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Understanding the potential of sustainability turn in farming: review of sociotechnical adoption factors of agri-environmental cropping practices

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Review Article

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Abstract

While farming practices such as intercropping, cover cropping, and green manuring are promoted as contributors to environment-friendly agriculture by balancing agricultural production with environmental sustainability, their uptake by farmers has still been limited. This paper provides a holistic global view of the adoption factors of such agri-environmental cropping practices based on a systematic literature review of 53 international peer-reviewed articles. Qualitative analysis of the reviewed studies shows that adoption factors explored by researchers can be categorized along nine thematic groups (sociodemographic characteristics, socioeconomic/financial conditions, environmental conditions, tangible assets and inventory, pre-existing farm practices, agrotechnical aspects of the practice, public support instruments, information and knowledge resources, community dynamics) and two transversal dimensions (generic and practice-specific attitudes), with an additional differentiation of micro- and macro-levels within the former. While many individual factors across the various groups and dimensions are highly context sensitive in terms of their impact on practice adoption, the analysis also identifies a set of factors that demonstrate common trends across the studies. The offered holistic conceptualization and analysis of the adoption factors of the reviewed set of practices contribute to a more comprehensive understanding of the broader potential impact pathways in the farmer reorientation toward sustainable crop production.

Introduction

The dominant practices of agricultural production across the globe are seen by many expert panels as alarmingly unsustainable in the light of the environmental impacts, calling for more determined steps in harnessing, maintaining, and enhancing biological and ecological processes in agricultural production (HLPE, 2019), along with ensuring the reduction of greenhouse gas (GHG) emissions and the sequestration of CO_2 (IPCC, 2022). International organizations have highlighted the need for widespread adoption of climate-smart and carbon-neutral production processes and technologies (European Commission, 2019; OECD/FAO, 2023), enabling movement toward environment- and climate-friendly farming. The anticipated shift in practice orientation requires different measures to reach this ambition (Peeters et al., 2020). These measures range across arable, horticultural, and mixed farming, with cropping being one area where this interest has materialized in a range of new and rediscovered practices (Wezel et al., 2014) that contribute to sustainable crop production.

Among these agri-environmental cropping practices, which aim to balance agricultural production with environmental sustainability, experts promote sequential or simultaneous growing of two or more compatible crops on the same field during a single growing season as a nature-based alternative to conventional agriculture. Such practices that enable a more sustainable soil use include intercropping, cover cropping (including catch crops), and green manuring. Intercropping, or mixed cropping, refers to the practice of growing one crop together with another cash crop or a service crop (i.e., a crop grown to provide services to other crops rather than for production purposes) (Lithourgidis et al., 2011; Gardarin et al., 2022). Intercropping is described as a sustainable practice that can improve resource use efficiency for both nutrients and water, thereby facilitating low-input agricultural practices (Mazzafera, Favarin and Andrade, 2021; Jensen, Carlsson and Hauggard-Nielsen, 2020), and it is found to provide benefits in terms of weed, pathogen, insect pest control, relative yield, and gross profitability (Huss, Holmes and Blubaugh, 2022). Cover crops are primarily planted for covering and protecting the soil during periods when the main cash crop is not in the field. Aside from reducing farmer dependence on external inputs, cover cropping contributes to soil health and carbon sequestration, pest and weed management, as well as prevents erosion and enhances nutrient cycling (Scholberg et al., 2010; Gerhards and Schappert, 2020). Green manure crops are specifically grown to be incorporated into the soil while still green and actively growing with the primarily goal of improving soil fertility and structure (Fageria, 2007; Talgre et al., 2012). These crops are featured as important in sustainable farming because of nitrogen fixation, nutrient enhancement, enhancement of organic matter, improvement of rooting action, soil and water conservation, soil microbial activity, and weed suppression (Reddy, 2016). By exploiting the inherent properties of supplementary crops, such practices can thus altogether help improve soil quality, reduce the release of carbon dioxide from the soil, and reduce GHG emissions due to lower chemical fertilizer and pesticide inputs, thereby contributing to the mitigation of climate change.

Despite the demonstrated benefits of the aforementioned practices and attempts to facilitate their more widespread use, uptake by farmers across the world has been limited. This, in turn, raises questions about the reasons behind adoption decisions, which has been a topic for original national studies across the world. Over recent decades there has been a growing body of systematic literature reviews analyzing these studies to obtain a more comprehensive view of the factors underlying innovation adoption in sustainable farming (see, e.g., Knowler and Bradshaw, 2007; Prokopy et al., 2008; Baumgart-Getz, Prokopy and Floress, 2012; Ahnström et al., 2008; Liu, Bruins and Heberling, 2018; Tey et al., 2017; Prokopy et al., 2019; Serebrennikov et al., 2020; Piñeiro et al., 2020; Ogieriakhi and Woodward, 2022), which provide valuable insights regarding the overall diversity and specific types of adoption factors among farmers. However, these studies either cover only specific countries or regions, or take broader clusters of practices as their entry points.

The present analysis is based on a qualitative systematic review of peer-reviewed articles published between 2010 and 2020, which focus specifically on one or several agri-environmental farming practices involving intercropping, cover cropping, and green manuring, or include these among the broader set of explored practices. The present contribution aims to provide a global holistic view of the adoption factors of such practices. This analysis also contributes to the understanding of potential impact pathways in facilitating farmer reorientation toward sustainable farming.

We first lay out the methodological principles applied for the identification, screening, and selection of the articles covered by the review, followed by a brief overview of their profile. We then proceed with the presentation of results regarding the inductively identified groups of adoption factors, and the conclusions drawn on their impact. We conclude with the main findings and a discussion of their implications for both theory and practice.

Materials and methods

This study is based on a qualitative systematic literature review (Finfgeld-Connett, 2014) with an aim of describing and extending the current knowledge on the topic of the review (Paré et al., 2015; Templier and Paré, 2015). The search of articles was carried out on 6 June 2021 in both Scopus and Web of Science databases, which are prominent sources covering peer-reviewed academic papers. The search was limited to the last decade, spanning from 2010 to 2020, focusing on the title, abstract, and keywords fields for the identification of relevant articles. The focus practices were selected based on a particular set of agri-environmental cropping practices involving the intentional cultivation and management of different cash crops and/or agricultural service crops in proximity. This includes mixed cropping in strips as part of intercropping, the use of cover crops, catch crops, and green manure. The given set of practices (which will henceforth be jointly referred to as agri-environmental cropping practices) is by no means deemed exhaustive or most representative of those applied in sustainable crop production, but this selection allowed to restrict the scope of the review to a more focused segment of studies.

The content-wise inclusion criteria for the aims of the review were as follows: the articles had to (i) address at least one of the focus practices (intercropping, cover crops, green manure), (ii) deal with adoption of the practice by farmers, and (iii) be based on original research using data sourced from farmers. Two basic Boolean operations (OR, AND) were used for combining different search queries, also using quotation marks (“”) to retrieve specific combinations of words and an asterisk (*) to retrieve articles with relevant variations of specific words:

Scopus: TITLE-ABS-KEY (intercropping OR “mixed crop*” OR “green manur*” OR “cover crop*” OR “catch crop*” OR “service crop*” OR “strip crop*” AND farmer AND adoption AND factor) AND PUBYEAR > 2009 AND PUBYEAR < 2021

Web of Science: [TOPIC] intercropping OR “mixed crop*” OR “green manur*” OR “cover crop*” OR “catch crop*” OR “service crop*” OR “strip crop*” *AND* [TOPIC] farmer AND adoption AND factor

Based on the chosen set of keywords as the initial set of inclusion criteria, a total of 194 articles were retrieved from both databases. After the elimination of duplicates, 123 unique articles were identified (see Fig. 1). Articles were initially screened by title and abstract, based on their thematic relevance for the review. This screening was conducted independently by both authors, then jointly discussed to decide which articles should be included and excluded.

