23] (see Table 1).

Table 1. Description of studies

Author	Theory	Agricultural sector & country	Target practice	Data collection and sample
Blythe et al. (2017)[18]	Diffusion of innovation	Aquaculture Solomon Islands	Aquaculture innovations (Introduction of tilapia fish)	Semi-structured interviews, workshop, and observations with adopters (n=16) and non-adopters (n=12)
Goldberger et al. (2015) [24]	Diffusion of innovation	Crop farming (specialty crops, including organic) United States	Biological Control (Biodegradable plastic mulches)	Surveys and focus group with specialty crop growers, agricultural extension agents, agricultural input suppliers, mulch manufacturers, other stakeholders (n=101)
Vidogbena et al. (2016) [25]	Diffusion of innovation	Crop farming (cabbage) Benin	Pest control/management (eco-friendly nets)	Survey with small-scale vegetable farmers (n=214)
McCarthy & Schurmann (2015)[19]	Diffusion of innovation	Horticulture and crop farming Australia	Sustainable farming practice (various)	Semi-structured interviews with farming professionals, supermarket manager, conventional growers, organic certified and not certified organic growers (n=22)

Author	Theory	Agricultural sector & country	Target practice	Data collection and sample
Ndah et al. (2018) [26]	QAToCA	Crop farming Zambia	Conservation Agriculture (minimal tillage, permanent soil cover, crop rotations)	Focus group (n=12), farm observations (n=9 visits) Semi-structured farmer interviews (n=26); semi-structured expert interviews (n=6)
Zeweld et al. (2017)[27]	Decomposed theory of planned behaviour	Crop farming Ethiopia	Sustainable Agricultural Practice (minimum tillage and row planting practices)	Survey of smallholder farmers (n=350)
Márquez-Garciá et al. (2018)[20]	Theory of planned behaviour	Viticulture Chile	Sustainable agriculture practices, private land conservation, and wildlife-friendly practices	Semi-structured interviews with managers of WCB vineyard (n=14) and comparison vineyard (n=11)
Martin et al. (2015)[21]	Neo-institutional theory	Palm oil cultivation Malaysia	Sustainable palm oil cultivation	Semi-structured individual interviews with small-holder growers (n=34).
Bonfiglio et al. (2019) [22]	Agricultural Innovation System (AIS) (Lamprinopoulou et al., 2014) [28]	Agroforestry (tree and crop combinations) Belgium	Agroforestry (combination of trees crops and/or livestock)	Semi-structured interviews (n=25); focus group (n=16)

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Author	Theory	Agricultural sector; Location	Target practice	Data collection and sample
Brown et al. (2018a)[29]	Livelihood Platforms Approach (LPA)	Mixed crop farming (maize/legume) Ethiopia, Uganda, Kenya, Malawi, Zambia & Mozambique	Conservation Agriculture (various)	Semi-structured interviews with extension service providers (n=76)
Brown et al. (2018b)[30]	Livelihood Platforms Approach (LPA)	Mixed crop farming (maize/legume) Ethiopia, Uganda, Kenya, Malawi, Zambia & Mozambique	Conservation Agriculture (various)	Semi-structured interviews with community leaders (n=46)
Blesh & Wolf (2014)[31]	Socio-ecological approach (Modified resource based framework Wolf & Primmer, 2006)	Mixed cropping (Grain/legume) and livestock United States	Agroecological management practices (crop rotation and mixed crops; MIRG livestock production)	Semi-structured interviews with grain farmers and rotational graziers from contrasting regions of Iowa, and representing two management systems identified by the ecological study as being efficient with respect to nitrogen cycling (n=18)

