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Review

Theoretical Underpinnings in Research Investigating Barriers for Implementing Environmentally Sustainable Farming Practices: Insights from a Systematic Literature Review

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Abstract: 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. Based on the assumption that theory-informed research can contribute to adoption policy and practice, this review ascertained and described the use of theory in the identification and examination of barriers to adoption in studies included in a recent systematic literature review. Following the application of criteria for 'theory use', 16 studies out of 75 were found to have applied or built upon one or more of 14 theories and models in their research approaches, including established theories in the social and behavioural sciences, as well as systems based models developed specifically in the sustainable agriculture space. Following a description of theory and model use in the studies, results are discussed relative to how theoretical constructs and mechanisms within individual and across studies can assist in explaining why and how adoption of sustainable practices is constrained.

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

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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, frequent soil tillage, and the intensification of inputs such as pesticides and chemical fertilizers [1]. However, this is not sustainable. With the world population predicted to reach nearly 10 billion people by the year 2050, future global food security requires fundamental and immediate actions at all levels of food systems [2]. The reduction and reversal of negative environmental impacts from agricultural practices on land and water resources, is among the most pressing of necessary actions. Agriculture generates around a quarter of annual greenhouse gas emissions, when including food production and land-use changes associated with farming [2,3]. Agriculture uses around 70% of water resources. Cropping and livestock systems and aquaculture contribute to pollution of water bodies through discharges of chemicals, organic matter, drug residues, sediments and saline drainage [1]. With regional and local variations within and across countries, agricultural production is already caught in a vicious cycle whereby environmental degradation caused by the externalities of traditional agriculture leads to further unsustainable practices to maintain production levels and livelihoods [1,2]. In this context, food security is inextricably linked to climate adaptation and mitigation at a global level.

Potential solutions required for sustainable agricultural production are well documented. Several of the United Nations (UN) Sustainable Development Goals (SDGs) for

2030 are specifically dedicated to targets for responsible food production and consumption, the protection and rehabilitation of land and water resources, and the reversal of climate change. The 2019 World Resources Report [2] includes demand and supply measures and scenarios for achieving food security by 2050, through agricultural development, while reducing greenhouse gas (GHG) emissions and land and water degradation from farming. Similarly, the IPCC 2019 [3] special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems, examines the potential for climate mitigation and adaptation under several possible socio-economic pathways involving different pressures on agricultural production systems.

Implementation of solutions and the achievement of targets for sustainable agricultural production requires coordinated and integrated action by public and private organisations, and citizens across and within countries. However, the 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 is uneven and is highly dependent on environmental, social, economic, legislative, regulatory, political and cultural contexts at national, regional, and local levels [2,3].

Farming practice change and adoption of new technologies has been researched in many disciplinary contexts, including economics, sociology, psychology, marketing, agricultural extension and anthropology, producing an extensive and diverse body of literature [4]. The size and diversity of the literature may limit, frustrate, or confuse stakeholders who seek to understand and utilise research findings to inform policy efforts to broaden the uptake of sustainable farming practices. Systematic or narrative reviews of the adoption literature can assist in making sense of large amounts of information by exploring themes and commonalities in the evidence base for a specific topic [5]. Several reviews [4,6–10] of the adoption literature have sought to identify factors and their role in farming practice change, although results are not unequivocal.

Pannell et al. [4] integrated evidence from agriculture, psychology, economics, sociology and marketing to provide an overview of the determinants of adoption of new practices. Same authors found the core theme explaining adoption of a conservation practice to be the extent to which the practice allowed individuals to better achieve their goals [4]. From the empirical literature Pannell et al. [4] identified three sets of issues that were significant for individual perceptions of a new practice: the process of learning and experience; the characteristics and circumstances of the landholder within their social environment; and the characteristics of the practice [4]. In contrast, the main finding of Knowler and Bradshaw's [6] quantitative evidence review was that 'few, if any' independent variables were universally significant in explanations of farm-level adoption of conservation agriculture practices across 31 studies reviewed [6] (p. 42). Factors that were most frequently included as independent variables for technology adoption—age, education, tenure, off farm activities/income, farm size and rainfall—were those for which results were highly mixed across studies. While statistical method, geographical region, journal quality, and specific technology, explained some of the inconsistencies, Knowler and Bradshaw concluded that policy prescriptions for conservation agriculture would best be tailored to the specific context [6]. In a similar vein, Prokopy et al. [8] reviewed the adoption literature in the United States between 1980 and 2005 and concluded that all social factors commonly used in research (e.g., attitudes, awareness, demographic variables) were non-significant in most of the studies reviewed [8]. However, in a meta-analysis of influences of Best Management Practices (BMP) in the United States, Baumgart-Getz et al. [7] found that data type, aggregation of constructs, and specific practice could explain some of the apparent heterogeneity in the effects of individual social variables found in earlier reviews [7]. For example, while the effect of education on adoption was non-significant as a category, when it was disaggregated into its components, extension training had a significant positive impact [7]. Baumgart-Getz et al. indicated that research could focus on how individual social factors in areas of capacity, environmental awareness, and attitudes, combine to influence adoption

