Review of agriculture–nutrition linkages in South Asia

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Received: 4 August 2018
Accepted: 15 October 2018

doi: 10.1079/PAVSNNR201813046

The electronic version of this article is the definitive one. It is located here: http://www.cabi.org/cabreviews

Abstract

The paper reviews the evidence of agriculture–nutrition linkages with particular reference to South Asia from studies published during the period 2012–2018. South Asia houses the largest population of undernourished people in the world and a majority of the population in the region is dependent on agriculture and allied activities and live in rural areas. Following a review of agriculture nutrition linkage, the paper reviews recent work in South Asia focusing on the pathway of agriculture as an asset and source of food and the role of women in agriculture. The evidence from reviews of agriculture nutrition linkage finds lack of robust evidence of impact on nutrition outcomes. The studies from South Asia highlight the importance of production diversity, agriculture and land productivity and enabling factors of WASH and women's empowerment, for impact on dietary diversity and nutrition outcomes. This points to need for policy focus in these areas. Most of the studies were based on secondary data and the search yielded very few intervention-based studies; there were also no studies from Pakistan. The importance of leveraging agriculture for nutrition in order to progress towards the Sustainable Development Goals (SDGs) is now well accepted. Along with efforts to improve dietary diversity through agriculture, long-term intervention studies with robust design targeting nutrition indicators can help better inform policy.

Keywords: Agriculture–nutrition linkage, South Asia, women in agriculture, diet diversity, undernutrition

Review Methodology: We searched for studies on the basis of agriculture and nutrition linkages in South Asia for the period 2012–2018. The systematic search strategy involved narrowing down studies with agriculture nutrition linkages as the main theme from several search engines and important websites: Google Scholar, AgEcon Search, CAB Abstracts, CAB Direct, Eldis-IDS, Food and Agriculture Organization (FAO), International Food Policy Research Institute (IFPRI), Leveraging Agriculture for Nutrition in South Asia (LANSA), Harvest Plus, United Nations Children's Fund (UNICEF) and World Bank. After removing review reports, book chapters and grey literature, we arrived at 42 studies, 16 of which were used to set the context, 20 were reviewed under agriculture as a source of food and six under the role of women in agriculture.

Introduction

The role of agriculture in promoting better nutrition outcomes and health started getting discussed in international discourse towards the end of the last century [1], even as the focus was still largely on production, productivity and food security. While agriculture as in crop and animal husbandry, fisheries and agro-forestry is a recognized source of food, the thrust of the sector till recently, has largely been on improving production, productivity and incomes, the Green Revolution in South Asia being an example. The 1990s saw the acceptance of a broader definition of food security that encompassed nutrition security following the Rome Declaration on Food Security at the World Food Summit in 1996 [2].

The discourse has gained momentum in recent years with research on the pathways that link agriculture to nutrition, conceptual frameworks being developed, donor supported pilots and research initiatives and efforts to integrate nutrition-sensitive agriculture (NSA) by some governments in their country plans. The context being that agriculture is the main occupation of a large majority in rural areas and a considerable section of this population is also malnourished; further the economic costs of

malnutrition are well established [3]. Six main pathways have been outlined linking agriculture to nutrition [4–6]. Three are direct pathways emanating from agriculture as a source of food, as a source of income and food prices and agricultural policies that impact on food availability and access. The other three may be together called the gender pathways focusing on women's role in agriculture, their social status and decision making power in agriculture and household food security, their time allocation between agriculture, household and care work and leisure, and the impact of their work on their own health and nutrition status.

Globally, the link of agriculture to nutrition has been recognized and is enshrined in the UN Sustainable Development Goals (SDGs) [7]. Three of the targets under SDG2 (end hunger, achieve food security and improved nutrition and promote sustainable agriculture) pertain to the leveraging of agriculture policy and strategy for improved nutrition outcomes to ensure the ultimate goal of ending hunger and malnutrition in all its forms. Over the last decade, several reviews have been published that examine the nature and evidence of agriculture–nutrition linkage. A spectrum of these, both from observation and intervention studies, published during 2012–2018 is discussed here to make an assessment of where we are currently.

Broadly, the consensus that prevails is that while household food production impacts on consumption and diet patterns of its members, there is a lack of robust evidence of agricultural interventions improving nutrition outcomes; there is a need for proper research design and use of appropriate metrics and strengthening of the evidence base. A systematic review of 23 studies published after 1990 on agricultural interventions to improve nutrition outcomes of children [8], and another of 36 studies, which also included impact on women [9], highlighted these aspects. An attempt to synthesize 'current evidence of agriculture-to-nutrition linkages' through a study of ten reviews published since 2000 including [8] and [9] concluded that expectations on the potential for nutrition impact have to be set rationally and such initiatives should have high standards of research and communication, which currently seemed to be lacking [10]. A separate systematic review of the evidence of the agriculture food price pathway on nutrition outcomes surmised that 'developing credible impact evaluations for the effect of a food and agricultural policy on the nutrition status of individuals and populations is extremely challenging', and called for focus on 'cross-sectoral evidence generation' (p. 7) [11]. A review of nutritional effects of programmes in four different sectors including agriculture flagged poor quality evaluations and the need for rigorous effectiveness assessments [6]. Another study developed a conceptual framework linking agriculture, food and nutrition, to map current and planned research on agriculture for improved nutrition and concluded that there are critical gaps in research on pathways like income and agriculture policy through which agriculture impacts on nutrition; and on the impact of agriculture interventions on different target groups; calling for broader cooperation between agriculture and nutrition researchers in generating appropriate experimental designs and metrics [12]. The introductory chapter to a special issue on farm-level pathways to improved nutrition, which included papers based on studies in South Asia, flagged the issue of data gaps in understanding the causal factors and specific nature of the linkages between agriculture and nutrition outcomes [13].

