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FOOD SCIENCE & TECHNOLOGY | REVIEW ARTICLE

Impact of agricultural interventions on food and nutrition security in Ethiopia: Uncovering pathways linking agriculture to improved nutrition

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Abstract: Achieving sustainable food and nutrition security calls for multi-sectoral coordination mechanisms in implementing, among others, nutrition-sensitive agricultural interventions. Despite progresses made in evaluating the effectiveness/impact of these interventions in some countries, very little is known about the nature and causal effect of these interventions in Ethiopia. Therefore, this systematic review aims to provide evidence on the impact of nutrition-sensitive agricultural interventions and pathways linking agriculture to improved nutrition. Based on a comprehensive advanced literature search using keywords in various databases and setting inclusion/screening criteria, we identify 25 relevant studies conducted between 2008 and 2018. Overall, we find positive effects on knowledge, attitude, and practice of complementary feeding and economic indicators (income, poverty and asset accumulation). We also find an overwhelming positive effect on food consumption, dietary diversity, and food security indicators. However, we also note mixed effectiveness in relation to child anthropometry. The most important pathways linking agriculture to improved nutrition center on its role as a source of food and income, and its effect on food prices/market. Hence, enhancing community-based nutrition education, accelerating adoption of improved technologies, improving access to farm inputs and technical information, integrating farmers to

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PUBLIC INTEREST STATEMENT

Agriculture continues to be the life support mechanism for millions of smallholders across the globe. In addition to enabling food security, the sector is expected to positively impact nutritional security. Hence, there is a lot of attention given to uncover the link between agricultural investments and changes on food security status, household dietary diversity, and overall economic development. In developing countries like Ethiopia, however, there is a scanty systematic and empirical literature available to shed light on this role of agriculture. This contribution is, therefore, an attempt made to illuminate the role nutrition-sensitive agricultural interventions play in the context of Ethiopian livelihoods.

markets, and boosting enabling environments and capacities should be emboldened.

Subjects: Environment & Agriculture; Development Studies; Economics & Development; Rural Development

Keywords: nutrition-sensitive agriculture; effectiveness; impact; pathways; malnutrition; food security

JEL CLASSIFICATION: D13; I31; O13; O33; Q12; Q16

1. Introduction

There have been growing global consensus that multi-sectoral approaches and coordination mechanisms should be followed to address the debilitating impacts of malnutrition (FAO, 2017; Sassi, 2017; World Bank, 2015). In particular, nutrition-sensitive interventions in the food and agricultural sector are believed to play a pivotal role (Beyero, Judith, & Amanda, 2015; FAO, 2017; Herforth & Terri, 2016; Ruel & Harold, 2013) alongside the nutrition-specific interventions. According to FAO (2017), nutrition-sensitive agriculture entails the sustainable production of diverse, economically affordable, culturally acceptable, and safe animal-/plant-based foods in adequate quantity and quality in order to satisfy the dietary needs of populations. Such interventions can be a game-changer contingent upon favourable/enabling environments (Beyero et al., 2015; Ruel & Harold, 2013), appropriate policy and governance structures (Turner et al., 2013), and enhanced local implementation capacities (Warren and Edward, 2017).

In this regard, there have been progresses made in evaluating the effectiveness/impact of such interventions (see, for instance, Rahman & Islam, 2014; Yosef, Andrew, Barnali, & Stuart, 2015; Fiorella, Rona, Erin, & Lia, 2016). These studies provide evidence on how agriculture can potentially influence nutrition, entry points into nutrition-sensitive agriculture, specific interventions with a greater effect on nutritional outcomes, and challenges in targeting vulnerable segments of the society. Nevertheless, gaps still remain to draw definitive conclusions. For example, there are studies that show weak or little effect on nutritional outcomes (Haddad, 2013; McDermott, Myriam, Julien, & Nancy, 2013; Ruel & Harold, 2013; Webb & Eileen, 2014) or mixed efficacy of such interventions in some developing countries (Dorward, 2013).

A recent analysis shows weaknesses in study design, survey tools and measurements as the major contributing factors (Webb & Eileen, 2014). Realizing these gaps and variations in the design and implementation of nutrition-sensitive agricultural interventions across countries and regions, there is a need to generate additional knowledge to build a strong evidence base. In particular, methodologically rigorous and high-quality evaluations are required (Beyero et al., 2015; Girard, Julie, Corey, & Olafunke, 2012; Ruel & Harold, 2013). Furthermore, location-specific research is needed on many of the agriculture-nutrition pathways and processes (Yosef et al., 2015) and diverse outcome indicators (Herforth & Terri, 2016).

Therefore, the present study is one that addresses these gaps in order to provide specific and policy-relevant recommendations. In this regard, Ethiopia provides a special case because despite the high commitment from the government and other stakeholders—reflected through the National Nutrition Programme (NNP), increased budget, and promotion of nutrition-sensitive interventions—undernutrition remains to be a serious challenge (see Section 2 for details). In addition, there is little recent empirical evidence that evaluates the impact pathways especially after the introduction of the NNP in 2008. Hence, this study is aimed at identifying nutrition-sensitive agricultural interventions in the country, evaluating their impact primarily on food and nutrition security, and identifying key pathways linking agriculture to enhanced food and nutrition outcomes.

1.1. A brief review of agriculture–nutrition linkages in Ethiopia: progresses and gaps¹

According to the Global Nutrition Report (2017), worldwide 23% of children under five years of age were stunted and 8% were wasted in 2016. The data for Eastern Africa imply worsened conditions especially for stunting (37%). In Ethiopia, both stunting (38%) and wasting (10%) were higher. Huge gaps also remain in adolescent and adult nutritional status. Several interventions have been initiated to address the underlying and immediate causes, and thereby curb the effect, of under-nutrition in the country. The National Nutrition Strategy (NNS) was launched in 2008 and operationalized through the National Nutrition Programme (NNP). The NNP aims at mainstreaming nutrition into the programming of various sectors. The NNP has five strategic objectives (Federal Ministry of Health (FMOH) Government of Ethiopia, 2013): (1) improve nutritional status of women (15–49) and adolescents (10–19), (2) improve nutritional status of infants, young children and children under-five, (3) improve delivery of nutrition services for communicable and non-communicable/lifestyle-related diseases, (4) strengthen implementation of nutrition-sensitive interventions across sectors, and (5) improve multisectoral coordination and capacity. In the 2015–2020 revised NNP-II, the government is committed to reduce stunting to 26% by 2020 and to allocate additional domestic funding of US\$15 million (FMOH, 2013).