of BMP and that policy effort be targeted to address situations created by different combinations [7]. More recently, Prokopy et al. [9] and Ranjan et al. [10] reviewed a database of studies on adoption of agricultural conservation practices in the United States between 1982 and 2018 [11]. The data is from published peer-reviewed articles and reports, as well as non-peer reviewed reports, dissertations and theses [11]. Based on their analysis of quantitative studies in this database, Prokopy et al., similarly to their earlier work, found that overall few independent variables had a consistent statistically significant relationship with adoption of conservation practices [9]. Among the factors that emerged as likely to enable practice change were: attitudes towards the environment and towards specific programs and practices; self-identified motivations; experience of other conservation practices; use of information; awareness of programs or practices; farm size; and income. In their thematic synthesis of qualitative studies, Ranjan et al. identified trends for factors enabling adoption of conservation practices, including farmer characteristics, environmental awareness, and trust in information sources. Factors that represented primarily barriers to adoption were farm management; negative perceptions of a conservation practice and its risks; and land tenure. By focusing on qualitative studies, Ranjan et al. explored the complex interplay of individual and contextual characteristics and discussed the influence of economic factors, social norms, perceptions of programs, and farm characteristics, as operating along a 'motivation-barrier continuum' in the adoption of conservation practices [10] (p. 1174).

An aspect of adoption research that until recently received limited attention in reviews of the literature is the use of theory. Although Pannell et al. referred at times to diffusion of innovation [12] and collective action theory [13], they took a 'conscious avoidance' approach to use of theory, ideology, and jargon as their purpose was to integrate disciplinary approaches in adoption research [4] (p. 1408). When theory has been included as a study characteristic, reviews have converged in suggesting a greater role for theory in farming practice research, as well as more consistency and precision in its application [7,9,10]. Already in their meta-analysis of previous research, Baumgart-Getz et al. found that a frequent lack of theoretical precision in measures of behavioural constructs, particularly for attitudes and awareness, explained some of the earlier mixed and/or inconclusive results [7]. The Prokopy et al. and the Ranjan et al. reviews observed correspondence between empirical evidence from quantitative and qualitative studies and some key aspects and mechanisms of practice change incorporated in social and behavioural theories [9,10]. However, studies were often not theoretically framed, or used theory selectively, and there were many gaps in the evidence for specific theoretical aspects and mechanisms [7,9,10].

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 explains or predicts events or situations by specifying relations among variables [14,15]. Due to its abstract nature, theory may offer an approach to deliver shared understanding across content or topic areas. 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 [16,17]. 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. For example, researchers can examine if an initiative has had no effect upon the hypothesised mediator, or the hypothesised (and successfully influenced) mediator has had no effect upon adoption behaviour, thereby delivering a fine grained understanding of how an initiative may effect change [16,18,19].

Theory is a 'dynamic entity' whose value depends on its application and refinement based on empirical findings [16,19]. At its best, theory serves to create an organising framework that the research and practitioner community can confidently apply to achieve known and previously supported outcomes. Theories, therefore, might foster understanding of a particular phenomenon. Given that the same constructs appear in numerous theories we acknowledge the same phenomenon may be explained by multiple theories. Based

on empirical findings, theories may be optimised or discarded as additional evidence emerges [16].

Recent applications of communication and psychology concepts in policy theory suggest that stakeholders are more likely to process and appraise research findings when they are presented through storytelling and framing techniques [20]. It is suggested that a theory represents a viable frame for organising and presenting empirical findings to stakeholders responsible for developing and implementing initiatives that seek to broaden the uptake of sustainable farming practices. Against this background, this study focused on the role and use of theory 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?

Sustainable farming practice is used in this article as a general term for practices that share an overarching goal to meet changing human needs, while simultaneously ensuring the long-term productive potential of natural resources and the maintenance of their environmental functions [3]. Sustainable farming practices are variously described in the literature as agroecology, agroforestry, conservation agriculture, sustainable agricultural practices, sustainable land management, and climate smart agriculture. Where specific practices and principles are the object of study, for example conservation agriculture, reference is made to the terms used in the articles.

2. Materials and Methods

The present study is located within a wider systematic literature review. The systematic review was undertaken to identify recent (2014–2018) empirical research that focussed on understanding barriers to practice change. Studies located within the systematic literature review that reported theory or construct use were further analysed to identify the theoretical underpinnings of research on barriers to practice change.

2.1. Systematic Literature Review

The systematic literature review followed PRISMA Statement protocols [21] and procedures used in previously published systematic literature review studies focussed on understanding behaviour change [22,23]. A total of six databases (EBSCO All Databases, Emerald, ProQuest All Databases, Ovid All Databases, Web of Science and Scopus) were searched. Search terms and exclusion criteria are detailed in the Supplementary file.