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Author	Theory	Agricultural sector & country	Target practice	Data collection and sample
Lemken et al. (2017) [32]	Trans-theoretical model (TTM)	Crop farming Germany	Mixed cropping (grain, cereal and legumes)	Computer- assisted telephone interviews with Farm managers (n=152) in states where MC is a production option
Ngigi et al. (2019) [34]	Schwartz theory of basic values (2012) Vulnerability context (Bryan & Behrman, 2013)	Crop farming Kenya	Climate Smart Agricultural strategies (improved crop varieties; crop diversification; water conservation; soil conservation)	Laddering interviews with male (n=34) and female (n=26) farmers in 6 districts with diverse susceptibility to climate change
Tapsuwan et al. (2015) [29]	Walker's (2002) causes of non-adoption	Crop farming (citrus) Spain	Use of decision support tool (bulletin) for irrigation practices	Pre-trial surveys (n=5 farmers; n=5 advisors). Post-trial survey (n=4 farmers; n=4 advisors)
Tajeri moghadam et al. (2020) [35]	Health belief model	Crop farming Iran	Water conservation	Questionnaires with (n=238) farmers

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Note: The FAO definition of Conservation Agriculture (CA) includes three main principles for crop farming: 1) minimum mechanical soil disturbance (i.e. no tillage) through direct seed and/or fertilizer placement; 2) permanent soil organic cover (at least 30 percent) with crop residues and/or cover crops; 3) species diversification through varied crop sequences and associations involving at least three different crops [36]. Studies included one to all three CA principles.

4.2. Theories and models

Behavioural theories and models used or adapted in the development of research frameworks and designs included diffusion of innovations[37]; the transtheoretical model or stages of change[38]; the theory of planned behaviour [39][40][41] the theory of behaviour modification[42]; Schwartz theory of basic values[43]; means-end chain analysis approach[34]; vulnerability approach[44]; Walker's (2002) causes of non-adoption[45]; resistance to innovation[46]; and the health belief model[47]. Several studies framed their research in ecological theories or system based approaches, including neo-institutional theory[48]; the socio-ecological approach; World Bank innovation system concept[49]; sustainable livelihood approaches[50]; and agricultural innovation systems[28]. A brief overview of theories used across studies follows. The application and findings of studies are summarized in Table 2.

4.2.1. Diffusion of innovation

Diffusion of innovations[37] is a general process model for decision making and behaviour change research that aims to explain and predict rates of adoption of an innovation (practice or technology)[51]. Diffusion is the process through which an innovation, defined as an idea perceived as new, spreads via a range of communication channels over time among the members of a social system[51]. The process of diffusion is one of change from non-adopter to adopter of an innovation in five stages: awareness, persuasion, decision, implementation, and confirmation [37]. The order of stages is fluid and is influenced by individual perceptions of characteristics of the innovation, including relative advantage; compatibility; complexity; trialability; and observability. Relative advantage describes the degree to which an innovation is perceived to be better than the idea or practice it replaces. Compatibility describes the degree to which an innovation is perceived to be consistent with the existing values, past experience and needs. Complexity is the degree to which an innovation is perceived as difficult to understand and to use. Trialability is the degree to which an innovation may be experimented with prior to commitment. Similarly, observability is the extent to which the results of using an innovation are visible to potential adopters[37]. Subjective perceptions and expectations in the 'innovation-decision' process are assumed to be influenced by a combination of individual social, economic and cultural circumstances[37]. Concepts from the diffusion of innovations were applied in studies by Vidogbena et al.[25], Blythe et al.[18], and Goldberger et al. [24].

4.2.2. Theories of non-adoption

Two studies focussed specifically on characteristics of an innovation that led to negative innovation-decisions [19][23]. Tapsuwan et al.[23] explained non-adoption of practices with reference to Walker's (2002)[45] criteria for non-adoption of decision support tools in rural resource management (irrelevance, inaccessibility, inflexibility, lack of confidence, institutional and political barriers). McCarthy & Schurmann[19] framed their exploration of factors preventing the adoption of innovations with reference to MacVaugh and Schiavone's[46] model of non-adoption. MacVaugh and Schiavone hypothesise innovation diffusion as a system characterised by technological (utility, complexity, complementarity), social (context, orientation, contagion), and learning (capacity, capability, costs) conditions that interact to influence and be influenced by users in several domains (individual, community, and market/industry).