The Ministry of Agriculture and Natural Resources (MOANR) also included nutrition-sensitive provisions in the Productive Safety Net Program (PSNP) and Agricultural Growth Program II (AGP-II). In addition to ensuring food security and better livelihoods, the current phase (2015–2020, i.e., PSNP4) focuses on addressing undernutrition through multisectoral programming (World Bank, 2015). The MOANR also drafted a strategic plan for nutrition-sensitive agriculture in October 2016 (The FDRE MONR, 2016). This strategy aims at: (1) increasing production of diverse nutrient-dense foods, (2) increasing dietary diversity, (3) developing agricultural markets, and (4) enhancing enabling environment for nutrition-sensitive agriculture (Ethiopian Agricultural Transformation Agency [ATA], 2017). Other notable actions by the government include joining the global Scaling Up Nutrition (SUN) movement in 2010 and the 2015 Seqota Declaration to end the stunting of children under two years of age by 2030.

Despite these progresses, there are still widespread challenges associated with malnutrition in the country. The country has the seventh highest number of stunted children in the world (European Commission, 2017), and according to the Global Burden of Disease Study, childhood stunting, wasting and underweight are the major reasons for deaths of children under five years of age due to diarrhoea and other common infections (Deribew et al., 2010). Moreover, according to Save the Children (2014), the cost of malnutrition to the national economy in 2013 was US\$ 4.7 billion (i.e., 16.5% of GDP). So, what is the contribution of nutrition-sensitive agricultural interventions in the fight against malnutrition? This is one of the central questions that we investigate in this review.

2. Data and methods

2.1. Conceptual framework

A careful consideration is made in the development of a conceptual framework that illustrates the linkages between agriculture and nutrition and serves as a guide in the review process. In this regard, the conceptual frameworks in previous reviews, such as in Masset, Lawrence, Alex, and Jairo (2011), Gillespie, Harris, and Kadiyala (2012), Hawkes, Turner, and Waage (2012), Ruel and Harold (2013), and Kadiyala, Jody, Derek, Sivan, and Stuart (2014) are critically evaluated. In addition, conceptual frameworks in studies, such as Girard et al. (2012), Turner et al. (2013), Webb (2013), and Herforth and Terri (2016) are assessed. Consequently, the framework by Masset et al. (2011), with the addition of seven impact pathways (Webb, 2013), is adapted in our investigation.

2.2. Comprehensive literature search

As a second stage in the review process, past and current publications are searched to locate and list all the relevant interventions, pathways and processes. A similar approach was followed in previous studies (e.g., Girard et al., 2012; Masset et al., 2011; Turner et al., 2013; Webb & Eileen, 2014). The search is done in February 2018 on the following databases/search engines: PubMed, Web of Science (All Databases), EconLit, Popline, Scopus, The Lancet, Proquest, AGRIS, ELDIS, Ideas/repec, World Bank (Jolis), DFID, IFPRI, FAO (fapda) and Food Security Portal. The keywords used in the search relate to: agriculture, nutrition, food production, rural development, homestead garden, livestock, dairy, poultry, crop, food security, anthropometry, child growth, diet, health, and sustainable development.

The studies obtained through the search procedure are scrutinized for relevance through setting inclusion criteria. Such criteria were set and employed by previous studies, such as by Masset et al. (2011), Girard et al. (2012), Turner et al. (2013), and Kadiyala et al. (2014). The present study considers the following inclusion criteria: (1) time period: 2008–2018 (the year 2008 was chosen in order to coincide with the onset of the Ethiopian National Nutrition Programme); (2) studies that exclusively state improvements in nutritional outcomes as an objective; (3) studies that evaluate the impact/effect of agricultural interventions; (4) availability and accessibility of full-length peer-reviewed articles; and, (5) study design considerations. As a result, a total of 630 publications are obtained using the advanced search in the title field. After checking for duplicates and irrelevant contents, 284 papers are saved to Mendeley. From these, 163 relevant papers are found after reading the title, abstract, and keywords. A full-length quick scan resulted in 75 potentially suitable papers. Finally, after reading throughout these papers, 25 studies are selected for the review.²

3. Result and discussion

3.1. Description of the studies included in the review

The types of development interventions included in this review are given in Table 1. Geographically, we note a high concentration of studies in few regions of the country, i.e., Southern Nations, Nationalities and Peoples (SNNP), Amhara, Oromia, and Tigray. No studies are found for four regions (Afar, Benishangul Gumuz, Gambela, and Harari), Dire Dawa Administrative Council, and Addis Ababa City Administration. The main units of analysis in the reviewed studies are households (20%), children 6–24 months old (20%), children under five years of age (16%), and mother/caregiver and children (16%).

Table 1. Distribution of studies by intervention category

Intervention category	Number of studies ^a
Crop production	6
Livestock production and management (exclusive) ^b	6
Livestock (general) ^c	5
Productive safety net program (PSNP)	3
Nutrition education and complementary feeding	4
Agricultural water use	3
Agricultural production (general) ^d	4

^aThe numbers do not add up to 25 because some studies fell into more than one intervention category.

^bThese refer to interventions that focused entirely on livestock production and management.

^cThese are studies that have many components but treated livestock production as one aspect.

^dThese refer to general agricultural activities as reflected by crop-livestock mixed farming, access to farmland or farm input use.

Source: Based on the authors' elaboration of reviewed papers.

Concerning study design, 15 out of the 25 studies were based on cross-sectional survey design; seven studies used quasi-experimental design; and, the rest employed longitudinal design. All the studies used questionnaires to gather data; 12 of them applied measurements (to obtain anthropometric data). Other methods, such as focused group discussions (FGDs), key-informant interviews (KIIs), and observations were rarely used. Data analysis was predominantly carried out through regression techniques (60%) and mean comparisons (20%). Other analytical procedures include propensity score matching (PSM) combined with regression (8%), PSM only (8%), and qualitative analysis (4%). We identified a total of 21 outcome/impact indicators, which we grouped into six broader categories following Herforth and Terri (2016).³

3.2. Effectiveness/impact of agricultural development interventions

3.2.1. The effect of crop production on dietary diversity, consumption practices, and child anthropometry

The list of studies in the crop production category is presented in Table 2. We find that half of the studies measured dietary diversity in children in Amhara (Beyero et al., 2015; Gebremedhin et al., 2017) and SNNP (Dangura & Gebremedhin, 2017) regions. Overall, all the studies document a significant positive association between ownership of home/backyard garden and children's dietary diversity. In particular, possessing home gardens doubled the likelihood of children having minimum dietary diversity (Beyero et al., 2015). Dangura and Gebremedhin (2017) found that the dietary diversity score of such children is 0.32 higher than their counterparts in households without home gardens. Nonetheless, the relationship between home gardening and minimum meal frequency is found to be insignificant (Beyero et al., 2015).