2.2. Use of Theory

This paper is part of a wider project that sought to identify and locate papers reporting on factors enabling and inhibiting farming practice change. A total of 75 articles were located using search terms reported in the Supplementary file. The 75 papers reported research identifying, explaining and predicting elements that prevent, discourage, or otherwise deter farmers from changing farming practices to minimise or reduce negative consequences for the environment. Given that theory is one mechanism that can be applied to explain or predict change, a closer examination of reported theory use was warranted. To this end, all articles were searched for the following terms: theor*; framework; model; construct; concept. The search included *theor* followed by an asterisk *. This search term permits words with different endings to be identified by the research team. By inputting theor* into a search field (e.g., keyword; abstract; title) the results included documents that had terms like *theoretical*, *theory*, and *theories* in the relevant fields. Those articles that did not include any one of these terms were excluded from further review. The remaining 57 articles were then analysed in terms of their use of theory in reported studies. Based on theory use as qualified by Glanz and Bishop [14], studies were categorised as:

1. Informed by theory: A theoretical framework was identified, but no or limited application of the theory was used in specific study components and measures;

2. Applied theory: A theoretical framework was specified, and several of the constructs were applied in components of the study;
3. Tested theory: A theoretical framework was specified, and more than half the theoretical constructs were measured and explicitly tested, or two or more theories were compared to one another in a study; or
4. Building/creating theory: new or revised/expanded theory was developed using constructs specified, measured, and analysed in a study.

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 theory to date in the research on barriers to sustainable farming practices.

3. Results

3.1. 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 several continents. The largest group of studies examined crop farming (n = 12); agricultural areas included in other studies were aquaculture in the Solomon Islands [24], horticulture [25], viticulture [26], palm oil cultivation [27], and agroforestry [28].

The most frequently included sustainable farming practices in crop farming were minimum 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 farming practices were also examined [26,29]. In the aquaculture sector, Blythe et al. [24] examined the adoption of a new aquaculture variety (tilapia fish) among villagers in the Solomon Islands (see Table 1).

Table 1. Description of studies.

Author	Theory	Agricultural Sector & Country	Target Practice	Data Collection and Sample
Blythe et al. (2017) [24]	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) [30]	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) [31]	Diffusion of innovation	Crop farming (cabbage) Benin	Pest control/management (eco-friendly nets)	Survey with small-scale vegetable farmers (n = 214)
McCarthy & Schurmann (2015) [25]	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)
Ndah et al. (2018) [32]	QAToCA	Crop farming Zambia	Conservation Agriculture (minimum 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) [33]	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) [26]	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) [27]	Neo-institutional theory	Palm oil cultivation Malaysia	Sustainable palm oil cultivation	Semi-structured individual interviews with small-holder growers (n = 34)
Borremans et al. (2018) [28]	Agricultural Innovation System (AIS) (Lamprinopoulou et al., 2014)	Agroforestry (tree and crop combinations) Belgium	Agroforestry (combination of trees crops and/or livestock)	Semi-structured interviews (n = 25); focus group (n = 16)
Brown et al. (2018a) [34]	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) [35]	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)

Table 1. *Cont.*

Author	Theory	Agricultural Sector & Country	Target Practice	Data Collection and Sample
Blesh & Wolf (2014) [36]	Socio-ecological approach (Modified resource based framework; Wolf & Primmer, 2006)	Mixed crop farming (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)
Lemken et al. (2017) [37]	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. (2018) [38]	Means-End chain analysis approach [39]. 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 individual and group interviews with citrus farmers and agricultural advisors (n = 20) Pre-trial surveys (n = 5 farmers; n = 5 advisors). Post-trial survey (n = 4 farmers; n = 4 advisors)
Tajeri moghadam et al. (2020) [40]	Health belief model	Crop farming Iran	Water conservation	Questionnaires with (n = 235) farmers

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 [41]. Studies included one to all three CA principles.

3.2. Theories and Models

Behavioural theories and models used or adapted in the development of research frameworks and designs included diffusion of innovation [12]; the transtheoretical model or stages of change [42]; the theory of planned behaviour [43–45]; the theory of behaviour modification [46]; Schwartz theory of basic values [47]; means-end chain analysis approach [39]; vulnerability approach [48]; Walker's (2002) causes of non-adoption [49]; resistance to innovation [50]; and the health belief model [51]. Several studies framed their research in ecological theories or system based approaches, including neo-institutional theory [52]; the socio-ecological approach; World Bank innovation system concept [53]; sustainable livelihood approaches [54]; and agricultural innovation system [55]. Application of each theory is now discussed in turn (see Table 2 for a summary of results).

3.2.1. Diffusion of Innovation

Diffusion of innovation (DI) has been used extensively as a general process model in decision making and behaviour change research across most social sciences to explain and predict rates of adoption of an innovation (practice or technology) [56]. The seminal work for the theory was undertaken in the field of agricultural sociology in the 1940s by Ryan and Gross who observed the adoption of hybrid seed corn in two Iowa communities [57]. Diffusion is the process through which an innovation, defined as an idea perceived as new, spreads via certain communication channels over time among the members of a social system [56]. 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 [12]. 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 [12]. Subjective perceptions and expectations in the 'innovation-decision' process are assumed to be influenced by a combination of individual social, economic and cultural circumstances [12].

