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REVIEW ARTICLE

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A review on the contribution of crop diversification to Sustainable Development Goal 1 "No poverty" in different world regions

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Abstract

Crop diversification is one of the most cost-effective way of reducing uncertainties in farmer's income, especially among poor smallholder farmers. However, poverty is a complex concept, which includes more dimensions than only income. This review investigates the contribution of crop diversification to Sustainable Development Goal 1(SDG1) "No poverty" by also considering other dimensions of poverty, namely gender equality, food security and nutrition, and vulnerability to climate change. It demonstrates that the contribution of crop diversification to food security and nutrition, gender equality, and reduction of poor farmers' vulnerability to climate change has not been properly researched. Several factors across the studies analysed were found to influence the implementation of crop diversification, but these were hardly connected to poverty reduction. New research and policy impact evaluation methods that follow a sustainability approach perspective to poverty need to be undertaken in order to assess the contribution of crop diversification to SDG1.

KEYWORDS

agriculture, climate change, food security, gender, poverty dimensions

1 | INTRODUCTION

Reducing poverty has been at the forefront of international debates since the 1970s. In 2015, 193 member states of the United Nations adopted the Sustainable Development Goals (SDGs) which include Goal 1 "end poverty in its forms and everywhere" (UN, 2016). Alkire et al. (2014) state that 85% of all poor people across 105 countries live in rural areas. The International Fund for Agricultural Development (IFAD, 2010) considers smallholder agriculture (<2 hectares and low asset base) is a route out of poverty for many people living in rural areas, and several authors (e.g., Losch, Fréguin-Gresh, & White, 2011; Ravallion & Datt, 1996; Warr, 2003) believe that agricultural growth is more poverty reducing than growth in other sectors. According to the Food and Agriculture Organization (FAO), smallholder farmers produce much of the developing world's food supply but are generally much poorer than the rest of the population and less food secure than the urban poor (FAO, 2011).

For the World Bank (2008), growth and development of the agricultural sector is determinant to escape poverty traps in many developing countries. Within agriculture, one of the strategies suggested as a pathway to poverty alleviation is crop diversification (e.g., Birthal, Jha, Joshi, & Singh, 2006; FAO, 2011; Perz, 2004), considered one of the most ecologically feasible, cost-effective, and easier ways of reducing the effect of uncertainties, especially among small-scale farmers (Mugendi Njeru, 2013). One common definition of crop diversification is the addition of more crops to an existing cropping system

(Adjimoti, Kwadzo, Sarpong, & Onumah, 2017). Clements, Haggar, Quezada, and Torres (2011) associates crop diversification to the replacement of low-value commodities by high-value commodities, usually fruits and vegetables for the export market. Other types of diversification include the integration of crops and livestock, usually defined as mixed farming (e.g., Bacon et al., 2014), the integration of crops and trees, usually defined as agroforestry (e.g., Altieri, Nicholls, Henao, & Lana, 2015), or the production of cash crops (e.g., cashew and coffee). Table 1 presents a nonexhaustive list of the main advantages and main characteristics of several crop diversification systems, including mixed farming and agroforestry.

Many studies (e.g., Bravo-Ureta, Solis, Cochi, & Quiroga, 2006; Harris & Orr, 2014; Oladele, 2011; Weinberger & Lumpkin, 2007) have analysed the relation between crop diversification and poverty alleviation by investigating its contribution to rural incomes and creation of employment opportunities. Some authors (e.g., Narayan, Chambers, Shah, & Petesch, 1999), however, have pointed out that poverty alleviation should not be assessed by income alone. Schleicher et al. (2017) claim for an expanded account of poverty that includes environmental dimensions currently missing from existing approaches.

TABLE 1 Diversification of agricultural systems

Diversification types	Description of diversification	Main characteristics
Increased structural diversity	It makes crops within the field more structurally diverse; for example, strip intercropping, which consists of the production of more than one crop in strips that are narrow enough for the crops to interact, yet wide enough to permit independent cultivation.	Farm level; same land unit
Genetic diversity in monoculture	Growing mixed varieties of a species in a monoculture.	Farm level; same land unit
High-value crops	A shift from less profitable and sustainable crop or cropping system to more profitable and sustainable crop or cropping system.	Farm level; same land unit
Crop rotations	Temporal diversity through crop rotations.	Farm level; different spaces; different times
Polyculture	Growing two or more crop species and wild varieties within the field. Spatial and temporal diversity of crops.	Farm level; different spaces; different times.
Diversify field with noncrop vegetation	Growing weed strips or vegetation banks in and alongside crops.	Farm level; different spaces
Mixed farming	Crops and livestock.	Farm level; different spaces; different times.
Agroforestry	Growing crops and trees together.	Farm level; different spaces; different times.
Mixed landscapes	Development of larger scale diversified landscapes with multiple ecosystems.	Larger scale; spatial; temporal

Source: Modified from Lin (2011).

The United Nations, within the sustainable development agenda, considers poverty as the lack of basic services such as education, hunger, gender inequality, social discrimination and exclusion, and lack of participation in decision making (United Nations, 2015). In line with this definition, the achievement of SDG 1 "No poverty" is, therefore, dependent of the achievement of several other goals, especially Goals 2 (zero hunger), 3 (good health and wellbeing), 4 (quality education), 5 (gender equality), 6 (clean water and sanitation), 7 (affordable and clean energy), 8 (decent work and economic growth), 12 (sustainable production and consumption), 10 (reduced inequalities), 13 (climate action), or 15 (life on land). A summary of benefits resulting from crop diversification as well as their relation to the above SDGs is presented in Table 2. Schleicher et al. (2017) suggest the implementation of interdisciplinary approaches and a better integration of the learnings from environmental, sustainability, and poverty literatures to further understand the synergies and trade-offs between these agendas in order to develop better informed development policies.

The aim of this review is, therefore, (a) to provide a better understanding of the contribution of crop diversification (including diversification into crops and livestock and agroforestry) to SDG 1 "No poverty" considering more dimensions than only income and (b) to identify the factors influencing the implementation of crop diversification.