4.2.3. The Health Belief Model (HBM)

The Health Belief Model[47] has been widely used for explaining and influencing engagement in health related behaviours. The HBM suggests that the likelihood of engaging in a health promoting behaviour depends on individual beliefs regarding susceptibility or risk (the likelihood of getting ill); severity of the illness; the benefits deriving from positive health behaviour; barriers to engaging in health promoting behaviour (e.g., time, skill, money); and motivational factors, including self-efficacy or the conviction that one can successfully execute the behaviour; cue to action; and general health beliefs. Tajeri moghadam et al. (2020) used constructs of the HBM to explore farmers' water conservation behaviours in Iran.

4.2.4. Theory of Planned Behaviour (TPB)

The Theory of Planned Behaviour is concerned with the prediction of intentions to perform a behaviour. Behavioural, normative and control beliefs as well as attitudes, subjective norms and perceptions of behavioural control are assumed to feed into and explain behavioural intentions for individuals [39][40][41]. Whether intentions result in an actual behaviour depends in part on factors beyond the individual's control, thus the theory predicts the strength of the intention–behaviour relationship to be moderated by actual control over the behaviour [39][40][41]. Márquez-Garciá et al. adapted elements of TPB in a comparative analysis of corporate conservation behaviours in vineyards participating in a sustainability winegrowing program and non-participating vineyards[20].

The decomposed TPB[52] includes elements of diffusion of innovation theory, Theory of Planned Behaviour, and economic constraint theory. Within the decomposed TPB theoretical framework, behavioural intentions are explained by attitudinal beliefs and perceived behavioural control decomposed into self-efficacy and facilitating conditions/resources[52]. Zeweld et

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al.[27] applied the decomposed TPB, combined with social cognitive theory and diffusion of innovations to predict farmers intentions to adopt sustainable farming practices.

4.2.5. The Trans-Theoretical Model (TTM)

The Trans-Theoretical Model[38] originated as a model of health behaviour change and has since been adapted to behaviour change in other areas. The fundamental assumption of TTM is that change occurs in stages through multiple processes and at different levels. Up to six stages of change have been included in the model: precontemplation, contemplation, preparation, action, maintenance, and termination. Prochaska & Velicer identified ten processes for promoting progress through stages of change and included constructs of decisional balance (pros and cons of changing), self-efficacy, and temptations to explain variations in the process of change [38]. Lemken et al. [32]applied the transtheoretical model in their study.

4.2.6. Means-end chain analysis (MEC)

Means-End chain analysis originated as a practical approach for understanding choice criteria and underlying motivations in consumer decision making [34]. Conceptually, MEC draws upon psychological theories to describe how decisions for achieving an end goal are made based on relations between individual appraisals of product attributes, consequences, and individual values[34]. At an analytical level, the MEC approach involves the identification of a hierarchical value map (HVM) to describe alternative means-end chains corresponding to different values [34]. Ngigi et al.[33] used a modified MEC approach (replacing product attributes with strategies).

4.2.7. Theory of basic values

Schwartz's theory of basic values[43] includes ten types of basic values classified into motivational dimensions of self-enhancement (achievement and power), self-transcendence (benevolence and universalism), conservation (security, tradition and conformity), and openness to change (stimulation, hedonism and self-direction) [43]. According to Schwartz, values are desirable goals that motivate action and they guide selection of actions, whereas the consequences it will have on the desired outcomes [43]. Schwartz theory of basic values was also use by Ngigi et al. [33] in their study of 'climate-smart' farming strategies selection.