Diffusion of innovation [12] was applied to identify where farmers were situated in the innovation–decision process [30]; to identify the determinants of farmer perceptions about an innovation [24,31]; and examine the influence of perceived characteristics/attributes of practices in adoption behaviours [24,30,31]. Vidogbena et al. [31] examined the opinions of small-scale farmers about eco-friendly nets for pest control using concepts of anticipated performance (belief that using the innovation will improve livelihoods), ease of use, social pressure (degree to which one is influenced by others' opinions), and external support (access to knowledge and finance) [31]. Perceived high labour requirements were identified as the major barrier to adopting eco-friendly nets, particularly on larger vegetable crops, and among farmers who had little or no experience in a trial, and those living far from extension services [31].

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) [24]	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) [30]	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.
Vidogbena et al. (2016) [31]	Diffusion of innovation	Opinions about the use of eco-friendly 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) [25]	Diffusion of innovation (MacVaugh & Schiavone, 2010)	Factors that prevent the adoption of more sustainable farming practices across the 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) [32]	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.
Zeweld et al. (2017) [33]	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.

Table 2. *Cont.*

Author	Theory/Model	Study Focus	Theoretical Constructs/Models	Barriers to Practice Change
Márquez-Garciá et al. (2018) [26]	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) [27]	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.
Borremans et al. (2018) [28]	Agricultural Innovation System (AIS) (Lamprinopoulou et al., 2014)	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) [34]	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).

Table 2. *Cont.*

Author	Theory/Model	Study Focus	Theoretical Constructs/Models	Barriers to Practice Change
Brown et al. (2018b) [35]	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.
Blesh & Wolf (2014) [36]	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) [37]	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).	Attitude to mixed cropping 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) [38]	Means-End chain analysis approach [39]. 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 among female farmers hindered early land preparation and planting 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.

Table 2. *Cont.*

Author	Theory/Model	Study Focus	Theoretical Constructs/Models	Barriers to Practice Change
Tapsuwan et al. (2015) [29]	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 in relation to 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) [40]	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.

Blythe et al. [24] sought to understand innovation-decisions and decision-making processes underlying adoption and non-adoption of an aquaculture innovation in the absence of extension services. Based on the emphasis in diffusion of innovation theory on the role of communication channels over time among members of a social system, Blythe et al. explored the influence of opinion leaders as a channel for diffusion. Additionally, included in their study were socio-economic characteristics of adopters and characteristics of the innovation [24]. Blythe et al. found that opinion leaders were the most frequent communication channel for accessing information about the aquaculture innovation among both adopter and non-adopters. However, opinion leaders were not generally the source of 'how-to' knowledge unless they were adopters themselves, and lack of technical knowledge was one of the main reasons for non-adoption, along with commitment to other livelihoods, lack of tools, low trialability and observability of the practice [24].

Goldberger et al. [30] applied diffusion of innovation to study the use of biodegradable plastic mulches by specialty crop growers in several areas of the United States [30]. Factors acting as barriers and enablers to adoption were identified in the exploration of perceptions of relative advantage; compatibility; complexity; trialability; and observability of biodegradable mulches. Goldberger et al. identified lack of knowledge, high cost, unpredictable breakdown of biodegradable mulches, and the unknown impact of biodegradable mulches on the soil, as the major considerations regarding adoption for specialty crop farmers. Lack of sufficient knowledge and information on correct use of mulches represented a barrier for growers as well as intermediary agents [30].

3.2.2. Theories of Non-Adoption

Two studies focussed specifically on characteristics of an innovation that led to negative innovation-decisions [25,29]. Tapsuwan et al. [29] explained the non-adoption of an information bulletin for sustainable irrigation practices with reference to Walker's [49] criteria for non-adoption of decision support tools in rural resource management (irrelevance, inaccessibility, inflexibility, lack of confidence, institutional and political barriers). In a participatory pre-post evaluation of the bulletin, they found that relative importance of items contributing to causes of non-adoption changed from pre to post trials, indicating that barriers to adoption reflected the evolving needs of end-users as they became more familiar with the tool. This was evident, for example, in forecasting weather and evapotranspiration being replaced by representation of irrigated amounts versus crop water requirements of last week, as the most significant issue for relevance of the tool [29].

McCarthy & Schurmann [25] framed their exploration of factors preventing the adoption of innovations in a sample of Australian growers who practiced varying levels of sustainable farming, with reference to MacVaugh and Schiavone's [50] 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) [50]. McCarthy & Schurmann found that resistance to innovation was caused by a combination of factors including the perceived complexity of sustainable farming, labour intensity, and a requirement for skilled labour; financial risks relative to current income security; limited knowledge of or access to localised evidence and information which also reinforced fear of being locked-in to organic horticulture; finally, beliefs about symbols of 'good' farming, including high yields and 'tidy' farms (e.g., free of weeds), and consumer demand for high quality produce (e.g., large and unblemished) were important barriers to adoption among more conventional farmers [25].