2 | MATERIALS AND METHODS

In order to investigate the contribution of crop diversification to poverty alleviation and the factors influencing the implementation of crop diversification, a scoping review was undertaken. According to Colquhoun et al. (2014), a scoping review is a "form of knowledge synthesis that addresses an exploratory research question aimed at mapping key concepts, types of evidence, and gaps in research related to a defined area or field by systematically searching, selecting and synthesizing existing knowledge." Therefore, a literature search in the Web of Science (core selection) was carried out in 2016 using the search strings (a) "crop diversification AND "agricultural diversification AND "poverty alleviation", (b) agriculture" AND diversification" AND practice" AND market" AND system", and (c) "crop diversification" AND agricultural diversification" AND income" AND nutrition" AND food security" AND gender" AND climate change adaptation" AND climate change vulnerability. The last string was to ensure that different dimensions of poverty such as income, food security and nutrition, gender equality, and vulnerability to climate change were captured. The Web of Science was used because of its broad coverage of studies across disciplines, large temporal records, and collection of scientific studies published in renowned journals (Arezoo et al., 2013).

In total, 2,426 titles were retrieved in the literature search, including titles from scientific articles, reviews, working papers, and books or book chapters. The eligibility assessment of the studies was performed independently by the author. The titles of the studies retrieved in the literature search were screened and divided in two categories, namely, (1) titles considered relevant for the analysis and (2) titles considered not relevant for the analysis. In total, 100 titles were considered relevant for the analysis, and the abstracts associated to these titles were read. From these 100 titles and associated abstracts, 34 studies were

TABLE 2 Contribution of crop diversification to the achievement of the Sustainable Development Goals (SDGs)

SDG	Type of benefit	Specific benefits of crop diversification	Sources
Goal 15: life on land	Environmental protection	-Avoids soil exploitation; -Reduces soil erosion; -Provides habitat; - Greater nutrient uptake and cycling that sustains production on existing plots; -Maintaining biodiverse vegetation cover that provides environmental services; - Avoiding the need for forest clearing and the consequent environmental impacts.	Lin (2011) Joshi et al. (2004) Perz (2004) Ellis (2000) Nair (1993)
Goal 13: climate action	Climate change mitigation	-Reduces need for nitrogen fertiliser and consequently less greenhouse gas emissions.	Lin (2011)
	Climate change adaptation	• Improves tolerance to drought and water-logging; • Key adaptation strategy for smallholder farmers under climate change; • Increases yield stability; • Can serve as insurance against rainfall variability as different crops are affected differently by climate events; • Relative differences in productivity between monocultures and polycultures become more accentuated as water stress increases; • Crop diversification can improve resilience by engendering a greater ability to suppress pest outbreaks and reduce pathogen transmission, which may worsen under future climate scenarios, as well as by buffering crop production from the effects of greater climate variability and extreme events.	Alemayehu and Bewket (2017) Antwi-Agyei, Dougill, Fraser, and Stringer (2013) Mijatovic et al. (Mijatović, Van Oudenhoven, Eyzaguirre, & Hodgkin, 2013) Gajigo (2013) Lin (2011) Truscott, Aranda, Nagarajan, Tovignan, and Travaglini (2009) Nhemachena and Hassan (2007) Joshi (Joshi, Gulati, Birthal, & Tewari, 2004) Natarajan and Willey (1986) Holling (1973)
Goal 12: sustainable production	Crop productivity	-Increases soil fertility; -Can improve productivity of the main crop and can increase yields in general; -Increases production and increases production stability; - Reduces the risk arising from seasonal factors.	Makate, Wang, Makate, and Mango (2016) Mugandi Njeru (Mugendi Njeru, 2013) Lin (2011) Adger, Huq, Brown, Conway, and Hulme (2003) Orindi and Eriksen (2005)
	Protection against pests and diseases	-Can improve resilience in a variety by engendering a greater ability to suppress pest outbreaks and dampen pathogen transmission; -Controls pests and diseases; -Provides habitats for beneficial insects, and this can help in reducing the number of pests by rendering host crops less apparent for colonisation by parasites.	Mugandi Njeru (Mugendi Njeru, 2013) Shoffner and Tooker (2013) Lin (2011) Truscott et al. (2009)
	Safety against market oscillations	-Reduces financial risk; -Mitigates price risk as well as fluctuations in outputs; - Crop diversity is a strategy for risk avoidance due to sharp fluctuations in crop yield or prices.	Coromaldi, Pallante, and Savastano (2015) Yu (2015) Gajigo (2013) Ashfaq, Ashiq, Baig, and Saghir (2008) Mishra and Osta (Mishra & El-Osta, 2002) Ellis (2000)
Goal 8: decent work and economic growth and Goal 10: reduced inequalities	Increase income and employment	-Increases economic stability; -Stabilises farming income; -Increases choice of farm practices; -Stabilises employment through an extended on-farm season; -Generates employment opportunities; -Crop diversification significantly improves income from agricultural activities.	Makate et al. (2016) Huang, Wu, and Rozelle (2009) Birthal, Joshi, Roy, and Thorat (2007) Joshi (Joshi et al., 2004) Guvele (2001) Johnston, Vaupel, Kegel, and Cadet (1995)
Goal 5: gender equality	Gender equality	-Agriculture diversification empowers women farmers.	Joshi (Joshi et al., 2004)
Goal 2: zero hunger and Goal 12: sustainable consumption	Nutrition and food security	-More diverse production systems may contribute to more diverse household diets; -Fruits and vegetables production is beneficial for food security and ultimately anaemia status of individuals (in particular, women of childbearing age); -Crop diversification also has a direct effect on food availability and nutrition.	Mugandi Njeru (Mugendi Njeru, 2013) Makate et al. (2016) Jones, Shrivinas, and Bezner-Kerr (2014) Kabunga, Dubois, and Qaim (2014) Lin (2011)

downloaded and read in full, whereas the remaining 66 abstracts were considered not relevant or the studies associated to these abstracts not accessible for download (even with institutional login). In addition to the studies identified through the literature search, 15 more studies listed in the reference section of the articles previously retrieved were added to the analysis because of their relevance to the topic of the review. This process is known by snowballing, and it has been used in systematic literature studies. It refers to using the reference list of an article or the citations to the article to identify additional articles (Wohlin, 2014). In total, 49 studies were analysed in-depth and categorised according to the year of publication, country/region covered, type of study (analysis, review, working paper, and report), and poverty dimension (income, food security and nutrition, gender equality, vulnerability to climate change). The process of identifying relevant titles, abstracts, and themes was subjective, based on the judgement of the author. A first organisation of the selected studies focused on the impact (positive, negative, and neutral) of crop diversification on each dimension of poverty. A second organisation of the selected studies focused on the identification of factors influencing the implementation of crop diversification and their impact (enabler, barrier). The studies retrieved cover countries in the Global South and the regions of Central and Latin America, Asia, and Africa (see Supporting Information), were published between 1986 and 2018, and were all written in English.