With regard to the gender pathways linking agriculture to nutrition, an evidence review on women's empowerment and nutrition synthesized the findings from systematic reviews and 'key studies that focus on women's empowerment and that are directly or indirectly relevant to nutrition' [14]. It included agriculture interventions as one of the three themes. and concluded that many of the reviews included in the study pointed 'toward the limited research conducted on pathways of impact and toward a dearth of evidence on the impact of these programmes on women's knowledge and practices, time, health and nutritional status, and decision making processes within the household' (p. 21). Another exhaustive review of studies linking agriculture, time use and nutrition concluded that while women play a key role in agriculture as farmers and farm workers and are important actors in the uptake and response to agriculture interventions, there is a lack of clear-cut evidence on 'the nutritional implications of agricultural practices and interventions, even when these result in increased time spent on agricultural activities' [15].

There however seems to be improvement in terms of research design and methodology in recent times, although the concerns remain. A study published in early 2018 reviewed both empirical and observational studies published from 2014 and observed that the empirical studies reviewed had stronger and more 'nutrition-sensitive programme designs', clearer target groups and more rigorous research design and that the emerging evidence is generally positive although the size of impact is modest. On the observational studies reviewed also, they reported that the quality was better methodologically in comparison to earlier studies. The evidence of impact of NSA programmes on nutrition outcomes such as stunting was however limited, given the complexity of multi-sectoral components and limited timeframe of 2–4 years for impact assessment. The study recommended that agriculture should focus on improving dietary diversity and access to high-quality diets, as the precursor to better nutrition outcomes, understanding the context in which nutrition-sensitive agricultural programmes are implemented and examination of 'issues of sustainability, scale-up and cost-effectiveness', in order to better inform agriculture policy and strategies [16]. A review of the qualitative evidence in the public health and nutrition literature, on the role that agriculture plays in improving nutrition, recommended that for

leveraging agri-food systems, which are constantly evolving owing to globalization, trade liberalization and urbanization toward nutrition, creating and strengthening institutional and policy environments which support nutrition goals is important [17].

In this backdrop, the current study explores the evidence of agriculture–nutrition linkages in South Asia.

The evidence on agriculture nutrition linkage in South Asia

The South Asia region houses the largest population of undernourished people in the world. Globally, 25% of children under-5 years of age are stunted; the figure for the South Asian region is 38%, comparable to sub-Saharan Africa (37%) and much higher than Latin America (11%). With about 26% of the world's children under-5 years of age in South Asia, the region shoulders about 40% of the global burden of stunting [18]. A majority of the population in the region is dependent on agriculture and allied activities and live in rural areas.

Given the immensity of the problem, the region has been seeing both nutrition-specific research initiatives (e.g. Transform Nutrition, Partnerships and Opportunities to Strengthen and Harmonize Action for Nutrition in India – POSHAN) and NSA initiatives (e.g. Tackling the Agriculture Nutrition Disconnect in India (TANDI), System of Promoting Appropriate National Dynamism for Agriculture and Nutrition (SPANDAN), Technical Assistance and Research for Indian Nutrition and Agriculture (TARINA), Nutrition Innovation Lab that covers Nepal and Bangladesh from South Asia besides six other countries and Leveraging Agriculture for Nutrition in South Asia (LANSA)). Some of the countries of the region (Afghanistan, Bangladesh, Pakistan and Sri Lanka) are members of the Scaling Up Nutrition (SUN) network working to end malnutrition; the World Bank's South Asia Food and Nutrition Security Initiative (SAFANSI) has been supporting work in many countries; and the South Asia Policy Leadership for Nutrition and Growth (SAPLING) is perhaps the most recent.

Evidence on agriculture nutrition linkage in the region is being generated by several of these initiatives. The quality of research design and level of political priority are among the reasons cited as impacting on such evidence. A framework and review of the agriculture–nutrition disconnect in India was one of the exercises undertaken under TANDI [5]. The available evidence on linkages between agriculture and nutrition in Pakistan, India and Bangladesh was mapped by the LANSA research programme [19–21]. A systematic review under SPANDAN examined 25 studies published during the period 2000–2014, on the impact of agriculture and allied sector interventions on nutritional status of adults and children in South Asia. The study surmised that though the evidence of impact on nutrition status is small – 'agricultural interventions targeted at nutrient-rich crops and diversification of agricultural production system towards fruits, vegetables, and aquaculture through women empowerment hold the potential to improve the nutritional outcomes in South Asia' (p. 38); it also reiterated the need echoed in other reviews discussed earlier, for well-designed studies and integrated datasets to better understand agriculture–nutrition linkages [22].

The review of agriculture and nutrition linkages in Pakistan following the TANDI framework identified three disconnects for further research: mismatch between beneficiaries of growth and nutritionally deprived population segments; existing patterns of behaviour and preferences and pro-nutrition 'uses' of agricultural growth; and the supporting public infrastructure, especially in health and other social sectors, essential for agriculture to impact on nutrition outcomes that 'may be compromised by low levels of political priority and/or organizational effectiveness' [19]. The India evidence review examined 78 studies around the six pathways and study design [20]. It concluded that while the evidence base is weak, it is suggestive of an important role for NSA development; and recommended broadening the frontier in agriculture–nutrition research through more explicit experimental designs, specialized household surveys with a multi-sectoral approach, adoption of rigorous modelling methods for a better understanding of gender and intra household dynamics and 'more nutrition-sensitive macroeconomic simulation models that can rigorously gauge the nutritional impacts of large-scale policies and programmes' (p. 53). The Bangladesh evidence review reviewed 60 studies following the approach in [20]; it found a lacuna in establishing causality between agriculture intervention and nutrition outcomes and also identified research gaps relating to how farming households use their agricultural income; ways in which the status of women in agriculture affects households' expenditure on food, health and education; internal allocation of resources; child care practices; and women's own health [21].