Three out of the six studies assessed changes in consumption practices. The assessment of the orange-fleshed sweet potato (OFSP) intervention in the SNNP region revealed that although 63% of the sampled households grew potato, only 7% of them produced OFSP. Moreover, it was found that only 1% of the 63% of mothers consumed OFSP (Busse et al., 2017). Another study by Negash and Swinnen (2013) showed that castor bean contract farming in the SNNP region increased food consumption and reduced the length of food gap months.

Concerning child anthropometry, Zeng et al. (2017) showed that adoption of improved maize varieties (IMV) positively and significantly affected children's height-for-age Z-score (HAZ) and weight-for-age Z-score (WAZ) but not weight-for-height Z-score (WHZ) in four regional states of the country (i.e., Oromia, Amhara, SNNP, and Tigray). The empirical findings show that allocating 0.25 hectare of land for IMV cultivation resulted in a HAZ and WAZ increase of 0.257 and 0.176 standard deviations, respectively.

3.2.2. Livestock production and management

(a) Exclusive interventions in livestock production and management

Table 2. Characteristics of studies in crop production

Study	Study unit	Sample size
Busse et al. (2017)	Mothers	150
Zeng et al. (2017)	Children	1216
Negash and Swinnen (2013)	Households	476
Beyero et al. (2015)	Children	925
Gebremedhin et al. (2017)	Children	2080
Dangura and Gebremedhin (2017)	Children	417

Source: Based on the author's elaboration of reviewed papers.

Table 3. Characteristics of studies in the livestock sub-sector

Study	Study unit	Sample size
Kebebe (2017)	Households	669
Geday et al. (2016)	Households	333
Lenjiso et al. (2016)	Households & children 0–59 months old	164
Headey et al. (2017)	Mother & child (6–24 months old) dyads	2104
Headey and Hirvonen (2016)	Households & children 0–59 months old	2704 households; 3494 children
Hoddinott et al. (2015)	Households & children 0–59 months old	7930

Source: Based on the author's elaboration of reviewed papers.

Table 3 presents the six studies in this sub-category. It should be noted here that 50% of the studies (Geday et al., 2016; Kebebe, 2017; Lenjiso et al., 2016) were based on quasi-experimental designs of impact evaluation, with “intervention” and “control” groups specifically identified. Moreover, these studies employed the propensity score matching (PSM) technique in their analysis.

Four out of the six studies evaluated the impact on anthropometric indices. Starting with stunting (HAZ), we find that all the studies provide evidence of a positive and significant reduction in stunting levels. For instance, Hoddinott et al. (2015) showed that owning a single cow has the potential to increase HAZ (between 0.25 and 0.47 standard deviations) and reduce stunting levels (between 6% and 13%). Positive associations between livestock ownership and HAZ were also documented by Headey et al. (2017) and Headey and Hirvonen (2016). Lenjiso et al. (2016) also found a significant mean difference between non-participants and participants of the formal milk market. Concerning wasting (WHZ), three out of the four studies measured it but found mixed results. Whereas Lenjiso et al. (2016) and Hoddinott et al. (2015) found no significant impact, Headey et al. (2017) documented a positive association between livestock ownership and WHZ. Lenjiso et al. (2016) also found improvements in underweight (weight-for-age Z-score—WAZ) for children in market participant households, although the estimated mean difference between participants and non-participants is significant only with Kernel matching (and not with Nearest Neighbour matching).

Although the above studies provide empirical evidence that livestock ownership has the potential to improve nutrition, such a generalization is not always warranted. For instance, exposure to livestock excreta was shown to negatively affect HAZ and WHZ in Ethiopia (Headey et al. 2017). Likewise, keeping poultry in the same house with people is found to be negatively associated with HAZ (Headey and Hirvonen, 2016).

Two of the six studies analyzed the causal effect on household income. Kebebe (2017) found that adopters of dairy development interventions (i.e., cross-bred dairy cows and improved forage) earned a significantly higher income than non-adopters. The milk value-chain participation study by Geday et al. (2016) also found a positive and significant gain in household income, although the Kernel matching result was not significant, casting doubts on the robustness of the impact estimates.

A positive and significant effect was also found for dietary diversity in three out of six studies. A unique feature of the study by Lenjiso et al. (2016) is that it provides, in addition to the household dietary diversity, an analysis result of intra-household dietary diversity. In addition to dietary diversity, Geday et al. (2016) also showed that per-capita calorie intake was higher for participants. Nevertheless, similar to our earlier reservation, the average treatment effect (ATT) should also be treated with caution for the same reason.

Some of the studies investigated the impact on production, consumption, and marketing of animal source foods (ASFs). The evaluation by Lenjiso et al. (2016) showed that milk production was higher for market participant households. Concerning consumption, however, there are mixed findings. Whereas Hoddinott et al. (2015) found that cow ownership increases the probability and frequency of milk consumption, Geday et al. (2016) showed that participants of the milk value chain consumed less milk. On the contrary, Lenjiso et al. (2016) documented no significant difference between milk market participants and non-participants. There are also mixed findings on the consumption of other ASFs. Despite the findings that egg consumption by children increased, no evidence was found for increased consumption of meat and other dairy products due to poultry production (Headey and Hirvonen 2016). Hoddinott et al. (2015) demonstrated that cow ownership significantly increases dairy product consumption. In relation to marketing, Lenjiso et al. (2016) found that milk market participants sold higher quantities of milk, which may be the reason why such households had a lower level of milk consumption.

Only one of the six studies assessed the effect of livestock production on child illness and maternal/child cleanliness (Headey et al., 2017). The results indicate a strongly negative association between the presence of animal excreta around the homestead and maternal/child cleanliness. However, the presence of animal faeces or ownership of livestock was found to be not associated with illness (e.g., diarrhoea, fever, and cough/cold).