The resulting literature review offers no new data. Rather, its originality lies in linking separate literature fields, namely crop diversification and poverty, poverty with income, food security, gender equality, vulnerability to climate change, and with factors influencing the implementation of crop diversification. Food security has been defined as "Food security [is] a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2002). Gender equality has been defined as "providing women and girls with equal access to education, health care, decent work, and representation in political and economic decision-making processes will fuel sustainable economies and benefit societies and humanity at large" (UN, 2016). Vulnerability to climate change has been defined as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC, 1997). According to D'Souza, Cyphers, and Phipps (1993), factors affecting adoption of sustainable agricultural practices can be grouped under four categories, namely, human capital (e.g., age and education), structural (farm size, off-farm employment), institutional (e.g., participation in government programs), and environmental (e.g., rainfall and soil quality).

3 | RESULTS

3.1 | The contribution of crop diversification to SDG 1 "No poverty"

This study assesses the contribution of crop diversification to SDG 1 "No poverty" through an assessment of the impact of crop diversification on four dimensions of poverty, namely, income, food security and nutrition, gender equality, and vulnerability to climate change. The main types of crop diversification strategies found in the literature reviewed were crop diversification, not always specified by the studies but usually including crop mixes, polyculture and crop rotations, diversification into high-value crops, mostly fruits and vegetables, adoption of agricultural technology, usually modern varieties and improved crops, implementation of agroforestry, and crops and livestock diversification.

3.1.1 | Income

A significant positive association between crop diversification and farm income was found by Makate et al. (2016) in Zimbabwe, by Bravo-Ureta et al. (2006) in El Salvador and Honduras, and by Perz (2004) in the Brazilian Amazon. Bravo-Ureta et al. (2006) estimated a 21% average increase in farm income of the entire sample in the analysis, whereas Perz (2004) found a very strong positive relationship between diversification and income. Makate et al. (2016) observed that increased production from diversified cropping systems (crop rotations, intercropping) resulted in higher income for farmers.

The literature search revealed a growing body of literature on the effects of high-value commodities (e.g., vegetables, fruits, and livestock) on income, with most studies revealing a positive effect. In West Africa (Burkina Faso, Ghana, and Senegal), Douxchamps et al. (2015) observed that diversification with vegetables, and with livestock, increased household earnings from 360 to 640 USD, and from 990 USD to 1,040 USD, respectively. Emana, Afari-Sefa, and Dinssa (2015) discovered that in Ethiopia, vegetables can provide significant cash income for farmers since they sell the marketed surplus, that is, the share of the total production sold in the market, and buy other food, contributing to increase food accessibility and improve livelihoods. But these authors also observed that vegetable yields of small-scale and resource-poor farmers were very low and mainly for home consumption. Mandere, Anderberg, Armah, and Abaya (2011) undertook a sugar beet profit analysis for Kenya and showed that sugar beet could potentially increase household net income provided its market price is higher than the minimum price for sugar feedstock supplies. Nevertheless, the analysis also indicated that mainly households within the high income category, who can raise the required start-up capital were likely to benefit, whereas the low- and medium-income households were less likely to benefit. The authors concluded that alternative agriculture alone, such as adoption sugar beet, was not a sufficient strategy to address the problems of poverty and unemployment. A more favourable study is by Huang et al. (2009), who suggested that the expansion of fruit production in China was a good opportunity for less educated households, with older members (who are also poorer in China) to raise their incomes. Birthal, Joshi, Roy, and Thorat (2013) also suggested that in India, diversification towards fruits and vegetables could result in higher net incomes for small farmers (without any significant increase in variability) and consequently with a positive impact on poverty reduction. Joshi et al. (2004) analysed the diversification of agriculture in high-value commodities such as fruits, vegetables, livestock, and fisheries in South Asian countries and estimated that fruits were eight times more

profitable than cereals and that livestock activities had the potential to enhance smallholder farmers' income in Indian rural areas. Von Braun et al. (1989) analysed the diversification into vegetable production (snow peas, broccoli, cauliflower, parsley) for the export market by traditional small-scale farmers in the Western Highlands of Guatemala and discovered that household expenditure, a proxy for income, increased by 33%, moving the poorest upward on the income scale. Thapa, Kumar, Roy, and Josh (2018) estimated that in Nepal, households growing high-value crops such as vegetables, fruits, and spices or condiments had a mean monthly per capita expenditure 28% higher, on average, than non-growing farming households, and that high-value crop growers had a headcount ratio[1] 9% lower than nongrowers. Mukherjee (2015), however, found that the aggregate per capita net earnings from cultivation of high-value crops in West Bengal in India was lower in the more diversified villages and that farmers in these villages ended up with considerably less income compared with farmers in the less diversified villages. Immink and Alarcon (1991) found both positive and negative impacts of diversification into high-value crops (potatoes, wheat, vegetables) on farmers' income in Guatemala, this depending on the farm size. In general, they found an increase on the overall income of farmers who diversified from maize into potatoes, wheat, and vegetables of 7.8, 23, and 15.6%, respectively. But they also observed a negative impact of −9% on overall income of small farmers with less than 1.5 ha who diversified from maize to potatoes. Several studies argue that diversification into high-value crops can also contribute indirectly to reduce poverty through employment and higher incomes. Van den Broeck and Maertens (2016) concluded that the production of horticulture for the export market can increase the income purchasing power of contract farmers and workers in the export chain. Maertens and Swinnen (2009) found out that agro-industrial employment and contract farming for French beans in Senegal have a significant positive effect on rural incomes. These authors also found that participants in French bean production for the export market have 60% to 110% higher incomes than the average income in the study area. These authors concluded that high-standard agricultural trade benefits rural incomes and reduces poverty even if export production is undertaken at industrial estate farms. Huang et al. (2009) found out evidence that the rise of horticulture production in China provided households, which were unable to access jobs off the farm before, a chance to move into activities other than subsistence agriculture.