3.2.3. The Health Belief Model

The Health Belief Model (HBM) [51] 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 sus-

ceptibility 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. [40] used constructs of the HBM to explore farmers' water conservation behaviours in Iran and found that perceived barriers were negatively correlated with all other constructs in the model. However, barriers did not add to the overall HBM model's explanatory power beyond perceived susceptibility to risks associated with traditional irrigation and excessive water consumption; perceived benefits to farmers agricultural activities, including the avoidance of water fees, and the economy; and cues to action, including information and learning workshops [40].

3.2.4. Theory of Planned Behaviour

The theory of planned behaviour (TPB) 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 [43–45]. 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 [43–45].

Márquez-Garciá et al. adapted elements of TPB in a comparative analysis of corporate conservation behaviours in vineyards participating in a sustainability winegrowing program (WCB: Wine, Climate Change and Biodiversity) and non-participating vineyards [26]. The theoretical framework included attitudes towards conservation behaviour (belief strength and outcome evaluations); social influence (organizational pressure, community pressure; motivations to comply); and perceived behavioural control (self-efficacy, organisational support, and government support). Results indicated that most barriers to adoption related to organizational resources, both economic and human, or technical support (e.g., lack of professional expertise, lack of evidence-based research). Managers reported some management practices becoming more complex or inefficient with conservation, such as maintaining native trees within crop rows that may impede machinery. In addition, many managers did not see evidence of direct impacts on wine production, such as improved quality or higher yields, even from WCB vineyards, and this added to the economic and opportunity costs of holding conservation land rather than productive land. Furthermore, many managers perceived that the wine market did not require nor monetarily reward biodiversity conservation efforts. Overall, WCB vineyards identified more constraints, which Márquez-Garciá et al. suggested could be a result of their adopting more conservation practices or receiving more information about dealing with constraints than the comparison group [26].

In their analysis of smallholder farmers intentions to adopt sustainable farming practices (minimum tillage, row planting), Zeweld et al. [33] used decomposed TPB [58] which includes elements of diffusion of innovation theory, theory of planned behaviour, and economic constraint theory. Within the decomposed TPB theoretical framework, farmers' intentions to adopt are explained by attitudinal belief which includes perceived relative advantage, perceived complexity and perceived compatibility; and, perceived behavioural control decomposed into self-efficacy and facilitating conditions/resources [58]. Based on social cognitive theory described by Venkatesh et al. [59] and diffusion of innovation [12], the roles of social context and communication in farmers' intentions were included in the framework as normative influences, operationalised as media, technical training, extension services and social capital/social influence.

Zeweld et al. [33] found that attitudes and normative issues explained farmers' intentions to adopt both types of sustainable practice. In turn, farmers attitudes were predicted by perceived usefulness, social capital, and perceived ease of operation. Social capital and technical training also influenced normative issues. Some differences were found in con-

struct relationships for minimum tillage and row planting. Specifically, lack of labour and money acted as barriers to the adoption of minimum tillage, possibly due to the negative effect of resource shortages on farmers perceived control. In addition, minimum tillage was not perceived to be compatible with existing individual and social farming norms, which negatively influenced attitudes to adopting this practice. Contrary to the study's hypotheses, extension services had a significant negative effect on the normative issues of farmers for minimum tillage [33]. Zeweld et al. suggested further research might aid understanding the effect of extension services on normative issues [33].

3.2.5. The Trans-Theoretical Model

The trans-theoretical model (TTM) [42] 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 [42] 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. Lemken et al. [37] applied the transtheoretical model to analyse how attitudes towards mixed cropping and perceptions of technical barriers influenced where farmers were situated along the first four stages of the adoption process. Attitudes to mixed cropping were constructed to include worthiness, and promotion of a farmer's gain goals, normative goals, and hedonic goals. Technical barriers were defined as those that reduced the perceived feasibility of multiple cropping and were measured on adequate labour availability, synchronization of crop maturity and separation of the harvest or direct use of a mixed harvest [37]. Lemken et al. found that limited compatibility with a farmer's existing set of technologies and resources, labour efforts required for crop management, and the lack of specific political support were barriers to adoption of mixed cropping in Germany [37].

3.2.6. Means-End Chain Analysis

Means-End chain (MEC) analysis originated as a practical approach for understanding choice criteria and underlying motivations in consumer decision making [39]. 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 [39]. 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 [39]. Ngigi et al. [38] modified the MEC approach by replacing product attributes with strategies and analysed the values or goals underpinning the selection of 'climate-smart' farming strategies in Kenya from a gender perspective. The analysis of farmer values was based on the Schwartz theory of basic values [47] which 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) [47]. According to Schwartz, values are desirable end goals that motivate and guide selection of actions based on conscious and/or unconscious evaluations of action outcomes relative to values [47]. To incorporate the circumstances in which farmers operate and make choices, the Ngigi et al.'s theoretical framework incorporated elements of the 'vulnerability context' that consists of user characteristics, information and technology, institutional arrangements and geo-physical characteristics [48]. Ngigi et al. found gender-based differences in the relative importance of values which were reflected in preferred climate-smart strategies and the consequences imputed to selected strategies [38]. They also found that that gender-differentiated values and beliefs acted as barriers to climate adaptation when they prevented helpful strategies or promoted strategies that were inappropriate for geophysical conditions [38].