During this screening, 59 articles were excluded based on their (I) non-coverage of crop-related issues, (ii) absence of original empirical data, (iii) non-coverage of adoption factors, (iv) only marginal reference to the practices of interest in this review, (v) focus on agroforestry and/or mixed crop-livestock practices rather than only crop-specific ones, (vi) primary focus on no-till or reduced tillage, and/or (vii) focus on actors other than farmers. As a result, 64 articles were retained for further screening, undergoing full-text examination for eligibility assessment, with articles for review divided between both authors.

The data analysis was carried out by combining initial deductive analysis with a subsequent applied thematic analysis – an inductive analysis of qualitative data that focuses on ‘identifying and describing both implicit and explicit ideas within the data, that is, themes’ (Guest, MacQueen and Namey, 2012, p. 10). A shared Excel form for data coding was created, deductively identifying the key pre-defined descriptors of the articles, which are as follows: year of publication, analyzed country/region, general term(s) used for denoting the set of practices analyzed, specific technologies addressed, methods of data gathering, profile of informants, theory used (if any) in guiding the analysis, and main conclusions drawn on the adoption factors. This deductive coding was then complemented with an inductive coding of specific adoption factors explored by the reviewed studies. The authors met on a regular basis to share reflections and discuss individual articles in case of doubt on their relevance/eligibility.

The mutually agreed-upon principle for extracting and analyzing the texts was to focus on conclusions stemming directly from the analyzed data, while omitting interpretation of results.

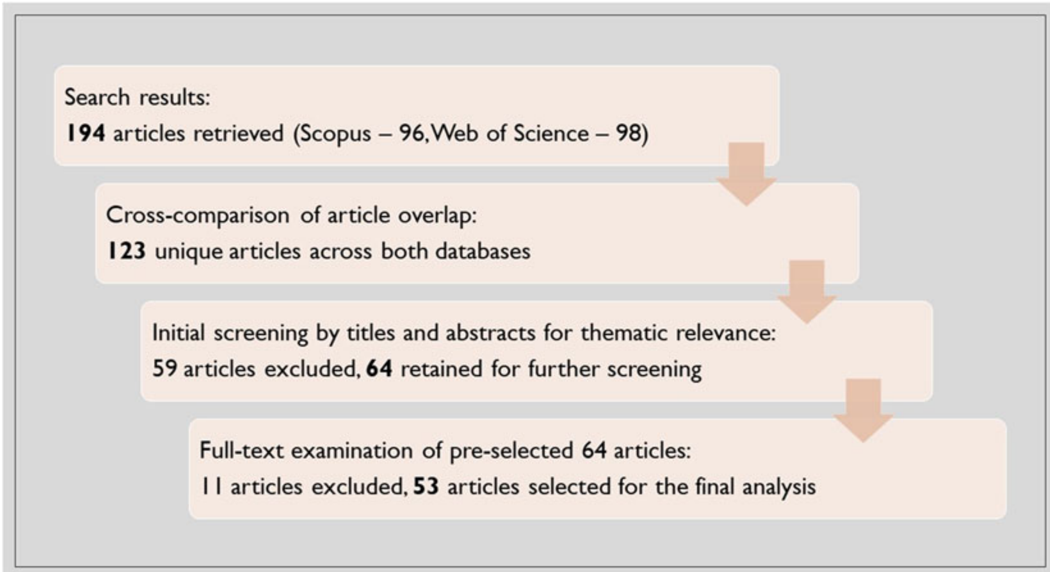

Figure 1. Stages of article selection for analysis.

In cases where several practices are covered, including practices that are not part of the list used for article search, it was decided to focus on the overall results across all the analyzed practices, rather than limiting to those initially specified, since not all articles presented disaggregated results per practice. Therefore, the underlying principle was that the specified practices were selected as an entry point for the review, but not as the sole focus of the analysis.

In the process of full text assessment, 11 additional articles were excluded based on the same exclusion criteria previously mentioned, the presence of which could not be identified during the initial screening of abstracts. This resulted in a final list of 53 articles selected for the systematic analysis (see Appendix A). For these articles, the Excel form was expanded by adding individual columns for each adoption factor explored until no additional factors were appearing. The initial coding of factors resulted in a list of 120 items that were subsequently categorized into larger thematic groups and transversal dimensions. This provided a view of the full scope of factors that have been hypothesized to impact adoption of the studied practices.

Results: characteristics of the reviewed articles

The number of articles, which address the adoption of the selected agri-environmental cropping practices, increased over the investigated decade, with the majority appearing from 2014 onwards (see Table 1). The publication sources include a wide spectrum of 39 journals, nine of which feature more than one of the reviewed articles. In terms of geographic scope, there is a considerable lack of studies from Europe, with the majority covering Africa and North America (USA), and some covering Asia and South America (see Table 2).

The reviewed papers address the selected farming practices as part of several broader categories, the most widely used concept being conservation agriculture, followed by sustainable intensification, best management practices, and soil conservation. Other concepts used in the articles to describe the covered practices include sustainable agriculture, organic farming, climate-smart agriculture, and climate change adaptation/mitigation measures. While all the reviewed articles do cover one or several of the focus practices pre-identified for this review, on average each article addresses five different practices as part of these broader categories. This should be kept in mind when considering the subsequent analysis, where at times these broader and other more specific sets of practices (e.g., cultivated land quality protection measures, natural resource management practices, ecosystem-based farm management practices) are referenced.

The reviewed studies employ empirical data collection methods which include a mix of qualitative and quantitative methods. However, the most commonly used methodology is semi-

Table 1. Distribution of reviewed publications by year

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of articles	3	0	0	3	6	2	6	7	9	6	11

Table 2. Distribution of reviewed publications by continent

Continent	Africa	North America	Asia	Europe	South America	Australia
Number of articles	20	15	10	6	2	0

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structured or structured surveys, conducted face-to-face or through the post. These surveys focus on the correlations between adoption and a set of variables. Additionally, almost half of the studies also use supplementary in-depth interviews, focus groups, workshops, expert panels, or other qualitative research methods, at times combining those with field experiments and on-farm trials.

Results: explored adoption factors

An inductive approach was used to systematize the different individual adoption factors explored by the reviewed studies. As a result, we have arrived at nine thematic factor groups, which are as follows: (1) sociodemographic characteristics, (2) socioeconomic and financial conditions, (3) environmental conditions, (4) tangible assets and inventory, (5) pre-existing farm practices, (6) agrotechnical aspects of the practice, (7) public support instruments, (8) information and knowledge resources, and (9) community dynamics (see Fig. 2). Within each thematic group, a further distinction is made between micro- and macro-level factors, highlighting the different scales of the factors in the adoption processes. Namely, we differentiate between factors that pertain directly to the farm (to both its physical and human aspects), and those that pertain to the wider context in which the farm operates.

In addition to the nine stand-alone thematic groups, we identify two transversal dimensions of adoption factors that cut across all thematic groups and have to do with more subjective aspects (human values, preferences, predispositions, perceptions, etc.), either generic or practice-specific farmer attitudes (see Fig. 2). While the generic farmer attitudes characterize more fundamental attitudes and values of the farmer regardless of the concrete practice, the practice-specific farmer attitudes are linked specifically to the individual practice in question.

In terms of the intensity of the different factor groups being explored by the reviewed studies (see Fig. 3), most attention by researchers is devoted to information and knowledge resources, socioeconomic and financial conditions, and sociodemographic characteristics, followed by tangible assets and inventory, and pre-existing farm practices. There is smaller coverage of factors that relate to community dynamics and environmental conditions, with even fewer studies exploring the generic and practice-specific famer attitudes, as well as those looking into the role of public support instruments and agrotechnical aspects of the practice.

In the following sections, we elaborate on each element of the conceptual scheme, describing the identified groups and the impact of selected individual factors as revealed by the studies. To ensure more fluent readability of the results, we henceforth reference the reviewed articles in square brackets with their numbering according to the alphabetical order as listed in Appendix A. In describing the individual factors in each sub-section, we list all the reviewed studies that have covered the explored variables in Table 3, but we only provide in-text references to studies that also explicitly report on the observed influence of the specific factor. Where applicable, we structure the analysis within the subsections by focusing first on the micro-level factors, followed by those attributable to the macro-level factors.