4.2.8. Qualitative expert Assessment Tool for CA adoption (QAToCA)

The Qualitative expert Assessment Tool for CA adoption (QAToCA) [53] was developed to model the adoption of CA in the African context. It explicitly includes adaptation and partial adoption as theoretical stages in a behavioural change process and in the diffusion of innovations more broadly. QAToCA has a multi-theoretical base reflected in 7 thematic areas of evaluation including: characteristics of CA as an object of adoption; capacity of promoting organisations; attributes of diffusion strategy; institutional frame conditions at regional level; institutional frame conditions at village level; market conditions at village and regional level; and, community's perception at village and regional level. [26]. Ndah et al.[26] combined the QAToCA[53] with diffusion of innovation [37], elements of the theory of behaviour modification[42] and of the Theory of Planned Behaviour[39][40][41] in their study. The World Bank innovation system concept [49] was used as the systemic overarching framework in which linkages among all elements were analysed.

4.2.9. Livelihood Platforms Approach (LPA)

The LPA is a framework for qualitative research that explores the uptake of agricultural technologies at individual, household, community, and institutional 'platform' levels [54]. The LPA is based on the sustainable livelihood frameworks which have been used extensively to analyse changes in rural livelihoods. Sustainable livelihood frameworks include five interacting factors: context, resources, institutions, strategies and outcomes and hypothesise that in any particular context, characterised by political, socio-economic, ecological, historical settings and conditions, a combination of resources contributes to the livelihood strategies that are used by stakeholders[55]. In LPA, the structure of platforms (individual, household, community, and institutional) is assumed to be hierarchical to reflect the embeddedness of each platform in a wider context. Four resource pillars (physical, financial, human and informational) support various livelihood strategies[54]. Decisions on the uptake of agricultural practices are made at each platform level, depending on the perceived benefits, feasibility and relevance of practices to livelihood strategy[54]. Brown et al. applied the LPA to explore constraints to the adoption of conservation agriculture (CA) from the perspectives of community leaders and extension officers in several Sub-Saharan African countries[29][30].

4.2.10. Neo-Institutional Theory

Neo-institutional theory (NIT) conceptualises organisational behaviour in terms of historical, social, economic, political and cultural influences deriving from the symbolic environment created by other organisations[48]. Organisational change and diversity are explained by connectedness and interrelations between individual actors' in a relevant ecosystem[48]. Contemporary NIT retains notions of rational myths, diffusion, legitimacy, and isomorphism, and focuses on systemic and individual level variables. Martin et al.[21] used NIT to frame their analysis of attitudes to sustainability investment and innovation held by micro and small enterprise palm oil cultivators in Malaysia.

4.2.11. Socio-ecological approach

Social ecological approaches in agricultural transformations emphasise the systemic dimensions of change and the interdependencies between micro, meso and macro level variables. Blesh and Wolf [31] used a resource-based model of innovation in their study. In this model of innovation, implementation of new, more sustainable land use practices is mediated by the case-specific configuration of relations between internal and external resources.

4.2.12. Agricultural Innovation System (AIS)

The conceptual premise of AIS is that innovation in agriculture is the outcome of an interactive and co-evolutionary process in which a wide network of actors is engaged. The thoughts and actions of those actors shape the extent to which policy, the market, or institutional environment enables an innovation. The similarities and divergences in the goals pursued by those actors influence the speed and direction of innovation processes. Methodologically, understanding innovation transitions requires analyses of the system's structural elements across domains (e.g., research and education, government); of the functions performed by elements (e.g., knowledge development, mobilizing resources, entrepreneurial activities); and of the coordination, alignment and harmonization between structures and functions[28]. Through these analyses, failures at micro and macro levels of an AIS system are identifiable relative to conditions or processes necessary for innovation. Borremans et al.[22] applied the AIS in their examination of the agroforestry industry in Belgium.