3.2.7. Qualitative Expert Assessment Tool for CA Adoption (QAToCA) & Diffusion of Innovation

Ndah et al. [32] combined the Qualitative expert Assessment Tool for CA adoption (QAToCA) [60], diffusion of innovation [12], elements of the theory of behaviour modification [46] and of the theory of planned behaviour [43–45], to assess perception, attitude, and intention of farmers at various stages of adaptation and adoption of CA or its modified version—the Conservation Farmers Unit (CFU)-CA—in Zambia. Variables included in the study were factors at the upper-scale socio-economic, institutional, and cultural levels, and at the household and farm levels; as well as characteristics of the innovations (trialability, compatibility, divisibility, relative advantage). The World Bank innovation system concept [53] was used as the systemic overarching framework in which linkages among all elements were analysed. Ndah et al. argued that adaptation and partial adoption represent theoretical stages in a behavioural change process and in the diffusion of innovations more broadly [32]. In their study, therefore, they focussed specifically on the factors that influenced CA adaptation and partial adoption within the selected case study regions, with the goal of deriving useful lessons for CA in other African countries [32]. Ndah et al. found that specific barriers to adaptation and adoption at the farmer and farm level included: difficulties with weed control, absence of markets for farm outputs, non-compatibility of CA with village rules, pests, static mind-sets on ploughing, land availability and ownership—especially for women, and seasonal variation in rainfall [32]. Hindering factors for a wider adaptation and adoption of CA in Zambia, notwithstanding a relatively supportive institutional environment, included issues such as limited credit facilities, absence of decentralized agencies for agriculture and development issues, uncertainty over land access, ownership, and absence of ready markets for CA products [32].

3.2.8. 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 [61]. 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 [62]. 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 [61]. 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 strategies [61].

Brown et al. [34,35] 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. 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 these countries [61]. In their studies, Brown et al. [34,35] identified resource constraints at all platform levels that explained low perceived benefits, feasibility and relevance of CA practices for individual farmers [34,35]. 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 [34,35]. Limited research and extension services at the institutional level, poor coordination and unequal access were constraints to knowledge and information dissemination. Socio-cultural aspects, including absence of connectivity and collaboration among farmers, and between farmers and other stakeholders, distrust in

extension service officers, and cultural norms, were also identified as significant barriers to uptake of CA [34,35].

3.2.9. 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 [52]. Organisational change and diversity are explained by connectedness and interrelations between individual actors' in a relevant ecosystem [52]. Contemporary NIT retains notions of rational myths, diffusion, legitimacy, and isomorphism, and focuses on systemic and individual level variables. Martin et al. [27] used NIT to frame their analysis of attitudes to sustainability investment and innovation held by micro and small enterprise palm oil cultivators in the state of Sabah in Malaysia. Barriers and enablers for sustainable change were explored relative to the dynamic interrelations between structural factors and cultural and cognitive structures that underlie behaviour and organizational arrangements. Martin et al. reported a general lack of interest in investing in sustainable innovations in the cultivation of palm trees. This was explained in terms of institutional blockages which prevented access to and engagement with users upstream in the palm oil production chain and with development policy initiatives. Institutional logics in the Sabah state included the strong influence of neighbours and friends, shared tacit knowledge and biases such as a distrust of outsiders and government or quasi-government representatives. In this context, farmers appeared to be passive price-takers relative to local millers with whom farmers preferred to interact relative to organised networks. In addition to unregulated and informal markets, local systems of land rights in the area were a source of insecurity for most farmers who had heard of or experienced land grabbing or loss of rights and had little trust in official processes for land title allocation. Farmers who relied solely on the land as a source of income had no or very limited knowledge of sustainability issues and associated farming practices. Marginally better knowledge was observed in farmers who had other sources of income beyond farming, although this did not appear to make a significant difference in attitudes to investment or farming practices [27].

3.2.10. 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 [36] took a socio-ecological approach to examine the adoption of new agroecological management practices in industrialised crop and livestock production in the United States. Using a resource-based model of innovation, they described how the relations between actor internal (ecological and farm enterprise resources; personal and cognitive resources) and external resources (network relations with peers; knowledge organizations; policy) enable and constrain adoption of innovations. 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. In their study, Blesh and Wolf compared processes of technical change toward farming systems with the greatest potential to reduce nitrogen pollution, in two contrasting regions of Iowa [36]. Blesh and Wolf reported that actors in both regions perceived that the macro agricultural policy framework was designed for conventional farming systems. Similarly, agroecological farm management was considered to be more complex than traditional industrial methods as it required more explicitly managing biological relationships. However, the opportunities and barriers encountered in transitioning to agroecology differed in the two regions due to their contrasting physiographic properties. Specifically, the relative geographic isolation of farms within the central Iowa region and distance supportive infrastructure (e.g., organizations and resources) constrained some opportunities for formal and informal learning, which were highly significant in mitigating some of the risks of transitioning in the north-eastern region of Iowa [36].