Thematic groups of adoption factors

Sociodemographic characteristics

Sociodemographic characteristics represent one of the factor groups that has been most studied, including micro-level factors such as age and gender. Attention is also devoted to the number of household members and/or dependents, the marital status of the farmer, as well as more marginal factors such as race and

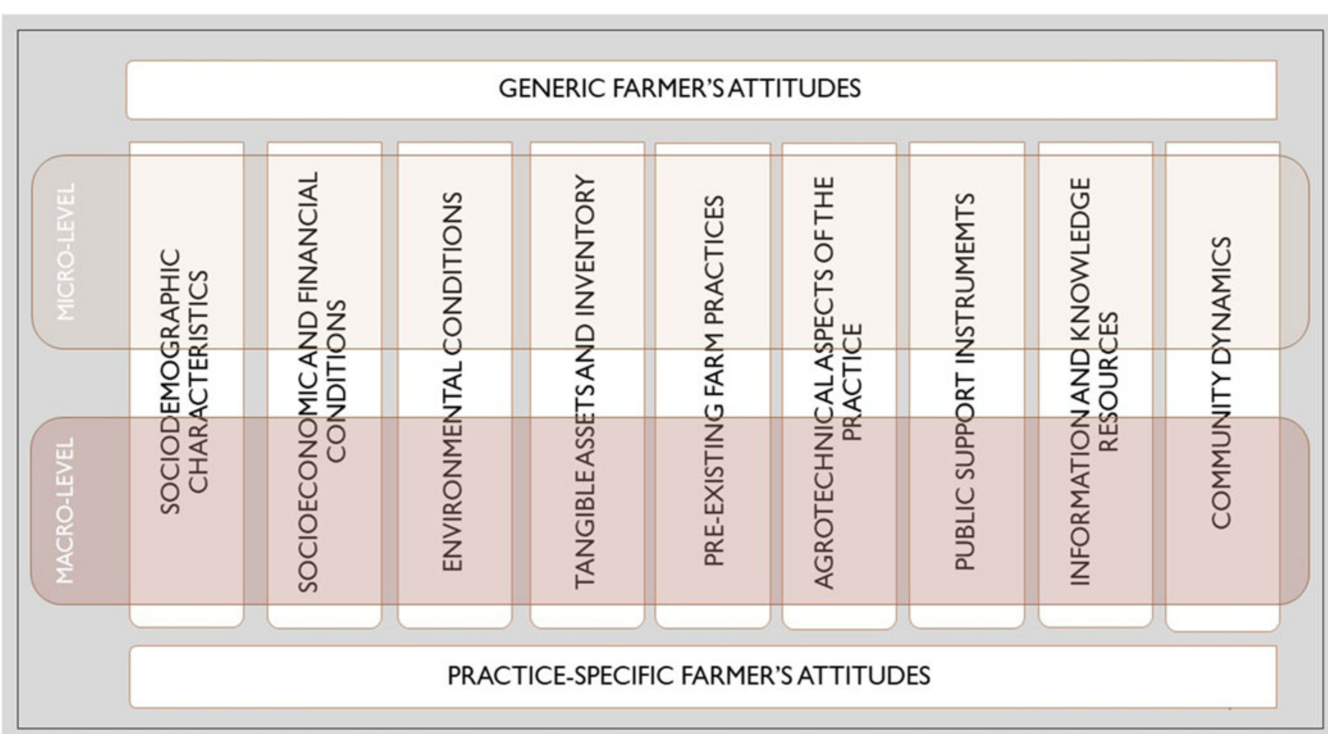

Figure 2. Categorization of the thematic groups and transversal dimensions of adoption factors explored by the reviewed studies.

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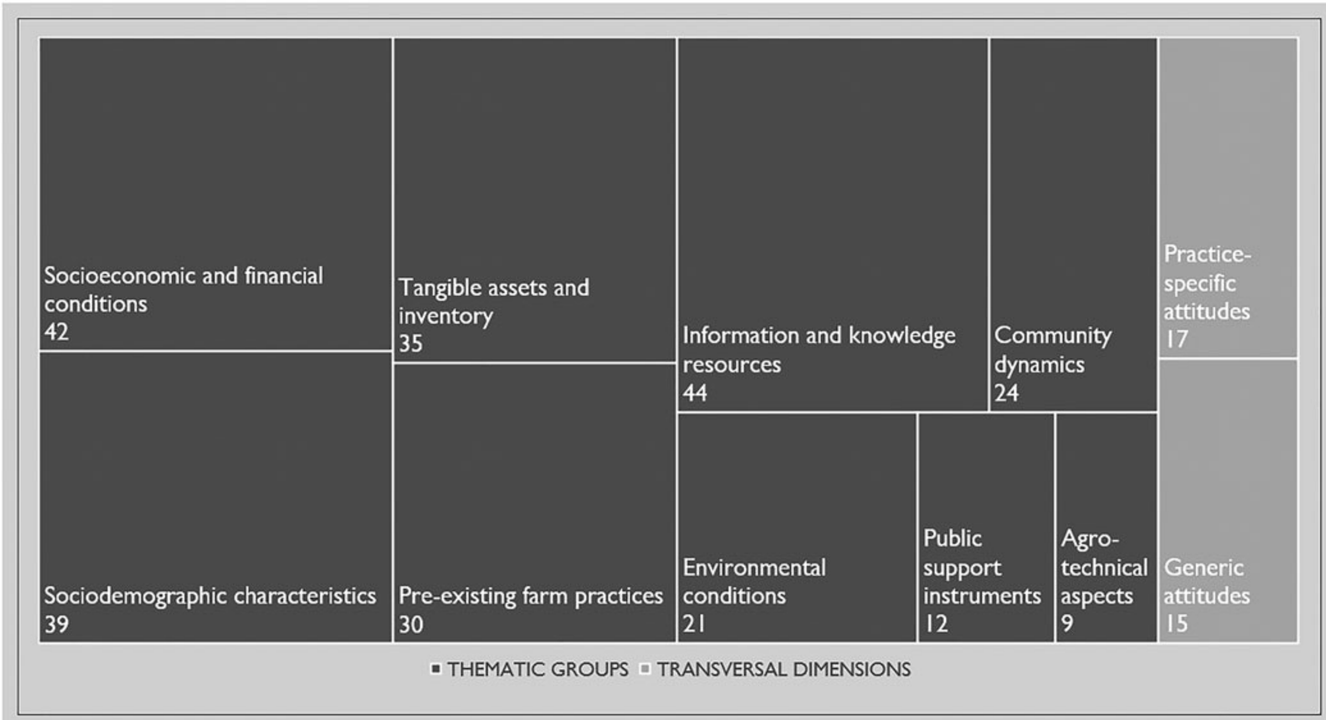

Figure 3. Relative frequencies of the thematic groups and transversal dimensions of adoption factors explored by the reviewed studies (number of unique articles addressing factors in each group/dimension).

ethnicity, farmer's origin (indigenous or immigrant), and presence or lack of successors. The individual studies, however, reveal no conclusive relationship between these factors and the adoption of the explored practices.

Studies conducted in the USA [16, 28], Nigeria [22], Tanzania [14], and Spain [44] demonstrated that older farmers were less likely to adopt different agri-environmental cropping practices. In Paraguay [40], users of green manure and cover crops were found to be younger than non-users. At the same time, in Uganda [34], an increase in the age of the heads of household increased the likelihood of adopting a set of climate smart agricultural practices.

While the reviewed studies show that gender matters in the adoption of agri-environmental cropping practices [11, 33], they demonstrated inconclusive results across countries and specific practices. For instance, in Nigeria, females were found to be more likely to adopt organic farming practices [3], while males were more likely to adopt climate change mitigation measures [22]. In Malaysia [48], research showed differences in the role of gender in the adoption of intercropping, on one hand, and cover crops/ mulches and integrated pest management, on the other. Furthermore, studies demonstrated that in Benin [29] women felt particularly affected by different constraints on the adoption of cover crops, and that the feminization of agriculture in Nepal [8] has limited the uptake of mechanized technologies for sustainable intensification.