(b) Other studies with a livestock component

The list of studies that have a livestock component is depicted in Table 4. The major focus of these studies is dietary diversity. It has to be noted, however, that none of these studies are strictly impact evaluations. In general, all the studies found a positive association between livestock ownership and dietary diversity. Specifically, it is noteworthy that although a huge rural-urban gap in children's dietary diversity was revealed, the higher probability of owning livestock in rural areas contributed to narrowing down this difference (Hirvonen, 2016). Concerning diet quantity, Goshu et al. (2013) found no effect on daily calorie availability.

3.2.3. *The Productive Safety Net Program (PSNP) and its impact on food security, asset holding, and child nutrition*

Three studies investigated the impact of Ethiopia's Productive Safety Net Program (PSNP) on food and nutrition security (Table 5). In a relatively large study based on longitudinal data obtained from four regions of the country (i.e., Oromia, Amhara, SNNP, and Tigray), Berhane et al. (2014) estimated impact of the PSNP, and that of other food security programs (OFSP) and household asset building programs (HABP) operating in the study regions. In doing so, the study not only accounted for some potential confounders but also quantified the combined impact of the PSNP and these programs. A key finding of the study is that participation in the PSNP improved food security and raised livestock holdings. The combined impact of the PSNP and OFSP/HABP is shown to be greater than the impact of each intervention separately.

Table 4. Characteristics of other studies in livestock production and management

Study	Study unit	Sample size
Goshu et al. (2013)	Households	260
Hirvonen (2016)	Children	2898
Hirvonen et al. (2017)	Households & children	775
Gebremedhin et al. (2017)	Children	2080
Dangura and Gebremedhin (2017)	Children	417

Source: Based on the author's elaboration of reviewed papers.

Table 5. Characteristics of studies in the Productive Safety Net Program (PSNP)

Study	Study unit	Sample size
Berhane et al. (2014)	Households	3140
Debela et al. (2015)	Children <5 years	383
Baye et al. (2014)	Households & children	195

Source: Based on the author's elaboration of reviewed papers.

The findings of Debela et al. (2015) in Tigray region revealed that children in PSNP member households have WHZ that were higher than those of children in non-member households. In another PSNP evaluation, Baye et al. (2014) documented that the dietary diversity of households receiving food was significantly lower than that of households receiving cash. Households receiving cash had significantly higher levels of consumption of oils and fats, and somewhat higher consumption of legumes and dairy products. Although statistically insignificant, the average HAZ and the prevalence of stunting were also lower in households receiving cash.

3.2.4. Nutrition education/complementary feeding interventions

The first three studies in Table 6 assessed the mediating role of nutrition education interventions in promoting pulse-based complementary feeding practices in the SNNP region.

One of the major findings of Yetnayet et al. (2017) relates to knowledge, attitude, and practice (KAP) of food-based approaches to nutrient deficiency. In this regard, the study found significant changes in the KAP scores of the participants due to exposure to the intervention. Concerning consumption, the study showed substantial improvements in the proportion and consumption frequency of pulse-based diets in the intervention group. Similar changes in knowledge and practice of complementary feeding were documented by Negash et al. (2014). However, unlike Yetnayet et al. (2017), they did not measure changes in attitude. Analogous to the findings in Yetnayet et al. (2017), there is clear evidence on the enhanced consumption of legumes as a result of the intervention. An added dimension in this study, unlike Yetnayet et al. (2017), is the analysis pertaining to anthropometric indices, although no significant changes in height and weight of children were detected.

The findings reported in Mulualem et al. (2016) are also the same as those found in Yetnayet et al. (2017) for KAP scores and consumption practices. They are also related to Negash et al. (2014) in terms of knowledge and practice scores. However, contrary to Negash et al. (2014), Mulualem et al. (2016) found a positive and significant effect of the intervention on WAZ and WHZ. However, the effect of the intervention on HAZ was found to be negative. The study by Hirvonen et al. (2017) investigated the role of caregiver's nutrition knowledge on dietary diversity of children in north-west Ethiopia and found a positive and considerable effect. However, the study also illustrated that the impact of nutrition knowledge decreases as one moves far away from the

Table 6. Characteristics of studies in nutrition education and complementary feeding

Study	Study unit	Sample size
Yetnayet et al. (2017)	Women 15–49 years old	200
Negash et al. (2014)	Caregivers (mothers) & children 6–23 months old	197
Mulualem et al. (2016)	Mother-child pairs	160
Hirvonen et al. (2017)	Households & children under five	775

Source: Based on the author's elaboration of reviewed papers.

main market, suggesting that the caregiver’s nutrition knowledge translates to improved dietary diversity conditional on well-functioning markets.

3.2.5. Agricultural water use (irrigation) interventions

There are three studies on agricultural water use (Table 7). Surprisingly, the observational study in Central and Hararghe highlands found that irrigation water use adversely affects the household’s daily calorie availability, diet diversity, and food security status (Goshu et al., 2013). In a stark contrast, however, Cafer et al. (2015) showed a positive effect of small-scale irrigation on food security in Amhara region. This study also found higher crop diversity and better nutritional status in villages where irrigation is practiced. Moreover, crop loss was minimal and drought-tolerance capacity was better in these villages.

The study by Hagos et al. (2017) also provides evidence for a positive effect of irrigation on the depth and severity of poverty. The study found a statistically significant difference between spate irrigation users and non-users in terms of absolute poverty, poverty gap, and severity of absolute poverty. The comparison between traditional and modern spate irrigation schemes indicated that the use of modern spate irrigation resulted in a significant reduction of household poverty levels.

3.2.6. Effect of general agriculture interventions on dietary diversity, food security, and nutritional status

The studies investigating the effect of food production and access to farm resources (i.e., general agriculture) are given in Table 8. We note that all the studies are not strictly impacted evaluations. Two of the studies found that dietary diversity is enhanced through improved access to farm resources (i.e., fertilizer in Goshu et al., 2013) that could result in production diversity. Hirvonen and Hoddinott (2017) showed that a one food group increase in household’s production diversity leads to a 0.49 (Poisson regression) to 0.62 (OLS regression) food group improvement in child’s dietary diversity score.