Three studies found a positive relation between the adoption of agricultural technology and income, namely, Kassie, Shiferaw, and Muricho (2011), who studied the adoption of improved groundnut varieties in rural Uganda, Asfaw et al. (2012), who analysed the adoption of improved pigeon pea in Tanzania, and Teclewold, Kassie, Shiferaw, and Kohlin (2013), who studied cropping system diversification, conservation tillage, and modern seed adoption in Ethiopia. Kassie et al. (2011) demonstrated that, on average, there was a yield increase (from 649 to 873 kg per hectare) and a 41% cost reduction (per kilogram produced) from growing new groundnut varieties, compared with traditional varieties. These authors estimated a potential increase in household crop income of 130 to 254 USD and a decrease in the headcount ratio of 7 to 9%. Asfaw et al. (2012) estimated that adopters of improved pigeon pea were about 20% more productive compared with nonadopters, and that variable costs for adopters were 34.5% lower, on average, than for nonadopters, this translating into a significantly higher average net income for adopters when compared with nonadopters. Teclewold et al. (2013) observed that in Ethiopia, farmers obtained a higher income when system diversification and conservation tillage practices were combined with improved seeds. One study reveals a negative impact of the adoption of modern varieties on farmers' income. This is Coromaldi et al. (2015), who found out that in Uganda, adopters of modern varieties of staple crops (mainly maize) lost, on average, 11.2% in crop profits per capita.

Finally, Basu (2014) observed that, in India, agroforestry systems offer opportunities for the improvement of poor peoples' livelihoods through the provision of economic security, namely employment generation.

3.1.2 | Food security and nutrition

The contribution of crop diversification to increased food security and nutrition in poor households is, according to the studies retrieved, mostly positive. Pretty, Morison, and Hine (2003) found out that 89 out of 208 agricultural diversification projects, such as home garden intensification with vegetables or tree crops, inclusion of vegetables on rice bunds, introduction of fish ponds in paddy fields, or dairy cows and trees on farms, implemented in 52 developing countries contributed to an increase of food production in a per hectare basis. For the successful projects, the impact of crop diversification on food production was very high, contributing, on average, to a 93% increase on food production per hectare. By assuming a direct relation between food production and food security, the authors also assumed a strong positive impact of the 89 diversification projects on food security. A positive correlation between crop diversification and dietary diversity in Malawi was found by Snapp and Fisher (2015). These authors estimated that one unit increase in the average number of intercrops per maize farm was associated to 2% increase in the Household Dietary Diversity Score[2] and that increasing the number of nonmaize crops grown on a farm by one was associated to 1% increase in the Food Consumption Score.[3] Makate et al. (2016) also discovered a significant positive impact of crop diversification on cereal crop productivity, on the food security, and on the nutrition indicators (Food Consumption Score and Household Dietary Diversity Score) in Zimbabwe. In Nicaragua, Bacon et al. (2014) confirmed the importance of mixing corn and beans, which Mesoamerican farmers have managed in their *milpa*

[1]**The headcount ratio**: the proportion of a population that exists, or lives, below the poverty line.

[2]Household Dietary Diversity Score: The Household Dietary Diversity Score is a continuous variable with values from zero to 12. In calculating the Household Dietary Diversity Score, food items were grouped into 12 different categories, and each food group was counted toward the household score if an item from the group was consumed in the last 7 days by a household member (Swindale & Bilinsky, 2006).

[3]Food Consumption Score: The Food Consumption Score is a continuous variable calculated on the basis of the frequency of consumption of nine different food groups consumed by a household's members during the 7 days prior to the survey (UNWFP-VAM, 2006).

production systems for thousands of years, but found out that simply adding more crops or animals had no significant impacts on seasonal hunger and that an integrated agroecology-based approach was needed. In Guatemala, evidence from an "ex-post" classification of crop diversification patterns and food security in a household survey indicated that crop diversification patterns varied extensively within and between regions, and that small farmers who diversified from maize to potatoes were more likely to suffer negative food insecurity and malnutrition than those who diversified from maize into wheat and vegetables (Immink & Alarcon, 1991).

This research only found few studies directly measuring the impact of high-value crops and commodities (e.g., fruits and vegetables and livestock) on food security and nutrition, and without consensus regarding its impact, with some studies suggesting a positive impact and others suggesting a low or even negative impact. Douxchamps et al. (2015) found out that in West Africa, households with diversifying into vegetables were 40% more food secure than those undertaking subsistence farming, and that mixed farming (crops and livestock) were 59% more food secure than those undertaking subsistence, diversified, and extensive farming. Emana et al. (2015) observed that in the Humid Tropics of Ethiopia, more than 65% of all major vegetables produced during the study year were sold on the market and that most households producing vegetables for the market also consumed a portion at home. They also observed that vegetables provided substantial cash income that allowed the farming community to access food and contributed substantially to food and nutrition security by complementing staple foods with vitamins and minerals. Snapp and Fisher (2015) showed that in Malawi, livestock diversity was positively associated with dietary diversity and consequently important for household consumption quality. In West Bengal, India, Mukherjee (2015) found an inverse association between intake of kcal per capita and crop diversification indices. She concluded that diversification towards high-value crop production was taken up by poor farming households as a survival strategy in places where lack of publicly supplied irrigation made it impossible to survive on water-intensive traditional crops and that poor and marginal farmers found it very hard to avoid extreme poverty and malnutrition by taking resort to diversification. According to Van den Broeck and Maertens (2016), the evidence available suggests that at the macro-level, the production of high-value crops for the export market can contribute to the stability of food security in developing countries and does not necessarily reduce food production for the country domestic market. However, these authors highlight the scarcity of empirical evidence at the macroeconomic level that directly measures the implications of increased horticultural exports for food availability and access. An expenditure and food consumption analysis undertaken by Von Braun et al. (1989) for Guatemala found that incremental income earned from high-value crops was relatively less spent on food, and consequently on calorie uptake, than other income, for same-income levels.

Snapp and Fisher (2015) consider the role of of agricultural technology (e.g., modern and improved varieties) in promoting a food-secure environments through experimentation with other crops and contribute to increased dietary options. However, this is difficult to confirm as only two studies, in two different countries (Tanzania and Uganda), were retrieved. Asfaw et al. (2012) found out that farmers' adoption of improved pigeon pea increased consumption expenditure (includes purchase of several food items such as food grains, livestock products, vegetables, sugar, salt, and beverages) by about 31% compared with nonadoption. Coromaldi et al. (2015) observed that the adoption of modern varieties produced a loss of 12.2% on food consumption per capita and had a negative impact on the crop richness (−25.7%) and evenness (−14.7%) conserved on-farm.