3.2.11. Agricultural Innovation System (AIS)

Borremans et al. [28] used the system-based framework of AIS [55] to understand the limited implementation of agroforestry which has been promoted as part of a broader move to diversified farming systems in Flanders, Belgium. 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 the innovation processes. A well-functioning innovation system should focus equally on how the whole innovation system adapts to emerging challenges, as well as on parts of the innovation system [55].

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 [55]. Through these analyses, failures at micro and macro levels of an AIS system are identifiable relative to conditions or processes necessary for innovation. Micro-level failures may be found in the structure of the physical, knowledge and financial requirements; in the hard and soft institutional conditions; in the interactions between actors; the capabilities (competencies and resources) of actors; and the conditions and relations between market parties. Macro-level failures may be observed in terms of directionality (e.g., lacking shared goals and vision); demand articulation (e.g., unmet user needs to enable the uptake of innovations); policy coordination (e.g., inadequate multi and across levels policy coordination); and reflexivity, or the ability of the system to monitor, anticipate and involve actors in self-governance [55].

In their study, Borremans et al. identified geophysical, technical, financial, legal, organizational and social elements that contributed to micro and macro level failures constraining transitions to agroforestry adoption [28]. For example, farmers considered existing modern machines to be incompatible with having trees on fields particularly with limited land sizes [28]. Farmers often felt locked into existing production systems as they had limited financial buffers to experiment with agroforestry which was perceived as being more complex and labour intensive; further, shade created by tree canopy would negatively impact production [28]. The policy and regulatory frameworks were complex and cumbersome, due also to mismatches in legislation of different policy sectors such as agriculture, nature, forestry, and spatial planning. For example, it remained difficult to gain permission of landowners for planting trees on leased land. Similarly, the subsidies encouraging establishment of agroforestry plots did not extend to their maintenance. Finally, knowledge of agroforestry was not widespread among farmers and their social context, due to their very limited integration in the Flemish agroforestry network and no communication dissemination channels for the broader community [28].

4. Discussion

Achieving the interrelated global goals of food security and climate change mitigation and adaptation by 2050 requires extensive changes in agricultural production and practices across the world. However, with variations across countries and regions, rates of change are reported to be below those needed to provide for the demands of the growing global population while preserving and enhancing natural resources on which agriculture depends. Understanding both the enablers and barriers to adoption is an integral element in initiatives to accelerate the rate of change. Reviews of the adoption literature suggest that limited conclusions can be drawn on the explanatory power of research on the determinants of change to sustainable farming practices [4,6–10]. Differences in research results underline that adoption of new farming practices, whether it be in the context of conventional or sustainable farming systems, is complex not only due to the multitude of possible factors involved [12,56]; but also because of the variations in the specific social, economic, and

ecological conditions in which adoption efforts occur [6,10]. However, the under-utilisation or inconsistent application of theoretical constructs, has also likely hindered the extent of analyses and comparisons of results needed to build a critical body of knowledge [9,10]. Based on our assumption that theory-informed research can contribute to adoption policy and practice, this review ascertained and described the use of theory in the identification and examination of barriers to adoption in recent literature.

This review of theory use in 75 peer reviewed articles is located in an evidence review that sought to identify factors enabling and inhibiting growing practice change. Close examination of the 75 articles resulted in the inclusion of 16 studies for this review, across which a total of 14 theories and models informed research approaches. Many theories and models in the studies have been used across disciplines in the social and behavioural sciences, including: diffusion of innovation [12,56]; the transtheoretical model or stages of change [42]; the health belief model [51]; the theory of planned behaviour [43–45]; and the socio-ecological approach. This review also identified several studies that based their research in system models specific to the agricultural sector (Tables 1 and 2).

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).

While there is overlap among several theoretical concepts appearing in social and behavioural theories, they generally vary in terms of their focus on explaining a behaviour or a situation, relative to their focus on identifying factors and processes involved in changing behaviour [15]. Similarly, when applied, socio-ecological and systems approaches may vary in terms of their focus on the current situation relative to a potential future [34,35]. Examination of adoption through a behavioural theory lens, assists in identifying the role of internal constructs in adoption behaviours (e.g., attitudes, intention formation, self-efficacy), as well as the possible pathways by which individual internal constructs may be influenced by perceptions of factors in the environment. The most frequently used theory overall was diffusion of innovation [12,56], both as the basis of theoretical frameworks e.g., [24,30,31] and as the source of frequently used theoretical constructs that were 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., [26,28,32,33,37].