Table 2. Study focus and summary of barriers to practice change

Author	Theory/model	Study focus	Theoretical constructs/models	Barriers to practice change
Blythe et al. (2017) [18]	Diffusion of innovation	Factors that influence the diffusion of aquaculture innovation from farmer to farmer in the absence of formal extension services	Socio-economic characteristics of adopters; the role of opinion leaders in the adoption-decision process; and characteristics of innovation	Lack of technical knowledge; commitment to other livelihoods; lack of tools; low trialability; low observability.
Goldberger et al. (2015) [24]	Diffusion of innovation	Barriers and bridges to the adoption of biodegradable mulches for US specialty crop production.	Characteristics of innovation: relative advantage; compatibility; complexity; trialability; and observability	High costs; unpredictable breakdown of biodegradable mulches and its impact soil.

Author	Theory/model	Study focus	Theoretical constructs/models	Barriers to practice change
Vidogbena et al. (2016) [25]	Diffusion of innovation	Opinions about the use of Ecofriendly nets as an alternative to the exclusive use of synthetic pesticides; factors influencing opinions and acceptance of nets.	Anticipated performance; ease of use; social pressure; external support.	High labour requirements; no or limited experience; limited access to extension services.
McCarthy & Schurmann (2015)[19]	Diffusion of innovation (MacVaugh & Schiavone, 2010)	Factors that prevent growers from adopting more sustainable farming practices across conventional to organic farming spectrum	Technological (utility, complexity, complementarity); Social (context, orientation, contagion); Learning (capacity, capability, costs); user domains (individual, community, and market/industry).	Complexity of technology; knowledge and time intensive; subject to trial-and-error; financial costs (switching costs) and stress (lower yields/lower income); market forces (niche-market; consumer price/quality expectations); fears of lock-in.
Ndah et al. (2018) [26]	Qualitative expert Assessment Tool for CA adoption (QAToCA); diffusion of innovation; theory of planned behaviour; innovation system.	Adaptation and partial adoption as preconditions for full adoption of CA in Africa	Characteristics of innovation (trialability, compatibility, divisibility, relative advantage); attitude; intention; institutional capacity; dissemination strategy; institutional frames; market conditions; community perceptions.	Low local support; weed infestations; absence of markets for farm outputs/ legume produce; non-compatibility with village rules; static mind-set on ploughing; limited land availability and ownership; seasonal rainfall variation.

Author	Theory/model	Study focus	Theoretical constructs/models	Barriers to practice change
Zeweld et al. (2017) [27]	Decomposed TPB	Behavioural intentions towards future use of sustainable practices (minimum tillage and row planting)	Intention, attitude, perceived control; normative issues; media influence, technical training, social capital, extension services, perceived usefulness, perceived ease of operation, personal efficacy, perceived compatibility and perceived resources.	For minimum tillage: low compatibility and low ease of use; negative influence of extension services on normative beliefs.
Márquez-Garciá et al. (2018) [20]	Theory of planned behaviour	Conservation behaviours of winegrowers' participating in a sustainable winegrowing program relative to non-participating group	Attitudes (belief strength and outcome evaluations); social influence (organizational pressure, community pressure; motivations to comply); perceived behavioural control (self-efficacy, organisational support, and government support).	Management practices more complex or inefficient; organizational economic and human resource costs; scarcity of conservation professionals.
Martin et al. (2015) [21]	Neo-institutional theory	Attitudes to investment and to sustainability for palm oil cultivation practices by smallholders who depend entirely on farming for their income and those who have other sources of off-farm income	Structural factors: property rights in land; legal and administrative systems. Relational factors: belief systems; political and family ties.	Insecure & unpredictable land rights (fear of land-grabbing, reliance on non-farm income); scepticism about investment value; poor infrastructure; poor bargaining power; lack of, or poor, knowledge of sustainability issues; limited knowledge of fertilizer composition; disengagement with industry; lack of interest.