3.1.3 | Gender equality

This review found only a limited number of articles that investigated and established a relation between crop diversification and gender equality. Nevertheless, some notions can be drawn from the available literature. Dolan and Sorby (2003) considered that any discussion about the impact of crop diversification on gender equality has to consider its impact on food security. Teclewold et al. (2013) observed that adoption of crop system diversification and adoption of agricultural technology (modern maize seeds) in Ethiopia significantly increased the average female labour demand and advised that this may negatively affect larger households by diverting time from food preparation and childcare. Snapp and Fisher (2015) cited several studies showing a positive relationship between high levels of crop and livestock diversity and improved diets in female-headed households in Malawi and between vegetable production diversity and dietary diversity of smallholder female farmers in Tanzania, Kenya, and Burkina Faso. Pretty et al. (2003) reported cases where women cultivating fruits and vegetables alleviated their households from hunger.

Regarding the participation of women in high-value crop production for the export markets, Dolan and Sorby (2003) found no indication that household nutritional and health status was negatively affected, and Van den Broeck and Maertens (2016) observed that the development of rural labour markets and participation of women was favourable to improved food security. Maertens and Swinnen (2009) found that in Senegal, the growth of high-value agricultural production positively benefited rural women through increased wage income and consequently, reduced gender inequalities in rural areas, especially in large-scale estate production and agro-industrial processing. Evers and Walters, cited by Dolan and Sorby (2003), stated that women who obtained an income through their participation in high-value crop production were less dependent on the male head of household as a source of income and experienced a stronger position in household bargaining. Maertens and Swinnen (2009) states that although female income is positively related with spending on children's education, increased female labour demand might have a negative impact on girls' education if they are removed from school, either to participate in the labour market or to replace their mothers in household activities.

3.1.4 | Vulnerability to climate change

Climate change represents a significant threat to current agricultural production and poses serious challenges to millions of poor farmers who live in areas often located in arid or semi-arid zones and in

ecologically vulnerable mountains and hills (Müller, Cramer, Hare, & Lotze-Campen, 2011; Thornton & Herrero, 2014). Recent studies have demonstrated that crop diversification practices help to buffer microclimatic fluctuations (e.g., Altieri et al., 2015; Lin, 2011; Müller et al., 2011; Thornton & Herrero, 2014), and others empirically analysed the resilience of diversified systems, such as polycultures, livestock diversification, and agroforestry systems, to extreme climatic events (e.g., McCord, Cox, Schmitt-Harsh, & Evans, 2015; Megersa et al., 2014; Holt-Giménez, Philpott et al., and Lin cited by McCord et al., 2015). However, only few studies mention the contribution of crop diversification to reduced vulnerability of poor farmers to climate change. Douxchamps et al. (2015) showed that in West Africa, households that implement crop diversification and intensification strategies have higher climate change adaptation capacity and higher food security status. Makate et al. (2016) concluded that greater implementation of diversified cropping systems, especially by those who diversified the least, reduced vulnerability to climate change and variability in smallholder farming systems in southern Africa by significantly improved crop yields, income, food security, and nutrition. Coromaldi et al. (2015) found that in Uganda, above a threshold level of intensification, the economic return of adopters is determined by low adaptability of available modern varieties to poor soils conditions, local climate, and random agricultural shocks. They also observed that both adopters and nonadopters react to agro-climatic shocks by increasing crop richness and evenness.

3.2 | Factors influencing the implementation of crop diversification

Six main factors across the studies analysed were found to influence the implementation of crop diversification, namely, access to roads and markets, access to irrigation, land size, land and water rights, chronic poverty, and policy interventions.

3.2.1 | Access to roads and markets

According to Mukherjee (2015), effectiveness of crop diversification as a strategy for reducing rural poverty depends, to a great extent, on the existence of good infrastructure with good linkages to the markets, which can ensure remunerative prices as well as access to inputs at reasonable prices. In Bhutan, Tobgay and McCullough (2008) found out that farmers who lived closer to roads were more likely to participate in output markets and more likely to grow a crop mix than farmers living in remote areas. Birthal et al. (2013) assumed that the density of paved roads was positively related to the adoption of perishable high-value crops in India, but found that better road density led to livestock diversification (dairy, fisheries, poultry) instead. Emana et al. (2015) observed that the adoption of high-value crops by smallholders in rural areas in Ethiopia was constrained by poor transportation facilities and links to the markets. McCullough and Pingali (2008) found that in Kenya, despite the decline in profitability of maize-based agriculture, the adoption of high-value crops was not widespread due to high input and transport costs and poor market infrastructure. Kassie et al. (2011) discovered that distance to main market was negatively associated to adoption of agricultural technology (improved groundnut varieties) in Uganda.

3.2.2 | Access to irrigation

According to Smith (2004), one way that irrigation can reduce poverty is through increased opportunities for rural livelihood diversification such as alternative high-value crops, intensified livestock production, and other market openings. Zimmerer (2014) believes that irrigation can improve diversity in the farm by allowing crops with different maturation periods to be cultivated through extension of the growing seasons. In India, Mukherjee (2015) found a strong positive relation between the extent of irrigation and crop diversification, which related positively with consumption level and net income. This author also observed that in areas with difficult conditions to build irrigation infrastructure, small farmers (<0.5 ha and 0.5–1 ha) were more likely to produce fruits, oilseeds, jute, and fibres, compared with those from districts endowed with irrigation facilities, in order to meet their cash needs. Thapa et al. (2018) estimated a positive correlation between household access to irrigation and the adoption of high-value crops in Nepal.

3.2.3 | Land size

There is a vast literature analysing the impact of land size on crop diversification. A review of literature undertaken by Harris and Orr (2014) concluded that bigger farm size was usually associated to with crop diversification and commercialisation. Makate et al. (2016) found out that a 1-acre[4] increase in land size accessed by the household was associated with 15.8% increase in the probability of adopting crop diversification in Zimbabwe. Similar positive relationships were also verified by Dorsey (1999) in Kenya, Chibwana, Fisher, and Shively (2012) in Malawi, McCord et al. (2015) in semiarid agricultural systems near Mount Kenya, Hitayezu, Zegeye, and Ortmann (2016) in South Africa, and Shahbaz, Boz, and Haq (2017) in Pakistan. Contrary to this, Adjimoti et al. (2017) found out that in Benin, larger land holdings were associated with lower diversification, mainly due to the fact that large farm size holders tended to diversify into high-value crops and then specialise on this crop (e.g., cashew cultivation). In fact, Birthal et al. (2013) considers that large-scale farmers are often better able to bear the risks associated with the production and marketing of high-value commodities than small-scale farmers. In Tanzania, Asfaw et al. (2012) also found that farm size and plot numbers had a significant and positive effect on the adoption of agricultural technology, namely improved pigeon pea. Mandere et al. (2011) estimated that in Kenya, farmers with a larger portion of land would be more likely to allocate land area to a new crop (sugar beet) by reducing the land area of some of their current crops.