The impact of the number of household members has been very mixed across study sites and practices. Separate studies in Pakistan [23] and Nigeria [3] found that households with a lower number of members were more likely to adopt agri-environmental cropping practices. At the same time, other studies in Uganda [34] and in Nigeria [4] found the opposite – that larger households featured higher adoption intensity. Concerning marital status, explored in studies in Africa, it was found that in Nigeria single farmers were more likely to adopt organic farming technology than married farmers [3], but in Ghana married farmers were willing to pay more for sustaining ecosystem-based farm management practices than those not married [7].

At the macro-level, the aforementioned set of farm-level factors is complemented by the population density in the area, however this did not prove to influence cover crop adoption in Benin [29]. Aside from that, the district or region within the same country has been shown to make a difference in adoption patterns. For instance, research carried out in Tanzania [14] showed that the adoption of conservation agriculture was influenced by regional context, with practices chosen by farmers according to both site-specific and socioeconomic characteristics. In Malawi [38], farmer preferences were found to be shaped by regional differences in agroclimatic and market conditions, while in the USA [30], the adoption of sustainable agricultural practices was localized very specifically depending on the district. Likewise, in Malaysia [48] the geographical location of the farms in terms of the country's region was found to be a dominant factor present across all practices covered by their study.

Socioeconomic and financial conditions

A notable number of factors are related to the farm's socioeconomic and financial conditions. At the micro-level, these primarily pertain to the labor status of the household members, specifically regarding on/off-farm employment and full/part-time employment, along with the availability of on-farm labor force, including hired laborers and labor constraints. Additionally, this group of factors also covers farms' income sources by their type

Table 3. Overview of identified factors studied and respective references per factor

Group of factors	Individual factors (m – micro-level; M – macro-level)	List of studies covering the factor (see Appendix A for full references)
Thematic groups of adoption factors		
Sociodemographic characteristics	(m) age	1, 2, 3, 4, 6, 7, 10, 11, 14, 16, 18, 19, 21, 22, 24, 25, 26, 27, 28, 30, 31, 33, 34, 35, 36, 39, 40, 42, 44, 48, 50, 51, 53
	(m) gender	1, 2, 3, 4, 6, 7, 8, 11, 14, 18, 21, 22, 24, 26, 29, 31, 32, 33, 34, 36, 39, 40, 48, 50
	(m) number of household members and/or dependents	1, 3, 4, 6, 7, 21, 23, 26, 29, 32, 34, 35, 37, 39, 51, 53
	(m) marital status	2, 3, 4, 6, 7, 26, 34, 48
	(m) race and ethnicity	36, 48
	(m) origin	29
	(m) presence or lack of successors	28
	(M) population density in the area	29
	(M) country district/region	14, 30, 38, 48
Socioeconomic and financial conditions	(m) labor status of the household members (on/off-farm, full/part-time)	1, 14, 25, 30, 34, 36, 48, 53
	(m) availability of on-farm labor force	25, 26, 27, 28, 29, 38, 46, 48
	(m) income sources (type, number)	16, 30, 34, 36, 37, 40, 48, 51, 53
	(m) level of income	1, 8, 10, 11, 22, 24, 31, 35, 36, 42, 48
	(m) debt/loan/credit obligation	35, 39, 51
	(m) crop insurance involvement	18, 25, 42
	(M) production costs	8, 9, 12, 13, 16, 17, 18, 20, 27, 28, 39, 41, 43, 45, 50, 51, 52
	(M) access to credit	2, 14, 22, 23, 26, 29, 32, 34, 37, 40, 48
	(M) sales opportunities	13, 16, 23, 35, 38, 43, 51, 52
Environmental conditions	(m) topography of the area and soil quality	2, 6, 7, 11, 18, 27, 35, 47, 48, 51, 53
	(m) on-farm water supplies	6, 7, 26, 30, 34, 44, 50, 53
	(M) precipitation and temperature levels	11, 16, 23, 25, 37, 42
Tangible assets and inventory	(m) farm size	3, 4, 6, 11, 16, 18, 22, 23, 24, 25, 27, 30, 34, 39, 40, 47, 50, 53
	(m) land tenure	9, 10, 11, 14, 18, 22, 23, 24, 25, 28, 29, 30, 31, 34, 40, 43, 44, 46, 47, 48, 52
	(m) number of plots	14, 32, 37, 47
	(m) distance to the field	6, 35, 47
	(m) on-farm availability of appropriate equipment	11, 13, 14, 18, 21, 25, 34, 43
	(M) accessibility of land	52
	(M) availability of agricultural machinery services	53
	(M) availability of seeds, fertilizers, pesticides, herbicides	11, 34, 50, 51
Pre-existing farm practices	(m) organic vs. conventional farming	13, 19, 36, 48
	(m) on-farm use and type of such inputs as fertilizers, pesticides, and herbicides	11, 14, 26, 27, 37, 40, 51
	(m) type of land use or production system practiced on the farm	24, 29, 30, 31, 39, 40, 43, 46, 50, 51
	(m) diversity of grown crops	10, 25, 36, 42, 43, 46
	(m) livestock ownership	2, 10, 11, 14, 20, 23, 25, 28, 29, 30, 35, 36, 40, 43, 46, 48, 52
	(m) other onsite farming practices	25, 37
	(M) interrelations between different agri-environmental cropping practices	11, 14, 16, 23, 25, 26, 27, 36, 37, 40, 53

(*Continued*)

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Table 3. (*Continued.*)

Group of factors	Individual factors (m – micro-level; M – macro-level)	List of studies covering the factor (see Appendix A for full references)
Agrotechnical aspects of the practice	(m/M) inherent features of the specific practice	1, 13, 17, 18, 20, 25, 38, 43, 50, 51
	(m/M) practice performance	20, 38
Public support instruments	(m/M) policy incentives	7, 9, 16, 25, 28, 30, 35
	(m/M) public subsidies available for the practice	3, 11, 44
	(m/M) certification schemes	36, 48
Information and knowledge resources	(m) formal education	1, 2, 3, 4, 6, 7, 11, 14, 16, 18, 19, 21, 22, 23, 24, 25, 26, 27, 28, 30, 31, 32, 33, 34, 35, 36, 39, 40, 42, 44, 48, 53
	(m) farming experience	2, 3, 4, 18, 19, 22, 23, 27, 31, 36, 37, 40, 48
	(m) participation in practical trainings and on-farm trials	8, 17, 27, 31, 40, 42
	(m) direct contacts with extension services	2, 3, 4, 6, 22, 29, 37, 46
	(m) consultations regarding a particular practice	17, 44
	(m) consultations on agricultural policy	44
	(m) knowledge and experience linked to the practice	1, 3, 4, 6, 13, 24, 30, 39, 46, 51
	(m) environmental knowledge, including climate change and soil health	1, 9, 16, 27, 28, 32, 39, 44, 51
	(M) availability of professional advice	11, 13, 19, 23, 28, 34, 35, 40, 51, 53
	(M) proximity of agricultural education centers	3, 4, 26, 40
	(M) public availability of information	18, 23, 24, 27, 28, 40, 48
Community dynamics	(m) institutional activism, including producer groups and cooperatives	3, 4, 22, 23, 24, 34, 35, 37, 40, 48, 53
	(m) social networking	23, 24, 29, 35, 42, 46
	(m) human trust	10, 24
	(M) social pressure	12, 13, 20, 31, 45, 49, 50
	(M) level of innovation diffusion among peers	13, 16
Transversal dimensions of adoption factors		
Generic attitudes	aims of the farm	8, 9, 16, 28
	environmental awareness	1, 9, 16, 27, 28, 30, 39, 42
	satisfaction with the existing on-farm practices	30, 42, 48
	attitude toward risk taking	14, 16, 23
	religion	3, 4, 26
Practice-specific attitudes	intention to implement the new practice	4, 13, 20, 49
	attitude toward the practice	4, 12, 13, 24, 27, 49, 50
	assessment of the capacity to implement change	12, 13, 24, 42, 49, 50
	perceived difficulty of implementation	17, 27, 30, 36, 45, 49, 50
	perceived benefits and risks	10, 12, 13, 18, 41, 45
	cultural influences	8

or number, and the level of income, including wealth index, revenue from crop production, gross farm sales/revenue, and household resources more generally. Selected studies also focus on factors such as debt/loan/credit obligation and crop insurance involvement.