Author	Theory/model	Study focus	Theoretical constructs/models	Barriers to practice change
Borremans et al. (2018)[22]	Agricultural Innovation System (AIS) (Lamprinopoulou et al., 2014)[28]	Adoption of agroforestry (combination of tree crops and/or livestock)	System structure: actors in functional domains (research & education; intermediary; enterprise; government; social). System functions: key processes, related to the development, diffusion and use of new technology performed by actors. System transformational failures and merits (directionality, demand articulation, policy coordination, reflexivity).	Technical (AF skills, infrastructure incompatibility); financial (undeveloped markets; low financial buffers, decreased productivity/profitability); legal (uncertain & inconsistent legal frameworks, including subsidy programs); organizational (undeveloped communication and education channels); social (insufficient dialogue between influential groups; poor peer to peer support).
Brown et al. (2018a) [29]	Livelihood Platforms Approach (modified LPA)	Commonalities of factors that limit the utilisation of CA in communities in eastern and southern Africa (from perspective of extension service providers)	Perceived benefits, feasibility and relevance of livelihood strategies at individual, household, community, and institutional levels. Physical, financial, human and informational resources.	Financial resources (e.g. handout culture; limited household resources); informational resources (conflicting/confusing information; poor communication dissemination; limited extension services); physical resources (competing stover uses; non-functional input markets); human resources (labour requirements incompatible with farmer realities).
Brown et al. (2018b) [30]	Livelihood Platforms Approach (modified LPA)	Commonalities of factors that limit the utilisation of CA in communities in eastern and southern Africa (from perspective of community leaders)	Perceived benefits, feasibility and relevance of livelihood strategies at individual, household, community, and institutional levels. Physical, financial, human and informational resources.	Lack of engagement with community platform due to low input/low output farmer subsistence orientation and resource constraints; informational exchange mechanisms lead to perceived exclusivity, jealousy and distrust; systematic lack of local adaptation due to CA perceived as economically unfeasible in the absence of factors to facilitate a production-oriented system.

Author	Theory/model	Study focus	Theoretical constructs/models	Barriers to practice change
Blesh & Wolf (2014) [31]	Socio ecological approach (modified resource-based framework; Wolf & Primmer, 2006)	Transitions to agroecological management practices (crop rotation and mixed crops; MIRG livestock production) in different industrialised production systems	Ecological and farm enterprise resources Cognitive resources Network relations with peers, knowledge organisations, and policy.	Increased complexity of agroecological farm management; geographic isolation; agricultural policies designed prevalently for conventional farming systems.
Lemken et al. (2017) [32]	Trans-theoretical model (TTM)	Farmer and farm characteristics, attitudes and technical barriers in transitions (adoption & tendency to adoption) to mixed cropping (grain, cereal and legumes)	Mixed cropping (MC) adoption Attitude to MC in terms of worthiness, and compatibility with a farmer's gain goals, normative goals, and hedonic goals Technical barriers defined as those that reduced the perceived feasibility of multiple cropping.	Low perception of worthiness and compatibility with farmers goals; perception of technical difficulties, e.g., the coordination of crop maturity and the separation or direct use of harvest.
Ngigi et al. (2018) [33]	Means-End chain analysis approach [34]. Schwartz theory of basic values (2012). Vulnerability context (Bryan & Behrman, 2013).	Male and Female farmers intrinsic values and motivations for adopting various climate-smart agricultural practices in crop management (improved crop varieties; crop diversification; water conservation; soil conservation)	Motivational structures underlying choices of climate-smart practices, their consequences and end-values (Hierarchical Value Map) at different levels of concepts.	Gender norms and traditions hindered early land preparation and planting among female farmers because of women's role in household decision-making. Self-enhancing values among males may also result in unsustainable adaptation practices such as unsuitable but profitable tree species for agroforestry systems, which foster soil degradation and cause other harmful effects for ecosystems that affect the entire community.