3.2.4 | Land and water rights

The lack of land and water rights can be another obstacle for crop diversification. Pingali and Rosegrant (1995) noticed that securing

[4]1 acre = 0.40468564 ha.

land rights can improve significantly farmers' prospects for commercialisation of high-value crops and that establishing secure water rights could increase the potential for diversification of cropping systems. Shahbaz et al. (2017), found, however, that self-owned operated farms in Punjab region in Pakistan were less likely to undertake crop diversification than other forms of tenure, such as renters and shareholders, but they do not explain why. In Benin, Adjimoti et al. (2017) observed that female-headed households are less likely to diversify into agroforestry because of the traditional land tenure system, which is favourable to men.

3.2.5 | Chronic poverty

In the rural development literature, the concept chronic poverty describes the persistence of poverty over time, often over generations, being commonly understood as a poverty trap (Haider et al., 2017). Causes of poverty include unequal access to and control over resources (Green & Hulme cited by Haider et al., 2017), and cultural, social, political, and economic injustices in access to these resources can continue perpetuating chronic poverty despite agricultural development strategies (Tomich et al., *in press*). This review confirms the difficulty of the poorest farmers to implement the different types of crop diversification. Pal and Kar (2012) found in their study area in India that farmers' poverty was one of the major barriers against crop diversification. Gentle and Maraseni (2012) saw that poor households in Nepal had less possibility to diversify due to limited land ownership, decreasing numbers of livestock, and depletion of forest resources, whereas the well-off people, who owned irrigated land, were introducing some vegetables and other crop varieties. McCord et al. (2015) observed a small but positive effect of both household income and farmers' wealth on crop diversification levels in semiarid agricultural systems near Mount Kenya. In Ethiopia, Emana et al. (2015) observed that, even though most high-value crops, such as vegetables, were grown by resource-poor farmers, the scale of production was low and mainly for home consumption as they lacked capital to buy inputs such as seeds, land, irrigation facilities, and fertilisers that would ensure more intensive production and market participation. Both in India and in Latin America, Birthal et al. (2013) and Key and Runsten (1999) also noticed that high-value crops required significant levels of investment including use of specific inputs, for which savings or credit were needed, but which were usually nonexistent and inaccessible to poor farmers. Regarding the implementation of irrigation, needed to enable the diversification into high-value crops, Smith (2004) advised that this would be difficult for poorer farmers in developing countries as it required capital and training and was costly to operate. In fact, Namara, Gebregziabher, Giordano, and De Fraiture (2013) showed that private smallholder irrigation was mainly practiced by the wealthier farmers in his study on sub-Saharan Africa. Asfaw et al. (2012) found out that adopters of agricultural technology (pigeon pea) were less poor, and with an unconditional headcount poverty ratio 14.6% lower than nonadopters.

3.2.6 | Policy interventions

Crop diversification has been promoted as a poverty alleviation strategy by agriculture and rural development policies and by several developing agencies (Meert, Van Huylenbroeck, Vernimmen, Bourgeois, & van Hecke, 2005). Policy interventions appear usually in the form of measures to overcome existing barriers to the implementation of crop diversification (e.g., improving roads and other infrastructure, improving irrigation due to technological transfer, safeguarding property rights and land tenure security due to improvements of local institutions, and improving small-scale and poor farmers' access to credit). Several studies retrieved by this literature review provide examples of policies supporting the implementation of crop diversification in several developing countries but without informing about the impact of these policies on crop diversification and poverty alleviation. For example, for India, Birthal et al. (2013) mentions the establishment of the National Horticulture Board in 1984 to facilitate private sector participation in the food sector and to promote crop diversification, and Singh (2002) mentions the "New Agricultural Policy 2000" created to promote diversification towards high-value commodities such as fruits, vegetables, livestock, and fisheries. Immink and Alarcon (1991) describes the Guatemalan government programme on crop diversification, whose objective was to promote the production and consumption of cold-weather vegetables by offering credit possibilities for mini-irrigation systems, soil conservation and farm inputs, agricultural extension services, and food and nutrition education initiatives. In addition, Mandere et al. (2011) advise the Kenyan government to promote agricultural technology adoption (drought-resistant sugar beet) and the required infrastructure in order to benefit low- and medium-income farmers.

Two studies mention the impact of policy initiatives on crop diversification. Njeru (2003) observed that the introduction of local initiatives promoting innovations in the production and marketing of higher value fruit and dairy products in Kenya had a positive effect on the implementation of crop diversification in the country. Hewett (2012) concluded that substantial initial governmental funding, which enabled infrastructure development such as the implementation of irrigation systems, supply of quality planting material (propagated trees, plants, vegetable, and flower seeds), and extension services providing education and training to farmers, was essential for the success of high-value crop projects in Brazil, South Africa, and Mexico.

Some studies point out the mismatch of some policies regarding the implementation of crop diversification, mainly high-value crops and other crop mixes. For example, Birthal et al. (2013) found that, in India, incentives to support the price of cereals indirectly contributed to the implementation of taxes on high-value crops, and consequently, to the establishment of an anti-high-value crop bias. In Nepal, Thapa et al. (2018) mentions that although the government promotes diversification into high-value crops, the primal policy focus on cereals continues. These authors urge the Nepalese government to embed the provision of inputs such as irrigation, fertilisers, and improved seeds in the current projects supporting the production and commercialisation of high-value crops, especially in the remote parts of the country where poorer farmers are located. Delgado

(1995) mentioned that policy interventions intended to support rice production in rural Asia largely contributed to decrease the implementation of crop mixes, and consequently, crop diversification. Rosegrant, Schleyer, and Yadav (1995) observed that the artificially high profitability of rice due to the provision of free irrigation water in some Asian countries provided little incentive for farmers to shift to alternative crops. Akanda (2010) observed that in Bangladesh, rice-dominated food habits, government incentives on irrigation, and price floor[5] have encouraged farmers to focus on water-intensive rice farming rather than on crop diversification.