For the purpose of the review that follows on agriculture–nutrition linkage in South Asia, we keep undernutrition as the focus and the paper does not examine emerging problems of the other side of malnutrition, viz. overnutrition, obesity and non-communicable diseases, evidence of which is also beginning to manifest in the region. While geographically, South Asia comprises of eight countries, viz. Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan, India and Sri Lanka; in this paper, we examine agriculture–nutrition linkages in the four LANSA focus countries, Afghanistan, Bangladesh, India and Pakistan, with Nepal added as a fifth outer ring country. We have taken the period of review also from the start of LANSA in 2012 to July 2018.

The remainder of this paper is organized as follows. 'Methods and Materials' section discusses the methodology followed; 'Results' section gives a detailed discussion of the studies reviewed and the final section concludes.

Methods and materials

The objective of this review is to draw attention to studies which discuss agriculture–nutrition linkage in South Asia with undernutrition as the focus. We followed a systematic search process and searched for studies on the basis of agriculture and nutrition linkages in South Asia for the period 2012–2018. We defined agriculture broadly to include agriculture and allied activities, specifically in South Asia. Nutrition outcomes included outcome indicators for anthropometry, i.e. height-for-age (HAZ), weight-for-age (WAZ), weight-for-height (WHZ) measures for children and body mass index (BMI) for adults as well as intermediate outcome indicators such as total calorie intake, diet diversity and nutrient consumption. We also focused on the various pathways in which agriculture can influence nutrition.

Search strategy

The search strategy involved narrowing down the studies with agriculture–nutrition linkage as the main theme. A systematic search was completed with several search engines and important websites: Google Scholar, AgEcon Search, CAB Abstracts, CAB Direct, Eldis-IDS, Food and Agriculture Organization (FAO), International Food Policy Research Institute (IFPRI), Leveraging Agriculture for Nutrition in South Asia (LANSA), Harvest Plus, United Nations Children's Fund (UNICEF) and World Bank.

We also searched using the various known pathways by which agriculture might link with nutrition, viz. 'agriculture as a source of food', 'agriculture as a source of income', 'women in agriculture' and eliminated all duplicate searches. The search was repeated in the various databases specified, with different sites permitting different levels of search sophistication. We screened about 2000 studies from all searches, including the narrow searches. We included all peer-reviewed journal papers as well as peer-reviewed working papers. Review reports, book chapters and grey literature were not included. The detailed search from Google Scholar is given in Appendix Table A1.

After screening the titles for relevance and removing studies which did not mention South Asia focus *per se* and dropping duplicates, we narrowed down to 144 studies from all search engines. In the next step, we eliminated 42 studies we did not have access to and further removed the ones that did not seem relevant on reading abstracts, and arrived at 46 studies. At this stage, we checked papers cited in these studies and papers based on the authors' own information, and added another 33 papers. Finally, after removing reports, book chapters and trial-based studies from these 79 papers, we arrived at 42 studies (Fig. A1 in the Appendix). The following were not included, viz. papers based on (i) trial studies (e.g. feeding trials of biofortified crops) and not intervention studies per se, (ii) where the primary focus was on examining the agriculture–nutrition linkage through non-food factors, e.g. nutrition awareness, WASH, agriculture policy, (iii) impact of conflict and environmental fragility on agriculture–nutrition linkage, (iv) broader papers with food systems as the central theme and (v) where there was no impact being measured or the sample size and/or study period was very small. While we have reviewed the evidence on agriculture–nutrition linkage and with special focus on South Asia in a systematic way, it is not a systematic review as per standard guidelines.

Around 16 of these 42 studies were literature and systematic reviews on agriculture–nutrition linkage that included South Asia, with a few being specific to just South Asia (Appendix Table A2); these were used to check for additional references and for setting the context discussed in the previous section. The remaining 26 studies either focused on examining impact of agricultural growth, productivity, agricultural assets and agriculture as food on dietary diversity and nutrition outcomes or on the pathway of women in agriculture and nutrition. Twenty studies fell in the first category and six in the second. These have been tabulated (Appendix Table A3) and are discussed in the next section. We also found that there were a combination of observational studies and intervention-based primary data studies under both categories and have tabulated and discussed them on these lines. A few studies in the list of 26 shortlisted studies included analysis of countries other than from South Asia; the evidence relevant only to South Asia has been drawn from these.

Results

Agriculture as asset and source of food

Of the 20 papers based on the impact of agricultural performance, ownership of agriculture assets and agriculture as food, 16 are observational studies examining the agriculture–nutrition linkage using large datasets and three are intervention-based studies. There are two studies from Afghanistan, three from Bangladesh, two from Nepal and nine from India under the observational studies; and there are two intervention studies from Nepal and one from India. There is substantial evidence on improvement in diet diversity or dietary patterns with increased income, land, livestock and asset ownership. The role of enabling factors such as WASH, better infrastructure facilities for health and cooking is also emphasized in a couple of studies. The intervention studies focus on the importance of nutrition gardens in enhancing nutrition. The studies are discussed in detail below:

Observational studies

Nine out of the 16 observational studies have analysed diet diversity as an outcome variable. Several of these provide evidence of an improvement in diet diversity with

increased income and land, livestock or asset ownership [23–27]. In a specific study on sheep ownership in Afghanistan, it is found that sheep ownership reduces anaemia after controlling for wealth and other covariates and also promotes mutton consumption from own production [25]. In another study in Afghanistan, it is found that irrigation facilities are positively correlated with diversity of food intake from own production and irrigated garden plots are positively associated with greater diversity of food purchased at the market [26]. Another study in Nepal finds that agriculture-related changes explain at least 16% of improvement in dietary diversity [27]. A number of studies provide evidence of an improved dietary diversity with increased crop diversity [28–31]. One of these studies, in India, examined an impact on women's nutrition status in particular and found a positive correlation between cultivator households and women's BMI. The study emphasized that for improvement in an adult woman's BMI, equal importance must be given to environmental conditions such as WASH, smoke-free cooking area and better healthcare facilities [30].