The two studies that assessed food security found that access to farmland (Cafer et al., 2015) and the use of fertilizer (Goshu et al., 2013) had a positive effect on food security status. In addition, Goshu et al. (2013) found that fertilizer use enhanced daily calorie availability and intake. However, the studies investigating nutritional status reported conflicting results. Whereas Cafer et al. (2015) documented that access to farmland plays a significant role in household nutritional status, Derso et al. (2017) found higher odds of stunting among children whose parents use their own production as a source of food.

Table 7. Characteristics of studies in irrigation water use

Study	Study unit	Sample size
Goshu et al. (2013)	Households	260
Cafer et al. (2015)	Individuals	433
Hagos et al. (2017)	Households & children under five	122

Source: Based on the author’s elaboration of reviewed papers.

Table 8. Characteristics of studies in general agriculture

Study	Study unit	Sample size
Goshu et al. (2013)	Households	260
Cafer et al. (2015)	Individuals	433
Hirvonen and Hoddinott (2017)	Households and children 6–59 months	7011 households; 3448 children
Derso et al. (2017)	Mother–child (6–24 month) pairs	587

Source: Based on the author’s elaboration of reviewed papers.

3.3. Impact pathways from agriculture to improved nutrition

In the 25 studies reviewed, we find varying levels of evidence for 6 impact pathways. No evidence is found for agricultural interventions affecting nutrition through women’s enhanced control over resources. Overall, the most dominant mechanism linking agriculture to improved nutrition outcomes is through the production of crops to increase household consumption. This is followed by the income effect of agriculture. We find a very meagre support for the role of agriculture in enhancing non-food expenditures, and the nutrition and health of the household (Figure 1).

In Table 9, we present the proportion of the key pathways by intervention category. Although some pathways are common across the interventions, there are also a few of them uniquely important in only some intervention categories (see, for instance, “women’s time and caring practices” in the PSNP and nutrition education interventions). In general, in six out of seven categories, we find more than three mechanisms from agriculture to nutrition. In what follows, we present discussions by intervention category.

3.3.1. Impact pathways in crop production

Overall, in all the studies in crop production, we find overwhelming evidence that crop production contributed to household’s own consumption by serving as a source of food. For instance, Zeng et al. (2017) showed that improved maize cultivation raises household own-produced maize consumption that translates to increments in HAZ, WAZ, and WHZ. Likewise, Gebremedhin et al. (2017) indicated that households with home gardens are twice as likely to provide diversified food to their children. Beyero et al. (2015) found that most farmers possessing home gardens used the produce for home consumption. Likewise, Dangura and Gebremedhin (2017) documented that many children in household’s producing fruits and vegetables consumed vitamin A-rich foods. Finally, Negash and Swinnen (2013) illustrated that the production of cash crop (castor bean) helped farmers store their food crops to be consumed during the lean season.

Regarding the income effect of crop production, we find evidence only in one study (Negash and Swinnen 2013). In that study, it was shown that households earn income by selling castor beans. Such contract farming schemes also safeguarded farmers against low food crop prices during harvest because the farmers sell their castor beans to generate income, but store their food crops to be consumed or sold later. Hence, the households involved in the contract farming did not have to pay higher prices for food during the lean season. The OFSP study by Busse et al. (2017) suggests that women’s own health and nutrition could be improved through enhanced production and consumption of OFSP.

Figure 1. Proportion of identified key pathways (y-axis) from agriculture to nutrition

Source: Authors’ calculations.

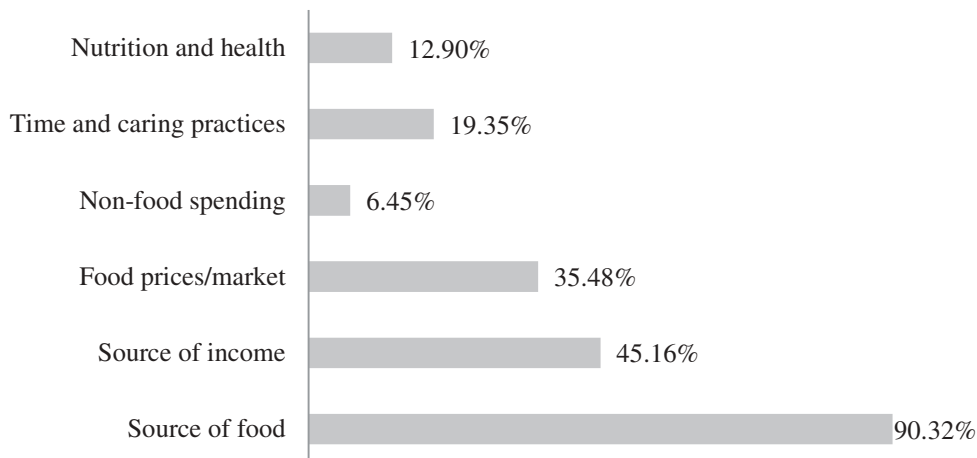


Table 9. Agriculture to nutrition pathways by intervention category

Pathways	Intervention category (per cent)						
	Crops	Livestock (exclusive)	Livestock (general)	Nutrition education/ complementary feeding	The PSNP	Irrigation	General agriculture
Source of food	100.00	100.00	60.00	75.00	100.00	100.00	100.00
Source of income	16.67	66.67	40.00	0.00	100.00	100.00	25.00
Food prices/market	16.67	33.33	40.00	25.00	100.00	33.33	25.00
Non-food spending	0.00	16.67	0.00	0.00	0.00	33.33	0.00
Time and caring practices	0.00	0.00	20.00	75.00	66.67	0.00	0.00
Nutrition and health	16.67	33.33	0.00	25.00	0.00	0.00	0.00

Source: Authors' calculations.

3.3.2. *Impact pathways in livestock production and management*

As can be seen in Table 9, the most prominent mechanisms in this category are through increased consumption and income. Concerning the consumption of animal source foods (ASFs), Hoddinott et al. (2015) found that cow ownership increases the likelihood and frequency of consuming milk, cheese, and yoghurt. Similarly, Headey and Hirvonen (2016) showed that poultry ownership increases the probability of egg consumption, but not the consumption of other ASFs. Contrary to Hoddinott et al. (2015) regarding milk consumption, Geday et al. (2016) found a negative relationship between production and household consumption due to the fact that most of the milk produced was sold. Lenjiso et al. (2016) found no significant difference in terms of milk consumption for the same reason. Similar to Headey and Hirvonen (2016), however, Lenjiso et al. (2016) also found no significant difference in terms of consumption of other ASFs. Suggestive evidence about enhanced consumption is also found in Kebebe (2017) and Headey et al. (2017).