This literature review also shows contradictory findings about the effect of input policies, such as fertiliser and seed subsidies, on crop diversification. Adjimoti et al. (2017) found a negative effect of input policies on crop diversification in rural Benin and observed that these led to specialisation on one specific crop instead. Sahley, Groelsema, Marchione, and Nelson (2005), Dorward and Chirwa cited by Chisinga, Mangani, and Mvula (2011), and Chibwana et al. (2012) observed that, in Malawi, programmes created by government policies to distribute maize seeds and fertiliser among smallholder farmers (e.g., Farm Input Subsidy Programme—FISP 2005–2006) contributed to simplify crop diversification. Chibwana et al. (2012) estimated that households receiving vouchers for fertiliser and seeds allocated 45% more land to improved maize and 21% less land to other crops (e.g., groundnuts, soybeans, and dry beans). These results were contested by those of Snapp and Fisher (2015), Kankwamba et al. (2012), and of Holden and Lunduka (2010), who found, instead, a positive association between agricultural input subsidies and crop diversification in Malawi. Snapp and Fisher (2015) assume that indirect pathways, such as subsidies and adoption of modern varieties, contribute to "fill the farmers' maize basket", freeing them to grow more mixed crops. Chibwana et al. (2012) observed a significant increase in legumes in the market after the government provision of both maize and legume vouchers for fertiliser and seeds in 2009–2010.

4 | DISCUSSION

Agriculture, and more specifically, crop diversification, has been pointed out as a pathway for poverty alleviation (Barghouti, Kane, Sorby, & Ali, 2004; Birthal et al., 2013) and consequently, to Sustainable Development Goal 1 "No poverty." However, despite the benefits of crop diversification for rural communities in developing countries and emerging economies, only limited research on this topic has been undertaken (Mugendi Njeru, 2013). The objective of this review is to provide a better understanding of the contribution of crop diversification to SDG 1 "No poverty," considering four dimensions of poverty, namely, income, food security and nutrition, gender balance, and vulnerability to climate change, and to identify the factors influencing the implementation of crop diversification.

Most the studies reviewed cover the contribution of crop diversification to income (20 studies) and to food security and nutrition (13 studies). There were only a limited number of studies focusing on the contribution of crop diversification to gender equality (five studies) and to the reduction of poor farmer's vulnerability to climate change (seven studies). The main crop diversification strategies described by the studies retrieved are the diversification into high-value crops, and the main dimension of poverty analysed is income. The indicators used by the studies are mainly quantitative (see Supporting Information). No study retrieved mentioned more than three dimensions of poverty alleviation, and only three studies (Coromaldi et al., 2015, Makate et al., 2016, and Douxchamps et al., 2016) looked simultaneously at three of these dimensions, namely income, food security and nutrition, and poor farmer's vulnerability to climate change. This confirms lack of integration of the learnings from environmental, sustainability, and poverty literatures, already pointed out by Schleicher et al. (2017).

Most studies report a positive contribution of diversification into high-value crops on income. More uncertain is the contribution of the diversification into high-value crops to food security and nutrition, with some studies revealing only a marginally positive, or even negative impact, on food security and nutrition. Van den Broeck and Maertens (2016) also acknowledges the lack of empirical evidence measuring the impacts of high-value commodities on food security and its underlying pathways. Regarding the adoption of agricultural technology, such as the adoption of modern varieties or improved crops, the studies retrieved reveal both a positive and negative impact on income and on food security and nutrition. In fact, Snapp and Fisher (2015) question whether the adoption of modern varieties is essential to the on-farm production pathway for development, and whether the uptake of modern varieties is typically associated with a reduction of farm diversity instead.

Only few studies mention the relation between crop diversification and gender equality, and these are mainly on the impact of high-value crops on employment opportunities for women. In some developing countries, women simply have no or have only limited access to land. Because of that, they are almost immediately excluded from the opportunity to farm and produce food (Sahley et al., 2005). Maertens and Swinnen (2009) suggest that women potentially benefit more from large-scale estate production of high-value crops and agro-industrial processing, through the creation of employment, than from smallholder contract farming. There is, however, a large gap in literature regarding the effects of high-value crops trade and modernisation of supply chains on gender (Fontana, Joekes, & Masika, 1998; Maertens & Swinnen, 2009). Meinzen-Dick et al. (in press) states that although there is strong evidence that secure land rights have a positive impact on technology adoption (high-value crops), there is almost no evidence on women's land rights specifically. This review confirms this statement.

This literature also exposes the scarcity of studies analysing the relation between crop diversification and vulnerability of poor farmers to climate change. One of the reasons of this scarcity might be the fact that a combination of strategies, rather than a single strategy, influences vulnerability, and this complexity is difficult to investigate. Douxchamps et al. (2015) showed that different types of adaptations happen simultaneously at the household level as people try to improve various aspects of their livelihoods, opportunistically. There is also a growing realisation that households, particularly those with small

[5]Price floor: Government-imposed price control or limit on how low a price can be charged for a product.

farms, cannot get by on agriculture alone, even less by implementing one individual strategy (e.g., crop diversification), and that farming must increasingly compete for family investment with off-farm and nonfarm opportunities sometimes contributing better to household goals and aspirations. Thus, it may not be logical to separate crop diversification from other strategies that reduce farmers' vulnerability to climate change (e.g., livelihood diversification and income diversification). Douxchamps et al. (2015) also noticed that despite the increase in the promotion of crop diversification as a climate change adaptation strategy, there is a lack of comprehensive analyses of its simultaneous impact on food security. Several studies (e.g., Lin, 2011) suggest that crop diversification has the potential to enhance resilience in agricultural systems against extreme climatic events, and consequently. the capacity to maintain the provision of services, such as nutrient cycling and food production, and consequently. food security. However, several barriers prevent the poorer farmers from implementing crop diversification in the first place. One of these barriers is chronic poverty, which, according to the studies reviewed, seems to prevent poor farmers from accessing agricultural inputs such as seeds, fertiliser, irrigation, or land that would allow them to diversify. Extremely poor households face very high levels of risk, which limit their investment capacity and their ability to innovate, including the implementation of crop diversification (Losch et al., 2011; Tomich et al., *in press*). The FAO recognises that poor farmers can only access technologies and farming systems with low efficiency and are more dependent on inputs and techniques that exacerbate land degradation and that reduce the resilience to rainfall variability (FAO, 2011). Weinberger and Lumpkin (2007) adverts that although diversification into high-value crops can offer good opportunities for poverty reduction by increasing income and generating employment, small and poor farmers might be excluded from the opportunities provided by the market. Therefore, there might be a problem of causal circularity (Myrdal, 1957), where diversification into high-value crops or other forms of crop diversification contribute positively to farmers' income, but where farmers with low income and are trapped in poverty do not have the capacity to implement it. Despite the assumed positive impact of high-value crops, more research needs to be undertaken regarding its impact on poor farmers' income, food security, and vulnerability to climate change.