Two studies focus on the dietary patterns and nutrition in India [32, 33]. The first study which used data from village-level studies by International Crops Research Institute for the Semi Arid Tropics (ICRISAT) found that the diets were dominated by cereals/carbohydrates; pulses were the major source of protein as meat and meat products (rich sources of protein) did not feature in the list of commonly consumed foods. The study reported a positive relation between the consumption of pulses and improved nutritional status in terms of BMI [32]. The second study used National Sample Survey (NSS) data between 1993 and 2009 and found more than moderate reductions in calorie intakes with dietary shifts. The study also found that food prices, expenditure, demographic characteristics and lifestyle are important factors influencing diet diversification and nutritional outcomes [33].

Three studies under LANSA in India [34–36] focused on how agricultural prosperity characterized by land productivity among other indicators increased percentage of nourished children; inequity in land holding hindered larger welfare gains in agricultural productivity from improving child nutrition. All the papers also emphasized the role of women's agency and WASH practices in reducing malnutrition. Another paper from India also examined agricultural performance and found that indicators of the level of agricultural performance or income show a strong and significant relationship with the indices of undernutrition among adults and children; the study also reported that access to sanitation facilities and women's literacy are strong factors affecting favourable nutrition outcomes [37].

A study in Bangladesh found that rice yields predict the earlier introduction of complementary foods to young children as well as increases in their WHZ but has limited impact on dietary diversity and called for diversification of the food basket through both supply and demand-side interventions for nutritional impact [38].

Intervention studies

All four intervention studies on agriculture as food have a focus on nutrition gardens. One study from Nepal is a randomized control trial based on an enhanced homestead food production programme that simultaneously promoted optimal nutrition practices and year-round availability and intake of diverse micronutrient-rich foods among poor households [39]. This study found marked improvement in household food security, early initiation of breastfeeding, exclusive breastfeeding, improved complementary feeding practices, and better hygiene practices of mothers and children among intervention households compared with control. At endline, anaemia was significantly lower among mothers and children in the intervention group. Another study from Nepal evaluated the combined impact of school gardens linked to complementary lessons and promotional activities about gardening and nutrition on the nutritional awareness, knowledge, perceptions, eating behaviour and nutritional status of 10- to 15-year-old schoolchildren after one year of intervention. The study did not find an impact on consumption and nutrition outcomes; however, it reported evidence of a significant increase in children's awareness about fruit and vegetables, sustainable agriculture, food, nutrition and health and their stated preferences for eating fruit and vegetables [40].

One study from India targeted pregnant women and mothers with pre-school children aged 6–24 months, registered with 11 Integrated Child Development Service (ICDS) centres in eight villages. The intervention focused on the introduction of homestead gardens, backyard poultry with high egg-yielding breeds of birds and health and nutrition education. Over the 3 years of intervention, a gradual decline was observed in the percentage of children suffering from moderate-to-severe malnutrition [41]. The second study from India examined the nutrition garden component of a larger study to address household dietary diversity in two districts; it found that the monthly per capita consumption of fruits and vegetables, both quantity consumed and frequency of consumption, showed marked increase between baseline (2014) and endline (2017). Increased availability of different groups of vegetables also fulfilled the household nutritional requirements [42].

Women in agriculture

There are two studies in the category of observational studies on women in agriculture from Bangladesh, two from Nepal and one multi-country analysis, which includes Bangladesh and Nepal from South Asia; and one intervention study from India. The studies find that women's empowerment is strongly associated with better nutritional

outcomes for their children along with improved dietary diversity for the household. The studies are discussed in detail below:

Observational studies

In a study conducted in Bangladesh on the link between women's empowerment and child nutrition, it was reported that gender gaps in empowerment are only weakly linked to children's nutrition, although significant differences exist between boys and girls depending on the empowerment measures used [43]. Increasing women's decision making over credit and assets is associated with improvements in girls' nutritional status (HAZ, WHZ), while increasing women's life satisfaction and participation in groups was associated with improvements in boys' nutritional status (WHZ, WAZ). Another study in the same geography examined the relationship between women's empowerment in agriculture (WEIA), and per capita calorie availability, dietary diversity and adult BMI [44]. It found that increases in women's empowerment are positively associated with calorie availability and dietary diversity at the household level. Overall, household wealth, education and occupation were found to be more important than women's empowerment, as determinants of adult nutritional status.

A study in Nepal found that production diversity is positively associated with mothers' dietary diversity and BMI and with dietary diversity for children under 2; and predicts WAZ, WHZ and HAZ *z*-scores of children over 2 years of age. Indicators of empowerment were significantly associated with maternal outcomes but had a variable effect on child outcomes. Women's autonomy in production and hours worked improved maternal and children's dietary diversity and child HAZ [45]. Another study using the WEIA index reported that it was positively associated with HAZ for children under 2 [46]. A multicountry study that included Bangladesh and Nepal from South Asia reported that women in Nepal have relatively higher work burden, spending about 11 hours a day on productive and reproductive work. Poor women face heavier workloads in Bangladesh and Nepal, particularly due to their substantial involvement in agricultural activities. Women's time in domestic work increases their dietary diversity in Nepal. Further, women who spend more time cooking have improved diets in Bangladesh and Nepal. In poor households, reductions in women's reproductive work time are detrimental to nutrition, especially for children. Owning small livestock was found to have a positive effect on women's dietary diversity in Nepal and on children's diets in Bangladesh and Nepal [47].