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 [56], studies in the review emphasised perceptions of comparative advantage among individual farmers as most significant, which is consistent with Pannell et al.'s [4] suggestion that a common theme explaining the adoption or non-adoption of sustainable farming practices was the extent to which they supported individuals to better achieve their goals. Similarly, perceived complexity of new practices and incompatibility with existing practices were barriers to positive attitudes and intentions, and were aggravated by the absence of trialability and observability. An exception was the Tajeri moghadam et al. [40] 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 [40]. Using a

means-end-chain (MEC) analysis to examine motivations of male and female farmers to change crop management practices, Ngigi et al. [38] found the common goal of minimising the negative consequences of weather variability to be prominent in the community [38]. 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 [40] and Ngigi et al. [38] 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 [25] study on 'resistance to adoption' [50] 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 [10,63]. Although socio-behavioural theories conceptualise adoption or non-adoption as a decision process in which multiple internal and external factors have a role [12], the behavioural unit of analysis is predominantly at the individual farmer level. Contextual elements, therefore, tend to be examined for their effects on the individual. 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 those at the level of farmers' practices [34,35]. Studies that based theoretical frameworks and models in systems approaches conceptualised barriers to adoption as the result of interrelationship and interactions among contextual elements (e.g., limited or inadequate extension services; limited supply and demand markets; land ownership structure; laws and regulations; poverty; embedded culture). Several studies included in this review based their theoretical frameworks in system models developed specifically to examine the adoption of sustainable farming practices. For example, the qualitative expert assessment tool for CA adoption in Africa (QAToCA) [32,60,64] 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. In addition to specific constraints to adoption at the farm level, Ndah et al. [32] identified long-term structural issues that hinder the full adoption of CA (as defined by FAO, [41]). They noted that the concurrent structural issues and lack of flexibility at the macro policy level regarding what constitutes adoption of CA, failed to recognise the significant role of partial adoption and adaptation in the transition to sustainable practices in Africa. Similar conclusions were reached by Brown and colleagues [34,35] who developed and applied the Livelihood Platforms Approach (LPA) to examine the role of extension services in the adoption of CA in non-mechanised smallholder subsistence farming. 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 [34,35]. Based on their approaches, Brown et al. [34,35] identified fundamental issues about the relevance and feasibility of CA in the African context noting these needed to be addressed as a priority to overcome constraints at the individual farmer level [34,35]. Similar dilemmas were raised by Martin et al. [27] in their neo-institutional analysis of the potential for sustainable innovations in the cultivation of palm oil in Malaysia. A general lack of interest in sustainable farming investment among small cultivars was representative of institutional logics permeating beliefs, norms, and perceptions of risk. In addition, inse-

cure land rights, fear of land grabbing, and lack of legal access to good quality land served to maintain the status quo [27]. Martin et al. also described challenges encountered during their studies, including how they negotiated language, geographical remoteness, lack of infrastructure, and cultural norms [27]. At a systemic level, these difficulties represent risks to the adoption of sustainable farming practices, in that they may effectively constrain or limit understanding of significant issues for policy and program development [27].

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 [36] and the agricultural innovation system (AIS) framework used by Borremans et al. [28] both examined the multiple constraints to shifting established large scale intensive farming systems into 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 [36]. Therefore, understanding why and how transitions take place requires approaches to integrate agency, collective action, landscapes, ecological interactions, and the political economic context [36]. 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 limited 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. [28] found that regulatory and legal structures acted as constraints to the further establishment of agroforestry. By applying the AIS framework to conceptualise a functioning agroforestry system of structures and functions, Borremans et al. were able to identify constraints to 'transformation' across domains and themes [28].

Although this review identified limited application or reporting of theory in research on barriers to practice change, it is suggested that when theory is applied different perspectives are evident. Namely theories focused on what individual farmers think or theories that acknowledge the many and varied influences interacting to support or deny the practice changes sought. In the context of research on highly complex issues such as the adoption of sustainable practices, a combination of theoretically based units and foci of analyses can offer complementary insights [10,14,17]. Findings emerging from this evidence review indicate improved reporting practices for theory are needed to build understanding in the field. Opportunities also exist to extend understanding with review searches that focus on application of specific theories in research across behaviour change contexts (e.g., Diffusion of Innovation) and more. The present review was limited to a five-year period to capture the most recent progress in the field. More can be learned from comparing research reporting practices across different time periods. Future research is recommended that takes a longitudinal approach, comparing reporting practices across different five-year periods. Longitudinal examinations would extend our understanding of theory use in the adoption literature over time.

5. Conclusions

Research has a critical role in supporting sustainable agriculture through delivery of evidence on what is and is not working. Theory offers one way for researchers to speak the same language through consistent terms and shared understanding that can be applied across time. Opportunities to extend theory use are evident with more than 4 in 5 studies currently not clearly reporting theory. Consistent with earlier work our results suggest that there are several theories and models that can be applied delivering a shared understanding of factors explaining the adoption of sustainable farming practices. Factors identified in this review stem from a range of theories indicating a range of individual,

institutional and ecological factors. Identification of a range of factors across alternate theoretical perspectives point to the need to extend theory testing and building efforts across studies and contexts to deliver clear shared stories that can be confidently applied to achieve the outcomes sought. This evidence review seeks to serve as a starting platform that can enable researchers to select a theory and commence efforts to deliver a coordinated approach needed to achieve 2050 targets.

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