In China [53], it has been observed that perennial out-migration of family members for work can constrain households' engagement in soil conservation, but part-time farming locally can promote such practices (including planting green manure crops). Studies conducted in the USA concluded that farmers with less off-farm work [25] or who work full-time on farm [36] were more likely to adopt agri-environmental cropping practices.

No conclusive impacts can be observed from studies exploring the role of labor force. While research in the USA [28] found no

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evidence that a higher supply of labor increases the likelihood of adopting cover cropping, in Malaysia [48] the number of full-time laborers on the farm was one of the most important factors in relation to conservation tillage and crop rotation, exerting a negative impact on adoption due to the shortage of farm labor. The labor force factor largely correlates with the labor-intensity of the specific practice (see section Agrotechnical aspects of the practice).

The studies exploring income-related factors tend to illustrate the positive effect of a stable and diversified household income on adoption. Researchers in Nigeria [37], Uganda [34], and China [53] have observed that farmers' decisions to adopt correlated with higher numbers of household income sources. In turn, in the USA [31] it was observed that organic vegetable farms that are more dependent on revenue from vegetable crops had a smaller proportion of vegetable acres planted with cover crops. In Nigeria [22], Malawi [11], Nepal [8], and Malaysia [48], it has been found that wealthier households are more likely to adopt these types of practices.

In Thailand [51], economic concerns were found to have a strong influence on farmers' adoption decisions featuring risk-averse behavior by those with accumulated debt. This echoes the observation that lower debt led to an increase in the probability of trying a multi-cropping system [39]. Similarly, a study in Kenya [35] showed that credit constrained households were less likely to adopt several sustainable intensification practices. Lastly, crop insurance requirements were not established to hinder the adoption of cover crops in the USA [18].

At the macro-level, relevant factors along the socioeconomic/financial dimension include production costs, access to credit, as well as sales opportunities, including distance to market and crop prices.

In the USA [17, 43], Germany [50], and Italy [12], it has been shown that increase in direct and indirect costs is among the main barriers to adoption. Conversely, profit prospects can balance the investments made in the implementation of the practice, as illustrated by studies conducted in Nepal [41] and North Africa [9]. At the same time, while costs formed the third most important group of adoption factors for selected conservation measures in Germany [45], the authors emphasized that economic rationality is not the main driver for farmers.

While several studies did not find that the accessibility of credit played a role in the adoption of a range of agri-environmental cropping practices, studies in Nigeria [22, 37], Benin [29], Malaysia [48], and South Africa [32] show that adoption can increase with enhanced access to credit. Sales opportunities represented by market access and crop prices are also shown to impact adoption. Favorable market conditions have been observed as a factor positively affecting adoption in the USA [16] and Thailand [51]. The overall instability or lack of a market, or farmers' inability to access it, has been established as a constraint for adoption of reviewed practices in Laos [52], Malawi [38], and Germany [13].

Environmental conditions

Another indispensable group of factors noted by the reviewed studies relate to environmental conditions on and around the farm. At the micro-level, in terms of the farm's location, factors such as the topography of the area and soil quality are considered to play a role, in addition to on-farm water supplies, including access to local water resources, and irrigation system and intensity.

Farmers' assessment of plot characteristics in terms of fertility, slope, and depth was found to be among the factors influencing adoption of sustainable intensification practices in Kenya [35], Malawi [11], Thailand [51], Ethiopia [2], USA [27], Malaysia [48], and China [47]. In Ghana [6, 7] farmers who considered their farmlands to be fertile were willing to pay more to sustain ecosystem-based farm management practices than those who considered their lands to be less fertile. At the same time, a study in the USA [18] focusing on cover crops and no-till/reduced tillage found that the physical features of the farmland, such as soil types, drainage, and/or topography, were only slightly limiting their adoption. In exploring the quality of cultivated land as part of farming conditions in the adoption of a set of soil conservation practices, a study in China [53] found that compared with non-adopters of cultivated land quality protection measures, adopters had poorer quality of land.

As for water supplies, lack of irrigation has been observed as playing an inhibiting role in the implementation of cover cropping among German farmers [50]. Access to domestic water sources and irrigation water has also been demonstrated to influence the adoption of a set of climate smart agricultural practices in Uganda [34] and intercropping in Spain [44]. The possession of irrigation facilities has been found to have a positive and significant relationship with the adoption intensity of sustainable agricultural practices among crop and vegetable growers in the USA [30].

At the macro-level, there is a set of environment-related factors such as the climatic zone of the country and the precipitation and temperature levels. A study in Malawi [11] paid extensive attention to exposure to climate stress, concluding that climate change related effects act as important determinants of adoption. Researchers in the USA [16], Nigeria [37] and Pakistan [23] established that the amount of rainfall significantly influences adoption, as do expectedly high temperatures [23].

Tangible assets and inventory

The implementation of agri-environmental cropping practices is also influenced by the tangible assets and inventory of the farm. At the micro-level, the most frequently explored factors include farm size and land tenure, with additional factors featuring the number of plots and distance to the field. More specific to individual practices is the on-farm availability of appropriate equipment.

Studies conducted in China [53], Pakistan [23], Paraguay [40], Nigeria [3, 4], Thailand [39], and Malawi [11] concluded that larger farms are more prone to adopting agri-environmental cropping practices. Likewise, more secure land arrangements have been observed to facilitate adoption across several studies. Research in China [47] showed that farmers tended to plant less green manure crop on rented-in plots compared with own-contracted plots, while land ownership was observed as a factor facilitating adoption in North Africa [9], Malawi [11], and Nigeria [22]. In the USA results have been more mixed, with one study [43] reporting that farmers consider landowners to have a greater incentive to consistently utilize cover crops to improve their soil resources than those renting land, while another [28] found no evidence confirming this. In Benin [29], farmland availability was found to have a significant influence on cover crop adoption. Closer distance of the field to the farmstead has been demonstrated to play a positive role in the adoption of the reviewed practices in Ghana [6] and China [47].

The role of the availability of appropriate equipment has been highlighted by several studies. This includes one in the USA [25], which showed that the presence of equipment for handling diverse crops already used on the farm served as an important factor facilitating adoption of cover cropping. Access to major agricultural implements/machinery was found to be one of the household-level determinants of adaptive capacity in Malawi [11].

At the macro-level, the group of tangible assets and inventory are represented by factors that are related to the more general accessibility of land, availability of agricultural machinery services and inputs such as seeds, fertilizers, pesticides, and herbicides. Lack of land has been identified among the barriers for agroecological intensification in Laos [52]. In turn, the availability of agricultural machinery services was found to be among the factors that had significant positive influence on the adoption of cultivated land quality protection behaviors by farmers in China [53]. The availability of seed and/or fertilizer vendors in a study in Malawi [11] was found to be positively correlated with the use of inorganic fertilizer and maize-legume intercropping, whereas in communities where their availability is limited, farmers tended to use more organic fertilizer and plant trees. In Uganda [34], an increase in access to improved seeds, fertilizers, pesticides, and herbicides has been observed to increase the probability of adoption of climate-smart agricultural practices. A lack of self-sufficient seed reproduction was observed as one of the barriers hindering the implementation of cover cropping by German farmers [50]. In turn, receiving free seeds was mentioned as a factor encouraging the adoption of rice bean in a maize-based cropping system in Thailand [51].

Pre-existing farm practices

The adoption of agri-environmental cropping practices is seen in the studies as closely interlinked with some general and specific features of the farming approach implemented by the farm, which in some respect aligns in with the notion of the technical or technological compatibility of the practice with the existing farm system [see 1, 28]. On the micro-level, studies look at the distinction between organic and conventional farming, on-farm use and type of inputs such as fertilizers, pesticides, and herbicides, type of land use or production system practiced on the farm, diversity of grown crops, livestock ownership, and other onsite farming practices.