Intervention study

A primary survey conducted in India under an intervention study across 12 villages in two Indian districts, Wardha (Maharashtra) and Koraput (Odisha), found that overall, women's work in agriculture seems to have a negative effect on household nutrition through two pathways: lack of adequate time for care work in peak agricultural seasons and seasonal energy stress with consequent losses in body weight. The lack of time to ensure proper feeding and hygiene of the children adversely affects their health and hampers normal growth. Also, women in general experience more seasonal weight loss compared with men [48].

Conclusion

The need to leverage agriculture for nutrition and the pathways through which agriculture can link with nutrition are now well recognized and accepted. However, weak study design and lack of robust evidence of impact of agriculture on nutrition outcomes is a common observation from the reviews examined in the first section. We further focused on the five South Asian countries of Afghanistan, Bangladesh, India, Nepal and Pakistan, and reviewed published studies during the period 2012–2018 that examined agriculture as an asset and source of food, and the role of women in agriculture, leading to improved nutrition.

Given the evidence from the review that production diversity promotes dietary diversity, efforts that encourage farmers to diversify their crop portfolios will help in improving dietary quality. The fact that a large majority of farmers in these countries are small and marginal farmers calls for special attention and policy focus towards them. In fact there is evidence that small and marginal farmers have a higher contribution in calorie, protein and fat production [49]. Likewise, improvement in land/agriculture productivity, addressing inequity in landholding, asset inequality and facilitating access to irrigation facility and livestock are also areas to be addressed, especially in countries with large population dependent on agricultural livelihoods, as seen from the evidence in the studies reviewed. The need for attention to enabling factors such as WASH, healthcare and women's empowerment and time for care work also emerge as important issues to be addressed for improvement in nutrition outcomes.

The search did not yield many intervention studies during the period 2012–2018 and the intervention focus of identified studies was primarily on nutrition gardens. There were also no studies from Pakistan other than one evidence review. Biofortified crop varieties that have been released by the agriculture research systems in countries such as India and Bangladesh and under international programmes like HarvestPlus are a potential source for improving nutrition outcomes; they have however not been tried at scale in the region and there is a dearth of studies around them other than evidence from feeding trials that we did not include in this review. The small number of intervention studies in the search is a matter of concern. The authors themselves are aware of many ongoing initiatives in the region; the lack of robust research design and mapping of evidence seems to be the major issue. More evidence is also

needed to understand the nuances of the gender pathway of agriculture nutrition linkage. Recent work under LANSA, especially on women in agriculture and nutrition in Pakistan and farming system for nutrition in India [50], is expected to add to the body of literature in this domain. Outputs are also expected from other agriculture nutrition initiatives in the region, to add to the current evidence base.

In line with previous reviews, this work also found that the evidence of agriculture–nutrition linkage is more with regard to intermediate outcomes such as diet diversity. There can however be no denying that changes are needed in agriculture systems accompanied by the support of other sectors for moving towards the SDG2 goal. While thrust on promoting dietary diversity through agriculture with an understanding of the local context seems to be a way forward, support for more in-depth and long-term well-designed intervention studies that focus on nutrition indicators to inform policy and focus on measures for ensuring sustained impact are required.

Acknowledgements

This paper is dedicated to late Dr Prakash Shetty, CEO, LANSA research programme consortium, who passed away on 3 September 2018, and had been a mentor to the authors. The paper is part of the research generated by the Leveraging Agriculture for Nutrition in South Asia (LANSA) research consortium funded by UK aid from the UK Government. The views expressed do not necessarily reflect the UK Government's official policies.

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Appendix

Table A1 Results of advanced search using Google Scholar

S.no.	With all words	Exact phrase	Time period	Number of papers
1	Agriculture nutrition			2 560 000
2	Agriculture nutrition South Asia			551 000
3	Agriculture nutrition South Asia	Agriculture nutrition		4560
4	Agriculture nutrition South Asia	Agriculture nutrition	2012–2018	2840
5	Linking agriculture nutrition South Asia	Agriculture nutrition	2012–2018	1950
6	Linking agriculture nutrition South Asia	Agriculture nutrition linkages	2012–2018	159
7	Agriculture as a source of food South Asia	Agriculture nutrition pathways	2012–2018	38
8	Agriculture as a source of income for food and nonfood expenditures South Asia	Agriculture nutrition pathways	2012–2018	20
9	Agricultural policy and food prices affecting food consumption South Asia	Agriculture nutrition pathways	2012–2018	40
10	Women in agriculture and intra-household decision making and resource allocation South Asia	Agriculture nutrition pathways	2012–2018	26
11	Maternal employment in agriculture and child care and feeding South Asia	Agriculture nutrition pathways	2012–2018	34
12	Women in agriculture and maternal nutrition and health status South Asia	Agriculture nutrition pathways	2012–2018	37
13	Agriculture, nutrition awareness and nutrition status South Asia	Agriculture nutrition pathways	2012–2018	41
14	Agriculture, WASH and Nutrition status South Asia	Agriculture nutrition pathways	2012–2018	36
15	Agriculture interventions and nutritional status South Asia	Agriculture nutrition linkages	2012–2018	154
16	Agriculture interventions and nutritional status South Asia	Agriculture nutrition pathways	2012–2018	39