Concerning the income effect of livestock interventions, we find evidence in four out of six studies. For instance, Kebebe (2017) found that adoption of cross-bred dairy cows and improved forages resulted in increased income; Lenjiso et al. (2016) showed that milk market participants have higher income that helped them boost their dietary diversity; and, Geday et al. (2016) indicated that higher incomes resulting from dairy value-chain participation may lead to consumption of better or diversified foods.

In relation to food prices/market, we find evidence only in two studies. Whereas Geday et al. (2016) indicated that higher income from milk value-chain participation can improve the ability of households to buy nutritious foods from the market (i.e., food expenditure), Hoddinott et al. (2015) argued that cow ownership is less relevant in situations where households have better access to markets. The study by Geday et al. (2016) also provided indicative evidence that higher income due to milk market participation can improve non-food expenditures.

Two studies indicated that exposure to livestock excreta can have adverse effects on nutrition and health. In particular, Headey and Hirvonen (2016) showed that indoor keeping of poultry is negatively associated with children's HAZ. Likewise, Headey et al. (2017) found that livestock ownership and poor personal cleanliness are strongly associated with the presence of animal excreta. Finally, among the five general livestock-related studies, we find evidence for consumption in three studies (Goshu et al., 2013; Hirvonen, 2016; Gebremedhin et al., 2017). Goshu et al. (2013) and Gebremedhin et al. (2017) also contain some proof for income effect. Gebremedhin et al. (2017) and Hirvonen et al. (2017) provide support for food price/market effect. Lastly, Hirvonen et al. (2017) showed that nutrition knowledge of caregivers positively affects children's dietary diversity through enhanced caring practices.

3.3.3. *Impact pathways in nutrition education and complementary feeding interventions*

As can be seen in Table 9, the two dominant pathways in this category are improved consumption and caring practices. Three out of four interventions provide evidence that nutrition education sessions enhanced consumption of locally available pulse-based diets by women and children (Negash et al., 2014; Mulualet al., 2016; Yetnayet et al., 2017). Additionally, we find evidence on enhanced caregivers' knowledge and practices regarding complementary feeding (Negash et al., 2014; Mulualet al., 2016; Hirvonen et al., 2017). Nevertheless, as Hirvonen et al. (2017) caution, better nutrition knowledge translates to substantial improvements in children's dietary diversity only in areas with relatively good market access, or better own production of nutritious foods. The market-related result complements the findings of Hoddinott et al. (2015) regarding the importance of integrating smallholders to well-functioning markets. Finally, it can be deduced from Yetnayet et al. (2017) that increased consumption of pulse-based foods can stimulate women's own nutrition and health.

3.3.4. *Impact pathways in the Productive Safety Net Program (PSNP)*

In all the PSNP interventions, we find strong evidence for enhanced consumption, income, and food price/market effects. The food-for-work component of the PSNP is one pathway to enhance household consumption. The cash transfer component of the PSNP works to improve household income that translates to, for instance, higher consumption of ASFs and vitamin A-rich plant foods (Baye et al., 2014). The PSNP also generally improved the household's purchasing power despite the rising food prices (Berhane et al., 2014) that adversely affect beneficiaries of the cash transfer component of the PSNP (Baye et al., 2014). Finally, since most Public Works activities of the PSNP occur in the months between January and June (Berhane et al., 2014), extra female labour can be mobilized for such activities (Debela et al., 2015) without affecting their time for farming and caring practices.

3.3.5. *Impact pathways in agricultural water use (irrigation) interventions*

In all the studies in agricultural water use, we find evidence for consumption and income effects. Generally, irrigation helped households produce diversified crops. However, Goshu et al. (2013) argue that the focus of crop production in irrigated agriculture may shift from staple food crop to cash crop production. This, in turn, may result in increased household income (Cafer et al., 2015; Hagos et al., 2017). Hagos et al. (2017) also showed that food and non-food expenditures were significantly higher for irrigation users, although the items purchased did not appear to have contributed to improved nutrition.

3.3.6. *Impact pathways in general agriculture*

All the studies in this category provide evidence for the consumption effect. For instance, access to farmland enhances crop diversity (Cafer et al., 2015), and increased crop diversity leads to improved children's dietary diversity (Hirvonen and Hoddinott, 2017). Contrary to these, own production as a source of food is found to be significantly associated with higher odds of stunting probably due to low productivity and poor complementary feeding practices (Derse et al., 2017). Regarding income effect, Goshu et al. (2013) showed that an increase in crop income reduced total income inequality. Finally, Hirvonen and Hoddinott (2017) illustrated that market access plays a greater role than production diversity in children's dietary diversity.

4. **Conclusions and policy implications**

In the present study, we investigate the impact of agricultural interventions and discuss the pathways linking agriculture to improved food and nutrition outcomes. Overall, we find positive effects on knowledge, attitude, and practice (KAP) and economic indicators (income, poverty and asset accumulation). We also find an overwhelming positive effect on food consumption, dietary diversity, and other food security indicators. However, we also note mixed effectiveness pertaining to anthropometric indices.⁴ In addition, the most important pathways linking agriculture to improved nutrition center on its role as source of food, source of income, and food prices/market. Consequently, the following are lessons and recommendations for practitioners, planners and implementers of nutrition-sensitive interventions, and policy makers.

To start with, sustained community-based nutrition education interventions in diverse agro-ecological settings are important to accelerate the adoption of improved technologies and best practices, and promote household's consumption of nutrient-dense foods. Such efforts should be complemented by strategies to improve access to farm inputs, physical and financial resources, technical information, and input/output markets. Social protection schemes, such as the PSNP, should be integrated with other rural development interventions for maximum effectiveness and sustainability of impact.