Author	Theory/model	Study focus	Theoretical constructs/models	Barriers to practice change
Tapsuwan et al. (2015) [23]	Walker's (2002) causes of non-adoption	Design an irrigation advisory bulletin to assist farmers in their irrigation decision-making process based on end-user feedback pre- and post-implementation of the tool.	Performance of and end-user satisfaction against a number of non-adoption criteria, including irrelevance, inflexibility, inaccessibility, lack of confidence and institutional and political barriers.	Perception of irrelevance; lack of clarity in information supplied; uncertain outcomes; cost to pay for the information.
Tajeri moghadam et al. (2020) [35]	Health belief model	Investigate factors predicting water conservation behaviour among farmers in the northeast area of Iran.	Perceived susceptibility (PS) Perceived severity (PSV) Perceived benefits (PB) Perceived barriers PBR) General beliefs (values, specific beliefs, and concerns about health) (GB) Self-efficacy (perceived ability to carry out an activity) (SE) Cue to action (triggers to act) (CA)	Difficulty in adopting new habits; insufficient water-saving infrastructure/technologies; more complex agricultural activities and crop production.

5. Discussion and conclusion

This evidence review indicates that theory use was relatively minor in the 2014-2018 research on barriers to adoption with approximately 20% of studies having applied and tested existing theories. The utilization of 14 theories across 16 studies suggests that there are several theories and models that explain barriers to adoption. Limited application of theories across a wide set of studies is limiting the adoption of sustainable farming practices.

The most frequently used theory was diffusion of innovation[36][51], as a direct theoretical framework e.g., [18][24][25] or in the application of theoretical constructs adopted or adapted in other studies. Specifically, perceived characteristics of new sustainable farming practices -- relative advantage, compatibility, complexity, trialability, and observability -- were included in several of the studies that utilised other theories or models e.g., [20][22][26][27][31]. When applied in the studies reviewed, the Theory of Planned Behaviour, diffusion of innovation, and the Trans-Theoretical Model supported the identification of individual and social elements acting as barriers to the 'innovation-decision' process leading to change. As adoption of sustainable farming practices entails the discontinuation of familiar or routine practices over time [51], studies in the review emphasised perceptions of comparative advantage among individual farmers as most significant. Similarly, perceived

complexity of new practices and incompatibility with existing practices were largely barriers to positive attitudes and intentions, and were aggravated by the absence of trialability and observability. An exception to this general finding was observed in the Tajeri moghadam et al. study, which used the Health Belief Model in its theoretical framework. In this study, HBM constructs of perceived benefits, perceived susceptibility, and cues to action were sufficient to explain adoption of sustainable irrigation practices[35]. Similarly, Ngigi et al. found the common goal of minimising the negative consequences of weather variability to be prominent in the community [33]. However, cultural norms and expectations about gender roles, often constrained women's actions and supported men's continuation of ultimately unsustainable practices. The findings of Tajeri Moghadam[35]and Ngigi et al. [33] also suggested that the elements contributing to the decision to adopt are not necessarily the same as those for non-adoption. This was partly explored in the McCarthy and Schurmann[19] study on 'resistance to adoption'[46]as conceptually separate from decision to not adopt.

An on-going criticism of research on sustainable farming practice adoption is a disproportionate focus on the roles of farmer and farm level characteristics relative to those of political, economic, social, and cultural structures, which may be harder to measure in terms of their influence[10][56]. Although socio-behavioural theories conceptualise adoption or non-adoption as a decision process in which multiple internal and external factors are interacting to influence individuals[37], the behavioural unit of analysis is predominantly at the individual farmer level, which overlooks the role of other actors within a system of change.