Table A2 Reviews referred to in 'Introduction' section

S. no.	Review authors	Brief description
1.	Gillespie *et al.* [5]	Review of the background literature for India, including an assessment of trends in nutrition and agriculture indicators. A conceptual framework is then put forward to aid in the systematic search for links and disconnects between agriculture and nutrition
2.	Girard *et al.* [9]	Examines and summarizes the effects of agricultural interventions to increase household food production on the nutrition and health outcomes of women and young children
3.	Masset *et al.* [8]	Assesses the effectiveness of agricultural interventions in improving the nutritional status of children in developing countries
4.	Dangour *et al.* [11]	Systematically reviews the available evidence on whether national or international agricultural policies that directly affect the price of food influence the prevalence rates of undernutrition or nutrition-related chronic disease in children and adults.
5.	Balagamwala and Gazdar [19]	Using evidence from Pakistan, this article reviews trends and policymaking in agriculture and applies a framework for analysing pathways between agriculture and nutrition
6.	Ruel and Alderman [6]	Evidence of nutritional effects of programmes in four sectors – agriculture, social safety nets, early child development and schooling
7.	Turner *et al.* [12]	Maps the extent and nature of current and planned research on agriculture for improved nutrition in order to identify gaps where more research might be useful
8.	van den Bold *et al.* [14]	Reviews the evidence of the impact of three types of interventions – cash transfer programmes, agricultural interventions and microfinance programmes – on women's empowerment, nutrition or both
9.	Webb and Kennedy [10]	Review of ten papers published since 2000 to synthesize current evidence of agriculture-to-nutrition linkages
10.	Kadiyala *et al.* [20]	This paper comprehensively maps existing evidence along agriculture–nutrition pathways in India and assesses both the quality and coverage of the existing literature
11.	Careletto *et al*. [13]	Systematically and empirically tests, using data from Africa and South Asia, whether a relationship between household agricultural production and nutrition can be found
12.	Johnston *et al.* [15]	This review considers a larger evidence base and explores time as one of the agriculture–nutrition pathways
13.	Yosef *et al.* [21]	To assess the emphasis of the literature on different agriculture–nutrition pathways in Bangladesh
14.	Pandey *et al.* [22]	Systematic review of studies which show an association between agricultural interventions and nutritional outcomes
15.	Gillespie and van den Bold [17]	Reviews the theory and recent qualitative evidence (particularly from 2010 to 2016) in the public health and nutrition literature, on the role that agriculture plays in improving nutrition, how food systems are changing rapidly due to globalization, trade liberalization and urbanization, and the implications this has for nutrition globally
16.	Ruel *et al.* [16]	Reviews recent empirical evidence (since 2014), including findings from impact evaluations of a variety of nutrition-sensitive agriculture programmes using experimental designs as well as observational studies that document linkages between agriculture, women's empowerment and nutrition linkages

Table A3 Summary of studies linking agriculture, women's empowerment and nutrition

S.No	Study	Outcome measure	Geographical area of research and data source	Main findings
I. Agriculture as asset and source of food				
Observation studies				
1.	Bhagowalia *et al.* [24]	Anthropometric outcomes (HAZ and WHZ for children 0–5 and 8–11 years)	India; data from the 2005 India Human Development Survey (IHDS) containing information from 41 554 households in 1503 villages and 971 urban neighbourhoods across all the States and Union Territories of India	• Agricultural income and production conditions have significant influence on household dietary diversity • Agricultural programmes aimed at irrigation, livestock ownership and crop diversification have significant impact on dietary diversity • Crop diversity is positively associated with diet diversity • Stunting and wasting rates are marginally higher for agricultural households vis-à-vis non-agricultural households • Children belonging to the highest income quantiles have higher HAZ vis-à-vis the poorest quantile; this effect is stronger for non-agricultural households • Income gradient for undernutrition is weak while non-income factors such as child vaccinations and female secondary education have strong significant effects on reducing malnutrition
2.	Gulati *et al.* [37]	Combined Normalized Malnutrition Index (CNMI), combining five indicators of child and adult undernutrition; Normalized Adult Malnutrition Index (NAMI), combining two indicators of adult undernutrition (the percentages of thin men and thin women 15–49 years); and Normalized Child Malnutrition Index (NCMI), combining three indicators of child undernutrition (stunting, wasting and underweight among children <5years of age)	India; Per Capita Gross State Domestic Product of Agriculture and Allied Activities (PCGSDPA) calculated using GSDPA (in constant 1999/2000 prices) and projected rural population from the 2001 census Gross Value of Output from Agriculture and Allied Activities data released by the CSO, Ministry of Statistics and Programme Implementation, and Land Use Statistics, estimated by the Ministry of Agri-culture, Govt of India National Family Health Survey (NFHS) data India, NFHS-III, 2005–2006	• Agricultural performance and income measures show high and significantly negative correlations with CNMI • Adult undernourishment status was negatively correlated with agricultural performance, women's literacy, presence of toilet facilities in the house, and maternal healthcare indicators • Normalized Child Malnutrition Index (NCMI) shows a strong correlation with agricultural performance, women's literacy and proportion of households with toilet facilities
3.	Gaiha *et al.* [33]	Diet diversity	India; National Sample Survey (NSS) 50th, 61st and 66th Rounds unit record data over three NSS Years (1993–2009)	• Dietary shifts are associated with more than moderate reductions in calorie intakes, i.e. taste for food variety, leading to lowered calorie intakes • Food prices, expenditure, demographic characteristics and lifestyle play important roles in diet diversification and nutritional outcomes

Table A3 (Continued)