A few studies explore the role of organic production, which is reported to have a significant positive relationship with adoption of innovative pollination management practices in the USA [19] and mixed cropping in Germany [13]. At the same time, another study in the USA [36] found no significant differences between certified organic and non-organic farmers in terms of implementation of crop rotations or cover cropping.

As for on-farm use of inputs, a positive correlation between the use of cover crops and lower nitrogen fertilizer use has been observed in the USA [27]. However, in Ethiopia [26], chemical fertilizer usage was demonstrated to have a negative effect on the adoption of intercropping. At the same time, a study of Paraguayan smallholders [40] established that external input of chemical fertilizers positively influenced the adoption of green manure and cover cropping, demonstrating the on-farm co-existence of mixed practices in terms of their sustainability.

Studies looking at the type of land use as a potential adoption factor reveal, for instance, that a high land-use intensity, correlated with lower availability of fallow land and higher soil degradation, served as an incentive for practice adoption in Benin [29]. In Thailand [39], researchers observed that households who were currently growing cash crops (e.g., maize, potato, rice, chickpea) were more likely to adopt the multi-cropping system than those who were growing fruit crops. As for the impact of other factors related to existing farm practices, several studies in the USA found that farms who already have diverse crops are more likely to adopt cover cropping [10, 25], while the adoption intensity of sustainable agricultural practices was found to be more common among crop and vegetable growers than livestock farmers [30].

The status of livestock ownership has received particular attention in the studies, yet with mixed results regarding its influence. For instance, studies in the USA [25, 28], Benin [29], and Malaysia [48] found that the adoption of cover cropping was more likely among livestock farmers. At the same time, other studies in the USA [36] and Pakistan [23] found that livestock producers were less likely to engage with different sustainable farming practices. Studies in Laos [52] and Malawi [20] also highlighted the problematic compatibility of intercropping and cover cropping with keeping free-range livestock.

More generally, the farming system factors can be viewed as related to different existing onsite farming practices that serve both as an indicator of the approach pursued by the given farm, and an enabler or disabler of the adoption of agri-environmental cropping practices. For instance, the on-farm production of renewable energy has been demonstrated to feature a positive correlation with the adoption of cover cropping in the USA [25]. A study in Nigeria [37], in turn, showed an increased probability of the adoption of crop rotation, use of animal manure, and crop residue retention (but not intercropping) by households who undertake frequent weeding.

At the macro-level, a notable number of studies have paid attention to the interrelations between different agri-environmental cropping practices, showing the importance of their complementarity or substitution. A positive correlation between different practices has been found in several studies in China [53], USA [16, 27, 36], Nigeria [37], and Pakistan [23]. As for substitution, a study in Tanzania [14] showed that the likelihood of applying conservation measures decreased if the use of another measure was increased. In Ethiopia [26], irrigation usage and intercropping as climate change adaptation strategies were found to reduce the adoption of improved potato varieties, thus showing that one farming strategy can preclude another.

Agrotechnical aspects of the practice

While it can be argued that the agrotechnical aspects of a practice form an integral part of its adoption, we contend that these aspects need to be singled out among the adoption factors. This argument is based on a set of studies exploring the role of inherent features of the specific practices and their performance in adoption decision-making, with this group representing a blend of both micro- and macro-level factors.

In the case of intercropping, the uneven maturing of crops in mixed stands was ranked amongst the most crucial obstacles for the implementation of this practice by German farmers [13]. In South Africa [1], researchers observed an impact of technical ease of adoption on the acceptance of different climate-smart agricultural practices, showing that, based on technical compatibility, a high level of acceptance was established in the case of organic manure, rotational cropping, mulching, and cultivation of cover crops. The impact of different practice-specific barriers such as time pressure and workload has also been addressed regarding the adoption of cover cropping in Germany [50] and

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the USA [17, 25, 43]. The labor-intensive nature of practicing legume-maize intercropping has also been highlighted as a barrier for its adoption among farmers in Malawi [38] and Thailand [51].

The performance of an agri-environmental cropping practice is, of course, of importance in its adoption and continuous implementation. Yet, different types of farmers can have varied perceptions of it. For instance, the case of legume-maize intercropping in Malawi [38] showed that the importance attributed to the yields of legume grain and/or maize differed among farmers based on their preferences and the perceived utility of the crop systems. This suggests that the adoption rates of any new agricultural technology are affected by high stochasticity of its performance [20].

Public support instruments

Although it could be expected that policies and regulations will have a substantial impact on the uptake of agri-environmental cropping practices, the analysis shows that there is just a handful of studies that have assessed the relevance of different public support instruments. There are three primary directions of analysis covering various policy incentives, subsidies available for the practice, and certification schemes. Support instruments generally function at the macro-level, although some distinction can be made between micro- and macro-levels regarding the availability of such instruments, in the latter case, and individual engagement, in the former.

Studies show that policies can become drivers of both adoption and dis-adoption. A comparative study conducted in Tunisia, Algeria, and Morocco [9] illustrated how energy policies (particularly focusing on fuel costs) can impact farmers' decisions on adopting reduced tillage. In the USA, monetary incentives [16, 25] and support programs [28, 30] were found to be important drivers encouraging adoption of conservation practices. A study in Kenya [35] illustrated that farmers' perception of government support being available can build farmers' confidence to invest in sustainable agricultural intensification practices despite uncertainty.

As for public subsidies, studies conducted in Nigeria [3], Malawi [11], and Spain [44] observed that this financial support had a positive impact on adoption. Lastly, with regards to the connection between certification and practice adoption, studies find weak links between the two factors. One study conducted in the USA on cover cropping [36] observed no evidence that national organic certification resulted in significant differences in practices or perceptions related to cover cropping. Another, conducted in Malaysia [48], suggested that a linkage between practice adoption and participation in a certification program can be observed in the case of cover crops and integrated pest management, yet without clear causality.

Information and knowledge resources

Unsurprisingly, information-related factors are identified by most of the articles as important in explaining farmers' willingness to uptake agri-environmental cropping practices. There are several ways in which the studies tie information and knowledge to on-farm practices and willingness to adopt these types of solutions. At the micro-level, they primarily focus on the role of formal education, farming experience, and participation in practical trainings and on-farm trials, along with direct contacts with extension services, consultations regarding a particular practice and agricultural policy. The studies also explore the role of knowledge and experience linked to the practice and environmental knowledge, including knowledge of climate change and soil health.

Most of the studies show a positive effect of education on the adoption of reviewed agri-environmental cropping practices. Higher level of education of a farm's head of household has been found to be positively correlated with adoption of different practices in Malawi [11], cultivated land quality protection measures in China [53] and Southern Africa [32], multi-cropping in Thailand [39], climate smart agricultural practices in Uganda [34], and green manure, cover cropping [4], and climate change mitigation measures [22] in Nigeria. In the USA, more educated farmers utilized a larger diversity and complexity of cover crops [31] and had a higher adoption intensity of practices [30], while more educated farmers in Ghana [7] were more willing to pay to sustain ecosystem-based farm management practices. At the same time, studies conducted in Pakistan [23], Paraguay [40], and Ethiopia [26] demonstrate inconclusive results, illustrating that under different contexts the impact of education level on adoption of new practices can differ.

Farming experience is mainly presented as having a positive impact on adoption. Several studies in Nigeria [3, 4, 22] concluded that such experience shows very strong significance in the adoption of various practices. A study in Ethiopia [2] found that with each additional year of experience, the probability of practicing mixed cropping increased. Somewhat similar findings are echoed in several studies in the USA [31, 36] and Paraguay [40]. However, there are some articles suggesting the opposite – in Nigeria [37] it was found that experience might have a negative impact on farmers' willingness to adopt soil conservation practices, while in Michigan, USA [19] it has been observed that experience and education significantly correlate with impacts associated with age. One of the explanations of why experience matters is provided by a study in Pakistan [23] – it concluded that more experienced farmers are better at creating synergies between natural resource management practices and modern inputs. An article assessing the adoption of conservation practices in Indiana, USA [27] offers an alternative perspective, attributing the positive effect of experience to financial stability.