The design, implementation, and evaluation of such interventions should take into account several issues. First, increased coordination among multisectoral actors (especially agricultural education, research and extension; health and nutrition) is required to build capacities

at various levels. Second, the interventions should be designed and implemented in such a way that they contribute to improvements in nutrition and health outcomes of individuals, households and communities. In this regard, there should be a concerted effort to improve methodological approaches: include diverse agricultural, health and nutrition indicators; collect pre-intervention/baseline data; implement (quasi-) experimental designs in treatment allocation; gather time-series/panel data that can capture seasonality of production and consumption; and, employ rigorous impact evaluation techniques that account for unobserved heterogeneity, spillover effects, and sensitivity of parameter estimates to different specifications. Moreover, there should be a special attention on more qualitative studies and mixed research designs in order to capture evolutionary dynamics in food habits and consumption patterns and preferences. Finally, future research should also investigate, in addition to the abovementioned issues, the impact of policies and governance structures and research and development expenditures in relation to nutrition-sensitive agricultural interventions by employing meta-analysis techniques.

Notes

1. See Appendix A for more on trends and patterns.
2. See Appendix B for a complete bibliography of the studies included in the review.
3. See Appendix C for details.
4. See Appendix D for a pictorial summary of the overall impact of the interventions.

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Competing Interests

The authors declare no competing interests.

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Appendix A

Brief Review of Agriculture-Nutrition Linkages in Ethiopia

As a result of the actions taken by the government and other stakeholders, some progresses have been made. For instance, in 2016, undernourishment decreased to 28.8%; depth of food deficit decreased to 201 kcal/capita/day; and, GDP per capita (PPP, constant 2011 international \$) increased to 1,608.3 (FAOSTAT, 2018). As can be seen in Table 1, the country reduced children underweight to 23.3%; infant mortality rate (number of deaths per 1,000 live births) to 48; and, under-five mortality rate (number of deaths per 1,000 live births) to 67. Available evidence also indicates that exclusive breastfeeding of infants under six months increased to 58% and the prevalence of anaemia decreased to 24% among women of reproductive age. Likewise, the median duration of exclusive breastfeeding increased from 2.5 to 3.1 months; the percentage of mothers receiving antenatal care (ANC) increased from 27% to 62%; and, institutional delivery by women increased from 5% to 26% during the period 2000 to 2016 (CSA and ICF, 2016).

Appendix B

Complete List of the 25 Studies Included in the Review

- (1) Baye K, Negussie R, and Cherinet A. (2014). Comparison of the Effects of Conditional Food and Cash Transfers of the Ethiopian Productive Safety Net Program on Household Food Security and Dietary Diversity in the Face of Rising Food Prices: Ways Forward for a More Nutrition-Sensitive Program. *Food and Nutrition Bulletin* 35(3): 289–95.

Table A1. Trends in Undernutrition, Health and Mortality in Ethiopia, 2000–2016

	2016	2011	2005	2000
Stunting of children U5 years of age (%) a,b,c	38.4	44.4	50.8	57.7
Wasting of children U5 years of age (%) a,b	9.9	9.7	12.2	12.2
Children underweight (%) ^b	23.3	28.7	32.9	41.2
Overweight of children U5 years of age (%) ^b	1	-	-	-
Exclusive breastfeeding of infants U6 months (%) ^b	58.0	52	49	-
Median duration of exclusive breastfeeding (months) ^b	3.1	2.3	-	2.5
Maternal health care (antenatal care – ANC in %) ^a	62	34	-	27
Institutional delivery (%) ^a	26	10	-	5
Total fertility rate (15–49) – number per woman ^b	4.6	4.8	5.4	5.5
Infant mortality rate – number per 1,000 live births ^b	48	59	77	97
U5 mortality rate – number per 1,000 live births ^b	67	88	123	166
Prevalence of anaemia (%) ^b Women of reproductive age	24.0	17	27	-
Children (6–59 months)	57	44	54	-
Iodized salt use (%) ^b	89	15	-	-

^aEthiopia Demographic and Health Survey 2016, key indicators (as reported in European Commission. Country Profile on Nutrition (Ethiopia). July 2017).

^bThe DHS Program Country QuickStats – <https://www.dhsprogram.com> – 19 October 2017. Central Statistical Agency (CSA) [Ethiopia] and ICF, 2016. Ethiopia Demographic and Health Survey 2016. Addis Ababa, Ethiopia, and Rockville, Maryland, USA: CSA and ICF.

^cNational target by 2020: 26% (4 million); WHA target by 2025: 3.68 million; Expected by 2025 (according to current trend): 5.05 million.

Note: WHA – World Health Assembly; DHS – Demographic and Health Survey (Ethiopia); U5 – under five; SDG – Sustainable Development Goal.