S.No	Study	Outcome measure	Geographical area of research and data source	Main findings
4.	Vepa *et al.* [34]	Percentage of underweight children, percentage of stunted children	India; child undernutrition data from the two National Family Health Survey (NFHS) datasets pertaining to the periods 1998–1999 and 2005–2006 (NFHS-2, and NFHS-3) Agriculture data from NSS 50th round (1999–2000) and 55th round (2004–05)	• Differential negative influence of agricultural prosperity (land productivity) on underweight and stunting. • Other aspects of agriculture considered, such as female agricultural wages, reinforce the negative influence of agricultural prosperity on underweight in children • Land operational inequality dampens the impact of agricultural prosperity as it increases the incidence of stunting
5.	Vepa *et al.* [35]	Children's normal nutrition status (CNS), i.e. percentage of children above 2 SD for weight-for-age	India; District Level Household Facility Survey (DLHS-2) 2002–2004. Other sources are the department of agriculture and GDP data from Central Statistical Organization	• Both land productivity or worker productivity in agriculture show strong influence on underweight children • Women's agency aspects of literacy and its interaction with work participation and pregnant women's health status influence child-underweight • Lower income groups may continue to be malnourished, due to weak public provisioning
6.	Viswanathan *et al.* [30]	Women's BMI at individual level and dietary diversity at household level	India; data from the 2005 India Human Development Survey (IHDS)	• Women in cultivator households or those who have a higher share of agricultural incomes have lower rates of undernutrition and women in non-agricultural wage labour households are worse off • Dietary diversity improves with higher income, better wealth status, larger area under cultivation; access to better diets in a sustained manner, in the form of crop and income diversification, ownership of cows and buffaloes as well as market access to sell the crops; and better awareness among households
7.	Flores-Martinez *et al.* [25]	Anaemia, food consumption	Afghanistan; data from the Afghanistan Multiple Indicator Cluster Survey (AMICS) 2010–2011 covering 22 053 women from 13 314 households visited across Afghanistan's eight regions and National Risk and Vulnerability Assessment (NRVA) 2011–2012 data (representative survey of the living standards of 20 828 households undertaken by the CSO of Afghanistan)	• Sheep ownership reduces anaemia after controlling for wealth and other covariates • Sheep ownership promotes mutton consumption from own production in a setting where market-sourced provision of nutritious food is a challenge • Households sourcing mutton mostly from own production consumed mutton 1.5 days more frequently on average than households relying on market purchase resulting in 100 g per person per week higher mutton intake
8.	Headey and Hoddinott [38]	Two dimensions of undernutrition in children: acute undernutrition (weight for height); and chronic undernutrition	Bangladesh; synthetic panel by merging together five rounds of data on rural households and children from the	• Rice yields predict the earlier introduction of complementary foods to young children (most frequently rice) as well as increases in their weight-for-height, but no

Table A3 (Continued)

S.No	Study	Outcome measure	Geographical area of research and data source	Main findings
		(height for age); introduction of complementary feeding, minimum dietary diversity	nationally representative Bangladesh Demographic Health Surveys (DHS) collected in the years 1996/97, 2000, 2004, 2007 and 2011, with district-level agricultural data (109 district-year observations in total with median no. of children in each district 352)	improvements in their dietary diversity or height-for-age
9.	Hossain *et al.* [23]	Dietary diversity score, nutrient intake, food consumption score	Bangladesh; Household income and expenditure surveys (HIES) data for the years 2000 and 2010. The entire country was divided into five divisions in 2000 and six divisions in 2010. The total sample size was 7440 households in HIES 2000 and 12240 in HIES 2010	• Diet diversity and food consumption score improved considerably in Bangladesh during 2000–2010 • The energy intake remained almost stagnant, but there was a significant improvement in the intake of protein, vitamin A and iron. The intake of zinc marginally declined • Household income, land ownership, level of education of the household head and the spouse, sex of the household head, and the level of infrastructure development as measured by access to electrification are significant factors affecting diet diversity • Agriculture promotes diet diversity, food consumption score and nutrition outcomes
10.	Kumar *et al.* [29]	Food consumption pattern, dietary diversity	India; household-level panel data (2010–2011 to 2014–2015) from 12 villages of Bihar, Jharkhand and Odisha (40 from each or 480 households) in eastern India	• Agricultural production diversity is a major determinant of dietary diversity which in turn has a strong effect on calorie and protein intake
11.	Padmaja *et al.* [32]	Dietary diversity, BMI	India; primary data from the ICRISAT Village Level Studies (VLS) nutrition surveys (eight villages from Telangana, Andhra Pradesh and Maharashtra) and the longitudinal panel micro-level data (for six villages of Telangana and Maharashtra) from 2009 to 2014	• The commonly consumed food groups for HDDS, IDDS and WDDS (Household, Individual and Women Dietary Diversity Score) show domination of foods rich in carbohydrates in the diets • Pulses are the major source of protein in these diets, as meat and meat products (rich sources of protein in the diets) do not feature in the list of commonly consumed foods • Positive relation between the consumption of pulses and nutritional status; those who consumed pulses more frequently had a higher tendency of having a normal BMI compared with those who consumed pulses less frequently • The frequency of consumption of pulses has a threshold point, after

Table A3 (Continued)