Another barrier that might prevent farmers from implementing crop diversification is farm size. Most of the studies reviewed found a positive relation between farm size and crop diversification, with only one study (Adjimoti et al., 2017) finding a negative relation. McCord et al. (2015) link the positive relation between farm size and crop diversification with increased farmers' ability to tolerate risk as it considers that farmers with larger landholdings have more cultivable space to experiment with new crops. But although this may be the case for crop diversification with several crop mixes and adoption of agricultural technology such as modern varieties, the increase in farm size may also lead to specialisation with fewer and more specialised high-value crops or cash crop production (Eneyew, 2012). Birthal et al. (2013) warns about the increased risk small farmers might bear by allocating land to a commercial crop instead of crops that ensure their food security. Several governments in developing countries were found to promote crop diversification through policies and programmes, but given the inconclusive evidence about their impact on poverty and its dimensions, more research and impact evaluation exercises should be undertaken.

In terms of the influence of access to roads and markets, there is no clear answer regarding its influence on crop diversification, with some studies revealing a negative effect, whereas others reveal a positive effect, independent of the type of crop diversification. In the case of land and water rights and irrigation, only few studies were retrieved. Because land and water rights are not the same for men and women in many countries (e.g., Malawi), it is imperative to undertake further research on the effect of these factors on crop diversification and in relation to "gender equality" and "no hunger." van Noordwijk (*in press*) considers that natural resource management

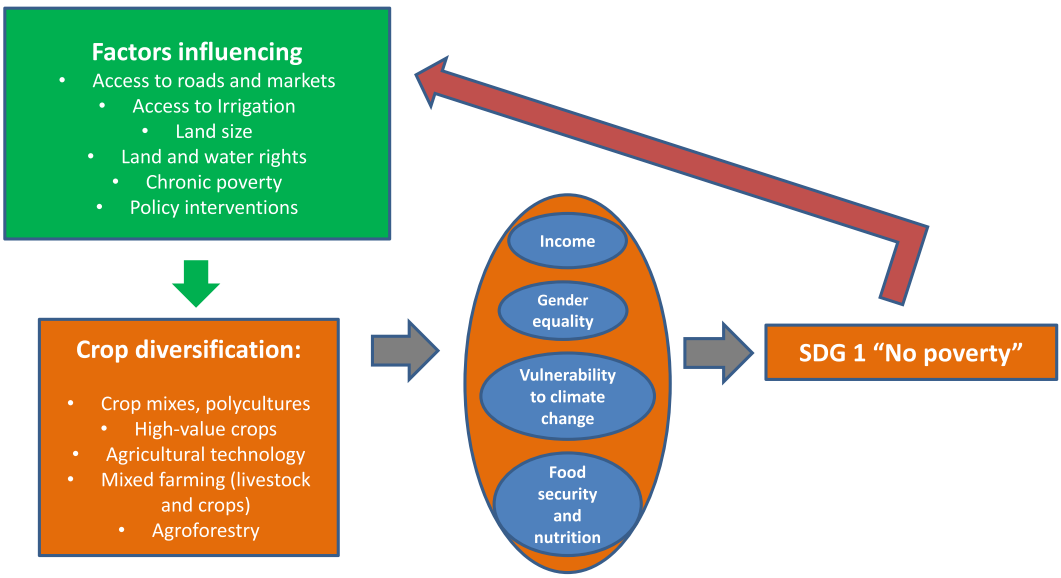

FIGURE 1 Several factors influence the implementation of crop diversification, which in turn contribute to the different dimensions of poverty. The "poverty condition" influence access to resources, which will influence the implementation of crop diversification [Colour figure can be viewed at wileyonlinelibrary.com]

policy research and institutional innovations can also build security of tenure and access to resources and thus have real impact on poverty reduction and vulnerability to external threats, both biophysical and anthropogenic.

In relation to the factors influencing the implementation of crop diversification, it is observed that depending on the contextual circumstances (e.g., country and region), and also to the type of crop diversification considered (crop mixes, high-value crops), the same factor might act as a barrier or enabler. In their study on semiarid systems near Mount Kenya, McCord et al. (2015) found high levels of crop diversification irrespective of income, biophysical conditions, or irrigation factors. Deep changes in the development context of most countries in the past 25 years (Tomich et al., *in press*) imply the need for an update on research design and policy and impact evaluation.

5 | CONCLUSION

This review concludes that studies on the impact of crop diversification on poverty mainly focus on economic indicators. Therefore, it is not possible to conclude the real effect of crop diversification on SDG 1 "No poverty" because studies on the other dimensions of poverty are very scarce, and only a very few analyse poverty alleviation from a sustainability approach perspective. Expanding the concept of poverty and differentiating the impact of crop diversification according to the different types implemented (e.g., high-value crops, crop mixes, and modern varieties) could better clarify policymakers about the real impacts of this strategy. A holistic evaluation of the impact of the different crop diversification types on SDG 1 "No poverty" should also be associated to any crop diversification promotion programme or policy. Qualitative approaches that strongly encourage stakeholder interaction and evaluation by practitioners and other experts with a stronger focus towards smaller spatial scales such as the community level should be developed (Williges, Mechler, Bowyer, & Balkovic, 2017), rather than mostly focusing on quantitative indicators. Future research should focus on the contribution of high-value crops and agricultural technology to income, gender equality, and vulnerability of poor farmers to climate change, and not only on farmers in general. The influence of factors such as land and water rights should be thoroughly analysed, and policymakers should prioritise measures that interrupt the poverty trapping circle and provide the poorest farmers (including women) with access to land, water, and other resources (e.g., extension services, education, and land reform) so they are not prevented on implementation and market participation. A conceptual model of the review undertaken in this study is provided by Figure 1.

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