- (2) Berhane G, Daniel OG, John H, Neha K, and Alemayehu ST. (2014). Can social protection work in Africa? The impact of Ethiopia's productive safety net programme. *Economic Development and Cultural Change* **63**(1): 1-26.
- (3) Beyene M, Abebaw GW, and Molla MW. (2015). Dietary Diversity, Meal Frequency and Associated Factors among Infant and Young Children in Northwest Ethiopia: A Cross- Sectional Study. *BMC Public Health* **15**(1): 1007.
- (4) Busse H, Henok K, Ptak M, and Fofanah M. (2017). A Food-Based Approach to Reduce Vitamin A Deficiency in Southern Ethiopia: A Cross-Sectional Study of Maternal Nutrition and Health Indicators. *African Journal of Food, Agriculture, Nutrition and Development* **17**(3): 12226-42.
- (5) Cafer AM, Mary SW, Shimelis B, and Martha M. (2015). Growing Healthy Families: Household Production, Food Security, and Well-Being in South Wollo, Ethiopia. *Culture, Agriculture, Food and Environment* **37**(2): 63-73.
- (6) Dangura D, Samson G. (2017). Dietary Diversity and Associated Factors among Children 6-23 Months of Age in Gorche District, Southern Ethiopia: Cross-Sectional Study. *BMC Pediatrics* **17**(1): 6.
- (7) Debela BL, Gerald S, and Stein TH. (2015). Does Ethiopia's Productive Safety Net Program Improve Child Nutrition? *Food Security* **7**(6): 1273-89.
- (8) Derso T, Amare T, Gashaw AB, and Molla MW. (2017). Stunting, Wasting and Associated Factors among Children Aged 6-24 Months in Dabat Health and Demographic Surveillance System Site: A Community Based Cross-Sectional Study in Ethiopia. *BMC Pediatrics* **17**(1), 96.
- (9) Elias AG, Tolossa D, Padilla M, Montaigne E. (2016). Food Security and Nutrition Impacts of Smallholder Farmers' Participation in Dairy Value Chain in Ethiopia. *Journal of International Business and Economics*. **16**.
- (10) Gebremedhin S, Kaleab B, Tilahun B, Manisha T, Yonas A, Yewelsew A, and Nigusse R. (2017). Predictors of Dietary Diversity in Children Ages 6 to 23 Mo in Largely Food-Insecure Area of South Wollo, Ethiopia. *Nutrition* **33**(January): 163-68.
- (11) Goshu D. (2013). Measuring Diet Quantity and Quality Dimensions of Food Security in Rural Ethiopia. *Journal of Development and Agricultural Economics* **5** (5): 174-85.
- (12) Headey D, Kalle H. (2016). Is Exposure to Poultry Harmful to Child Nutrition? An Observational Analysis for Rural Ethiopia. Edited by Jacobus van Wouwe. *PLOS ONE* **11**(8). Public Library of Science: e0160590.
- (13) HeadeyD, Phuong N, Sunny K, Rahul R, Marie R, and Purnima M. (2017). Is Exposure to Animal Feces Harmful to Child Nutrition and Health Outcomes? A Multicountry Observational Analysis. *American Journal of Tropical Medicine and Hygiene* **96**(4): 961-69.
- (14) Herforth A, Terri JB. (2016). Nutrition indicators in agriculture projects: Current measurement, priorities, and gaps. *Global Food Security* **10**(2016): 1-10.
- (15) Hirvonen K. (2016). Rural-urban Differences in Children's Dietary Diversity in Ethiopia: A Poisson Decomposition Analysis. *Economics Letters* **147**: 12-15.
- (16) Hirvonen K, and John H. (2017). Agricultural Production and Children's Diets: Evidence from Rural Ethiopia. *Agricultural Economics* **48**(4): 469-80.
- (17) Hirvonen K, John H, Bart M, and David S. (2017). Children's diets, nutrition knowledge, and access to markets. *World Development* **95**(2017): 303-315.
- (18) Hoddinott J, Derek H, and Mekdim D. (2015). Cows, Missing Milk Markets, and Nutrition in Rural Ethiopia. *Journal of Development Studies* **51**(8). Routledge: 958-75.
- (19) Kebebe EG. (2017). Household Nutrition and Income Impacts of Using Dairy Technologies in Mixed Crop-livestock Production Systems. *Australian Journal of Agricultural and Resource Economics* **61**(4): 626-44.
- (20) Lenjiso BM, Jeroen S, and Rued R. (2016). Smallholder Milk Market Participation, Dietary Diversity and Nutritional Status among Young Children in Ethiopia. *Journal of Gender, Agriculture and Food Security* **1**(2): 129-47.
- (21) Mulualem D, Carol JH, Getenesh B, and Susan JW. (2016). The Effectiveness of Nutrition Education: Applying the Health Belief Model in Child-Feeding Practices to Use Pulses for Complementary Feeding in Southern Ethiopia. *Ecology of Food and Nutrition* **55**(3): 308-23.
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Appendix C

Table C1. Outcome and impact indicators categorized according to Herforth and Terri (2016)

Category	Indicators
Knowledge, attitude, practice	Knowledge Attitude Practice
Health and caring	Illness (diarrhoea, fever, cough/cold) Maternal/child cleanliness
Economic indicators	Household income Livestock holdings Poverty Amount of milk sold
Food consumption	Dietary diversity Consumption of animal source foods (ASFs) Food consumption
Food security	Number of food gap months Food security Meal frequency Milk production Crop diversity and seasonality
Nutritional status	Stunting (HAZ) Wasting (WHZ) Underweight (WAZ) Nutritional status of adults (BMI)

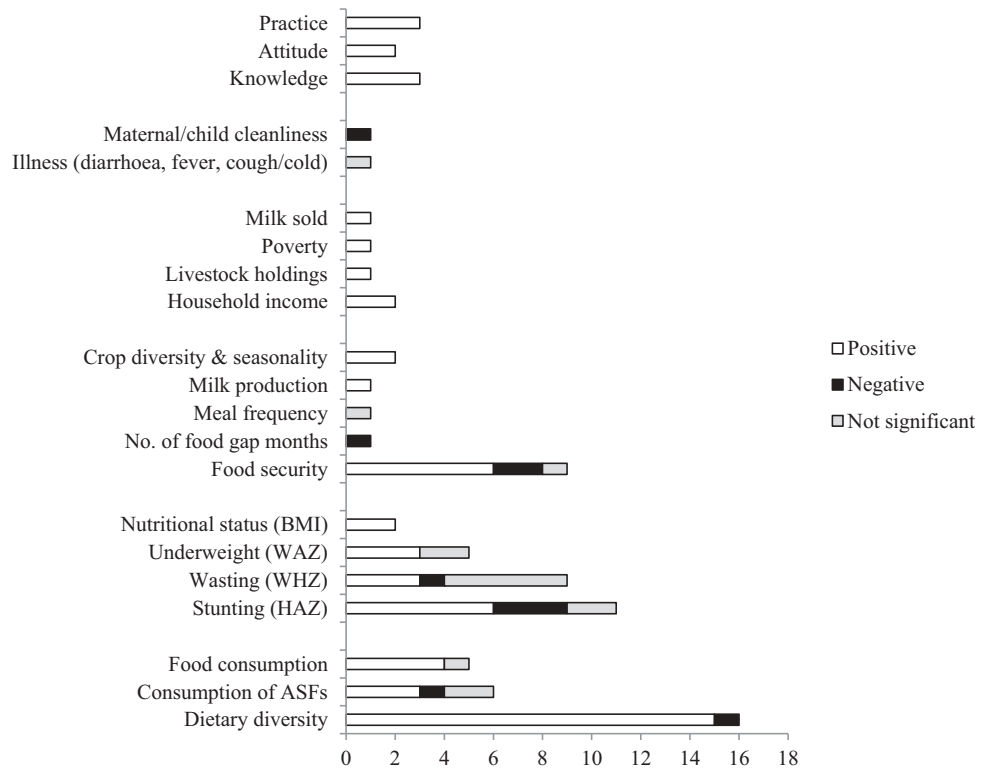
Source: Author's analysis.

Appendix D

Overall Impact of all the Interventions

Figure D1. Overall effect of all the interventions on outcome/ impact indicators (y-axis). Number of studies displayed on x-axis

Source: Author's analysis and illustration.





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