Only two articles directly tested the relationship between participation in practical trainings and adoption, one conducted in the USA [17] and one in Paraguay [40]. Both articles reported clear linkages between participation in trainings and adoption. Research from Nepal [8] and the USA [27, 31] demonstrated that engagement in on-farm trials serves as a positive motivator for adoption.

When discussing the significance of access to information, articles mainly point to the importance of close relations between extension services and farmers. Studies in Ethiopia [2], Ghana [6], Benin [29], Nigeria [37], Brazil [46], and Spain [44] demonstrated a positive correlation between extension contacts and farmers' willingness to engage with different agri-environmental cropping practices. More generally, evidence [17, 44] shows that farmers who have received consultations on this kind of solution were keener to try the new practice. At the same time, a study conducted in Nigeria [3] reported a negative correlation between farmers' contacts with extension services and their willingness to uptake organic farming.

A large group of articles indicate that personal knowledge and experience related to the practice has a substantial impact on adoption. Research conducted in Nigeria [3, 4] suggested that farmers' indigenous knowledge allows them to have a better understanding of how to benefit from implementation of studied organic agricultural practices. Studies conducted in Ghana [6] and Thailand [51] observed that farmers' knowledge of or experience with another practice that has some commonalities with the new one (e.g., growing legumes prior to practicing maize-legume intercropping) has a significant impact on farmers' willingness to adopt. Evidence from South Africa [1] and the USA [30] suggests that limited technical know-how induces negative attitudes toward practice adoption. In Germany [13], researchers recorded that more than half of farmers with and without hands-on mixed cropping experience claimed that insufficient knowledge is among the key obstacles to implementation.

Farmers' willingness to adopt agri-environmental cropping practices is also affected by their knowledge of broader environmental processes. Evidence from Spain [44] suggests that environmental awareness was among the factors positively influencing farmers' decisions to adopt climate change mitigation practices. A study conducted in South Africa [32] highlighted that the introduction of more sustainable practices is a way to reduce the environmental impacts, as well as a necessary change needed to continue farming.

The reviewed literature also points to the macro-level factors at play in supporting access to knowledge and information, emphasizing the importance of the availability of professional advice, proximity of agricultural education centers, and public availability of information in the uptake of the reviewed practices.

Presence of and access to agricultural extension services has been demonstrated to be a strong positive predictor of the adoption of various practices in Pakistan [23], Kenya [35], and Thailand [51]. A study conducted in China [53] stated that agricultural services and technical guidance has an overall positive effect on adoption of practices protecting the quality of cultivated land. Meanwhile, German farmers identified a lack of expert advice as one of the obstacles to the implementation of mixed cropping [13]. However, the links between adoption and access to extension services generally seem complex. A study in Malawi [11] found that for some techniques, access to extension services play an important role, while in other cases the effect is exactly the opposite. A study conducted in the USA [19] also found that at different stages of adoption, different knowledge brokers are needed. Some studies have also considered the linkages between the proximity of agricultural education centers and adoption, yet with inconclusive results. Studies conducted in Ethiopia [26] and Nigeria [4] reported that adoption increases if located closer to a farm service center, while a study on organic farming practices [3] found the opposite to be true.

In Pakistan [23] and Paraguay [40], public access to information was positively shaping farmers' willingness to adopt agri-environmental cropping practices. A study in the USA [24] observed that adoption probability increased with an increased diversity of information sources available. Meanwhile, another US study [28] concluded that not all information sources play an equal role when it comes to practice adoption – while access to public sources was not found to drive the adoption of cover cropping, access to private consultants boosted its probability.

Community dynamics

Community dynamics is a theme that is not very central, yet is reoccurring in the articles. The most common factor in this group at the micro-level is related to farmer personal engagement in various forms of institutional activism, including producer groups and cooperatives, as well as farmer's social networking and human trust.

According to these studies, personal engagement in formal and informal peer groups can act as important preconditions explaining farmers' willingness to uptake agri-environmental cropping practices. Organizational membership has been shown to be a positive factor in the adoption of organic farming practices in Nigeria [3], and of organic fertilizers/composts, conservation tillage and cover crops/mulches in Malaysia [48]. Research in Pakistan [23] concluded that adoption of the latest innovations is linked to farmers' promptness to network. In a similar vein, studies in Benin [29] and Brazil [46] highlighted that adoption can be increased if farmers have links to science institutions and scientists, while research in Kenya [35] demonstrated that a higher number of traders known to the household led to an increased probability of adopting new practices. In the USA, visiting other farmers to observe their practices [42] and integration into conservation networks [24] was positively associated with farmers' intentions to increase their use of the reviewed practices. Lastly, some articles point out the importance of farmers' trust in extension services and in the private sector [10, 24].

At the macro-level, external social pressure and level of innovation diffusion among peers is demonstrated to affect adoption. Studies conducted in the USA observed that the extent of cover cropping usage was positively correlated with the belief that most other farmers are using this practice [31], and that the cover crop adoption speed increased as the practice was used in the community for a longer period of time [16]. Importantly, the main difference between adopters and non-adopters of best management practices studied in Italy [12] was farmer referents' opinion on applying them. While research in Malawi [20] showed that engagement of other community members in communication about the new practice positively affects its uptake, it also highlighted the dampening effect of disappointed farmers. Research [13] assessing German farmers' intention to adopt mixed cropping concluded that perceived social pressure from peers had a positive effect on the intention to adopt, while perceived pressure from politics and society had a negative effect on the intention to adopt. At the same time, another study in Germany [45] demonstrated that the perceived compatibility of a conservation measure with the values of the farming community was of lesser importance to the farmers than the feeling that it can improve the farmers' image in society.

Transversal dimensions of adoption factors

Generic attitudes

Aside from the different groups of factors reviewed above, many influences in practice adoption can be attributed not to the exogeneous objective factors, but rather to the subjective motivations, attitudes, values, or psychological attributes of farmers in terms of their general worldview and social identity. Those include the aims of the farm, farmers' environmental awareness, satisfaction with the existing on-farm practices, attitude toward risk taking, and religion.

A prominent group of generic attitudes is represented by the overall aims of the farm, which are seen as more economically or environmentally driven. The priority of economic considerations over environmental considerations has been observed in several studies conducted in the USA [16], North Africa [9] and Nepal [8]. At the same time, several other US studies have demonstrated the decisive role of farmers' environmentally driven aims in practice adoption, such as preferences for environmental amenities in the case of conservation technologies [28],

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stewardship identity [42], and prospects of improved soil health and structure [27] in the case of cover cropping. Similar findings have been echoed by research in Thailand [39], where farmers highly concerned about the environment were more inclined to adopt a multi-cropping system.

Satisfaction with existing on-farm practices is another factor researchers have explored as a potential enabler of adoption [30]. A study of farmers from across the US Corn Belt [42] illustrated that those who reported high levels of confidence in their current practices were less likely to plan on changing their practices in response to climatic changes. This resonates with the notion of habit, as covered by a study on the adoption of sustainable agricultural practices in Malaysia [48], where it was seen as the inclination to routinize the practices already implemented on the farm.

Another adoption factor featuring the psychological profile of farmers is their attitude toward risk taking. Studies in the USA [16] and Pakistan [23] demonstrated that farmers' willingness to take risks significantly and positively affected the adoption rate of agri-environmental cropping practices. However, in Tanzania [14], a higher risk-taking attitude appeared to play a role only for more highly intensified, and thus better endowed, farms. Finally, while religion is not a widely explored factor, scholars in Nigeria [3] found that non-religious farmers were more likely to adopt organic farming practices than those who are religious.

Practice-specific attitudes

The group of factors related to practice-specific attitudes stems largely from the application of the theory of planned behavior in a set of reviewed studies. As such, this group pertains to the theory's concepts of (i) intention to implement the new practice, (ii) attitude toward the practice, (iii) perceived control in terms of one's assessment of the capacity to implement change, and (iv) perceived difficulty of implementation. In addition to these, other factors also deal with perceived benefits and risks and cultural influences. The difference of these factors from the generic farmer's attitudes lies in the fact that these factors are specific to the individual practice in question.