On the other hand, systems-based approaches aim to more directly include contextual social, economic, cultural, political, and geographic elements in explaining how and why agriculture is practiced at regional, local, and individual levels. Based on these ideas, transitioning towards sustainable agriculture is understood as a process of systemic change that requires adjustments beyond individual farmer practices[29][30]. Barriers to adoption are, therefore, conceptualized as the result of interrelationship and interactions among actors within a system of change (e.g., limited or inadequate extension services; limited supply and demand markets; land ownership structure; laws and regulations; poverty; embedded culture; history). These theoretical approaches assist in identifying structural constraints that may need to be addressed prior to expecting individuals to change. For example, CA has been widely promoted in Africa to simultaneously meet long-term food security requirements and to maintain environmental sustainability[3]. However, adoption of CA has been low in the mostly smallholder non-mechanised subsistence farming sector of many African countries[55]. For example, Brown and colleagues[29][30] applied the Livelihood Platforms Approach (LPA) to examine the role of extension services in the adoption of CA in non-mechanised smallholder subsistence farming in Africa. Based on existing structural constraints impacting the flow of resources across all system levels, they found that extension approaches failed to take the contextual realities of subsistence farmers into account. The livelihood imperative to meet basic needs among many smallholder farmers results in a cycle of low input-low output (LILO) agriculture that perpetually restricts farmers' output and income. In this context, communities have limited desire or ability to implement CA that is more complex and more labour intensive, and for which product markets are unavailable[29][30]. Resource constraints at all platform levels explained low perceived benefits, feasibility and relevance of CA practices for individual farmers[28][29]. Few exit pathways from low input-low output cycles were possible without sufficient income for meeting basic needs. Investment in CA was therefore unfeasible due to financial resource constraints and undeveloped markets at the community level, which reinforced the perceived lack of economic viability[28][29].

The application of systems approaches also highlighted the pervasive influence of historical institutional and structural elements in the adoption of sustainable farming practices in highly mechanised agricultural contexts. The socio-ecological approach taken by Blesh and Wolf[31] and the agricultural innovation system (AIS) framework used by Borremans et al.[22] both examined the multiple constraints preventing a shift from established large scale intensive farming systems to ecologically sustainable systems. The fundamental premise in Blesh and Wolf's study was that agriculture is multi-dimensional as it provides the basis of individual and collective identity, livelihood, sustenance, export, accumulation, resistance and more. Therefore, understanding why and how transitions take place requires approaches to integrate agency, collective action, landscapes, ecological interactions, and the political economic context[31]. Many of the barriers encountered by farmers in transitioning to sustainable practices originated in the geophysical conditions of the study areas. Geographic and social isolation across large cultivated land areas limits opportunities for formal and informal information, support, and capacity building at the individual farmer level. In the context of a regulatory system that favoured traditional agriculture, and in the absence of sufficient political will to assist, barriers appeared difficult to overcome even when individuals were willing to transition. In the context of more densely populated and cultivated areas in Germany, Borremans et al. found that regulatory and legal structures acted as constraints to the further establishment of agroforestry[22]. By applying the AIS framework to conceptualise a functioning agroforestry system of structures and functions, Borremans et al. identified constraints to 'transformation' across domains and themes.

Theories and models differ in their unit of analysis, with many theories in the social and behavioural sciences (e.g., HBM, TPB, TTM) being primarily concerned with individual behaviour and the role of internal constructs (e.g., attitudes, intentions, beliefs, control, values, motivations, and so on) and personal characteristics (e.g., socio-economic status, education level) on behaviour. Other theories and models focus more on contextual determinants of behaviours (e.g., socio-ecological approaches), and/or behaviours of entities such as organisations (e.g., neo-institutional theory). Systems-based theoretical approaches generally aim to include in their analysis the roles, behaviours, and interrelations of elements identified as relevant in an issue (e.g., limited or inadequate extension services; limited supply and demand markets; land ownership structure; laws and regulations; poverty; embedded culture). Variation in theoretically based units and foci of analyses were evident in the different emphases on the roles of specific elements in adoption of sustainable practices, from individual internal constructs to that of institutional and ecological settings. However, several conceptual constructs appeared in the context of studies that had different theoretical underpinnings, signifying that the same phenomena can be explained from different angles. Different emphases do not constitute limitations of specific theories or an impediment to theory use more generally. Rather they point to the need to extend efforts that clearly report theory application, testing and building across studies and contexts [10][13][15][17].