Studies conducted in Germany [13] and Belgium [49] both concluded that farmers' intentions to adopt were more important than the external factors. Likewise, a study conducted in Nigeria [4] observed that farmers' willingness to try the new practice had a very strong correlation with intensity of adoption.

Farmers' attitudes and perceived difficulty explain variations in the intention to apply cover cropping. German farmers [50] with a more positive attitude toward cover cropping and those who perceived cover crops as easier to apply were more likely to be among those who strongly intended to adopt this practice. These results are supported by research in the USA, which demonstrated that farmers' lack of confidence in their agronomic capacity was associated with lower likelihood of cover crop adoption [24], and that perceived difficulty of implementation was a key barrier to the adoption of sustainable agricultural practices [30].

Unsurprisingly, perceived benefits and risks associated with a given solution have been identified as significant factors affecting farmers' willingness to adopt. Studies from North America have observed that a lack of proven benefits was among the top factors limiting farmers' willingness to adopt cover cropping and no-till practices [18], and that farmers who associated more benefits with cover cropping were also more likely to implement the practice [10]. At the same time, a study of Italian dairy farmers [12] showed that the number of barriers to the adoption of specific practices was markedly smaller than the number of drivers to do so. Yet, even when farmers are aware of the benefits, the adoption remains limited. As observed by researchers in Nepal [41], farmers favor the option they perceive as having the least risk with the greatest immediate return. In many cases, studies specifically indicate that farmers are looking for clear economic benefits. In Germany, for example, lack of perceived economic benefits was listed among the top three main obstacles to implementing cover cropping [13]. Yet, another study concluded that, in addition to financial cost factors, acceptance of conservation measures was also strongly influenced by the associated risks, effectiveness, or time and effort necessary to implement a certain measure, along with its contribution to ensuring the production of healthy and unpolluted products, and in protecting resources for future generations [45].

Aside from these attitudinal factors, it is also worth mentioning the sporadic indications of the role of cultural influences in the adoption of specific practices. For instance, traditional preferences for certain grain colors and flavors limited the use of improved seed varieties, as revealed in a study on sustainable intensification in Nepal [8].

Discussion and conclusions

The results of the reviewed studies show that adoption factors empirically explored by researchers encompass a diverse landscape, ranging from bio-physical to socio-psychological, which we have grouped along nine thematic categories (sociodemographic characteristics, socioeconomic and financial conditions, environmental conditions, tangible assets and inventory, preexisting farm practices, agrotechnical aspects of the practice, public support instruments, information and knowledge resources, community dynamics) and two transversal dimensions (generic and practice-specific attitudes). All these factors, taken together, highlight the simultaneous importance of personal traits of farmers, household characteristics, geophysical location and conditions of the farmland, and the broader social context in which they must operate. It can also be observed that among the pool of factors explored there is a differentiation between ones that feature available opportunities and ones that pertain to the seizing of those opportunities.

Overall, the reviewed studies most extensively explore conventional factors such as farmer's age, formal education, gender, and land tenure, with the largest diversity of aspects present in the factor groups related to information and knowledge resources, sociodemographic characteristics, and socioeconomic and financial conditions. There is also a handful of individual factors that have attracted rather marginal attention within the set of the reviewed studies, such as the role of succession, level of diffusion of innovation among peers, specific cultural influences, distance to the field, and engagement in certification schemes. These factors could be explored in future adoption studies. The reviewed studies also highlight the importance of going beyond a single isolated practice, and instead considering the existing or aspired combinations of practices in light of their complementarity and substitution.

When comparing the results of the present review with the results of those conducted on related sets of agri-environmental farming practices, the classification of adoption factors proposed in this paper offers a slightly more complex view of the division into, and interrelationships between, thematic groups and transversal dimensions, and differentiation of micro- and macro-levels within the former. While we see the rationale for clustering adoption factors into a smaller number of broader categories (see, e.g., Prokopy et al., 2008; Baumgart-Getz, Prokopy and Floress, 2012; Knowler and Bradshaw, 2007), our inductive approach called for more refined grouping. This is not to dismiss earlier categorizations, but rather to offer a more nuanced perspective and emphasize the embeddedness of the practices in the multifaceted lifeworld of the farmer, which is influenced and shaped by both structural and individual factors.

The results clearly demonstrate that factors at play in the adoption of agri-environmental cropping practices can differ notably depending on the specific practice, even in the same geographical area. Thus, while there are a set of overarching adoption factors, many factors are practice-specific and therefore limit the possibility of generalization regarding their impact. Moreover, one should account for the risk of possible confounding effects of different identified and unidentified variables, making it difficult to disentangle their true effects on practice adoption. There are different and frequently underexplored interdependencies between individual factors that do not allow for definite conclusions to be drawn based on their segregated analysis, thereby calling for further in-depth studies of these complex cross-factor influences. A single factor can feature different levels and directions of impact depending on the attributes of the farmer, farm, specific technology, location, etc. There are also notable variations in the effect of different factors depending on the overall structure of farms and agricultural workforce present in each country.

Nevertheless, there are some dominant factors of influence across the different categories emerging from the analysis of the reviewed studies. It can be observed that adoption of agri-environmental cropping practices is generally facilitated by farmers' younger age, higher level/duration of education, higher level and diversified sources of income, accessibility of on-farm labor, larger farm size, land ownership, as well as access to credit, subsidies, and cost-share programs. Tangible effects of climate change experienced by the farm facilitate adoption. Higher levels of environmental awareness and stewardship act as an important precondition for practice adoption, along with lower levels of risk aversion and lower levels of satisfaction with current on-farm practices. Location of the plot closer to the homestead positively affects adoption. A topography that might pose a challenge for intensive farming (such as slopes, lowlands) and availability of irrigation also act as facilitating factors. Likewise, the ease of linking existing on-farm practices with the new environment-friendly practices positively affects farmers' willingness to change. Adoption is facilitated by availability of machinery compatible with the new practice, prior experience with diversified crop varieties, limited use of chemical fertilizers and pesticides, availability of seeds, and a profitable market for the secondary crop introduced as part of the new practice. The information space of the farmer and existing communication forms and channels affect the uptake of these practices. A lot of positive stimuli lie in the search for and access to information, in terms of participation in trainings, use of advisory services, diversity of consulted information sources, on-farm experimentation, engagement in formal and informal groups, and use of a wide network of social contacts. Last, but not least, the perceived ease of implementation, anticipated economic benefits, as well as a generally positive attitude toward the new practice and one's own implementation capacity play a facilitating role in the adoption decision-making.

When interpreting the results of the given review, some limitations need to be considered. First, the reviewed studies did not cover gray literature, as notable omissions could be made due to the non-presence of a single source for the identification of such studies across the globe, and studies in languages other than English. This inevitably limited the scope of the sourced literature. Secondly, while the entry point for this review covered intercropping, cover cropping, and green manuring, the practices addressed by the reviewed studies at times covered broader sets of practices, thus making the present analysis go beyond the initially established ones. Thirdly, even if presented as integral to sustainable farming, the environment-friendliness of selected additional practices covered by the reviewed articles could at times be questioned. In future reviews, a more stringent selection of articles that only focus on single practices (int. al. adhering to more rigid sustainability criteria) could be used to obtain more targeted and practice-specific insights. Last, but not least, this review included studies of both qualitative and quantitative nature, thus not allowing for any absolute statements regarding specific factors and their impact.

Nevertheless, we believe that this review contributes to a more comprehensive understanding of the manifold domains and dimensions of potential influence at play in the adoption decision-making by farmers surrounding new sustainable practices in crop production. As such, this review can serve both as a stand-alone overview of the current state of research and knowledge in regard to factors potentially at play in the adoption of agri-environmental cropping practices by farmers, and as an input for designing future research questions and tools to pursue holistic studies on the uptake of sustainable farming solutions.

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Appendix A. List and numbering of the reviewed articles

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