S.No	Study	Outcome measure	Geographical area of research and data source	Main findings
				which it has a negative impact on the individuals BMI status
12.	Vepa *et al.* [36]	Children's normal nutrition status (CNS), i.e. percentage of children above 2 SD for weight-for-age	India; children below 6 years or below, from the second round of District Level Household Facility Survey (DLHS-2) for the year 2002–2004; Agricultural variables are either from the Ministry of Agriculture and Farmers' Welfare for the years 2002, 2003 and 2004, or from the Agricultural Census of 2005–2006.	• A 1% increase in land productivity increases the percentage of nourished children below 6 years by about 0.08% • Use of oral rehydration salts in diarrhoea incidence improves the underweight rate by about 0.08% at the overall district level
13.	Kumar *et al.* [27]	Dietary diversity	Nepal; unit-level data from three rounds (1995, 2004 and 2011) of the Nepal Living Standards Survey (NLSS)	• Agriculture-related changes explain at least 16% of the observed improvement in dietary diversity and share of expenditure on non-staple foods • Changes in household characteristics account for at least 37% of the observed improvement • Variables positively associated with dietary quality are crop diversity, remittances, social cash transfers, parents' education, access to markets and paved roads and ownership of a television and telephone, among others
14.	Mulmi *et al.* [31]	Whether children (6 ± 59 months) reach a minimum dietary diversity threshold of four out of seven food groups consumed in the previous week	Nepal; Policy and Science for Health, Agriculture and Nutrition (PoSHAN) surveys conducted in 2013 and 2014 (two rounds) as part of a large portfolio of Feed the Future Nutrition Innovation Lab research for (5978 observations)	• Significant associations between child dietary diversity and agricultural diversity in terms of diversity of food groups and of species grown, especially for older children in poorer households, and particularly for fruits and vegetables, dairy and eggs
15.	Deb and Bayes [28]	Food intake, dietary diversity and nutritional status (BMI)	Bangladesh; panel household survey data collected from 500 households by ICRISAT and IRRI in Bangladesh (2010/11 to 2014/15) under the Village Dynamics in South Asia (VDSA) project	• Increase in crop diversity from an average of 8.2 crops in 2010/11 to 9.3 in 2014/15 • Daily consumption level of all food items increased except for slight reduction in that of milk • Average daily consumption of food items by producer household members was higher than that of non-producer household members • Crop diversity, per capita income of the household and educational level of the household head had significant positive contributions to the dietary diversity score of the household and nutritional status of household members
16.	Kawsary *et al.* [26]	Dietary diversity, food frequency and	Afghanistan; data from nationally	

Table A3 (Continued)

S.No	Study	Outcome measure	Geographical area of research and data source	Main findings
		relative nutritional importance of different food groups (these variables were used to create a Food Consumption Score)	representative Afghanistan Living Condition Survey (2013–2014) collected by the Central Statistical Organization (CSO) of the Islamic Republic of Afghanistan. The survey gathered information on 20 786 households from all 34 provinces of the country	• Irrigation facilities are positively correlated with diversity of food intake from own production • Irrigated garden plots are positively associated with greater diversity of food purchased at the market • Dietary diversity is positively associated with households' ratio of dietary diversity from own production
Intervention studies				
17.	Murty *et al.* [41]	Mean birthweight, Weight-for-age, nutrition awareness	India; 11 ICDS centres with a target of 335 families in eight villages of Medak district in Telangana. A sub-sample of 142 mothers with 6–24 months old children was followed over 3 years. Intervention: nutrition garden, awareness, backyard poultry	• Knowledge, attitude and practice (KAP) surveys of health and nutrition showed marked improvement in mother's knowledge and child-feeding practices • Percentage of families raising homestead gardens increased from 30 to over 70%. • Frequency and quantity of eggs and green leafy vegetables consumed per week increased • Gradual decline in percentage of children suffering from moderate–severe malnutrition over the 3-year experimental period
18.	Schreinemachers *et al.* [40]	Nutrition Awareness, food consumption (24 hour recall) and anthropometry	Nepal; cluster randomized controlled trial design from 30 schools and a sample of 1275 and 785 schoolchildren for the 2014 and 2015 school years respectively. Intervention: enhanced homestead food production programme (EHFP)	• After one year of intervention, significant increase in children's awareness about fruit and vegetables, sustainable agriculture, food, nutrition and health and their stated preferences for eating fruit and vegetables. • No significant improvements in fruit and vegetable consumption or nutritional status.
19.	Osei *et al.* [39]	Outcome variables (stunting, underweight, wasting and anaemia among children and underweight and anaemia among mothers)	Nepal; an unblinded cluster-randomized controlled trial involving pre- and post-surveys with independent samples in rural areas of Baitadi district; data (including weight, height/length and haemoglobin) obtained from 2106 and 2614 mother–child pairs at baseline and follow-up, respectively Intervention: school garden and awareness	• Maternal practices in breastfeeding and complementary feeding improved in treatment group • Improved hand washing with soap, antenatal visits, iron and folic acid supplementation and deworming during pregnancy, as well as children's immunization, vitamin A supplementation • Prevalence of anaemia was significantly lower among children and mothers and underweight was lower among mothers in the intervention households compared with the control • No impact on child nutrition
20.	Pradhan *et al.* [42]	Diet diversity and frequency of consumption	India; 190 households each in both Wardha district in Maharashtra and Koraput district in Odisha in baseline (2014) and endline (2017)	• Entire produce from nutrition garden was used for household production in Wardha while in Koraput, 10–20% was also distributed to neighbours or sold • Monthly per capita consumption of fruits and vegetables, both quantity consumed and frequency of

Table A3 (Continued)

S.No	Study	Outcome measure	Geographical area of research and data source	Main findings
			Intervention: nutrition garden	consumption showed marked increase between baseline and endline • Increased availability of different groups of vegetables also fulfilled the household nutritional requirements
II: Women in agriculture and nutrition				
1.	Malapit *et al.* [45]	Impact of women's empowerment in agriculture and production diversity on dietary diversity and anthropometric outcomes of mothers and children	Nepal; survey of 4080 households from 16 districts across the three agro-ecological zones in 2012	• Production diversity is positively associated with mothers' dietary diversity and body mass index • Production diversity is positively associated with dietary diversity for children under 2 and predicts WAZ, WHZ and HAZ z-scores of children over 2 years of age • Indicators of empowerment are significantly associated with maternal outcomes but have a variable effect on child outcomes • Women's autonomy in production and hours worked improve maternal and children's dietary diversity and child HAZ
2.	Sraboni *et al.* [44]	Relationship between women's empowerment in agriculture, measured using the WEIA and per capita calorie availability, dietary diversity and adult BMI.	Bangladesh; nationally representative data from the 2012 Bangladesh Integrated Household Survey (BIHS)	• Women's empowerment is positively associated with calorie availability and dietary diversity at the household level • Overall, household wealth, education and occupation are more important than women's empowerment as determinants of adult nutritional status • Negative impacts of group membership and credit on male BMI suggest that intra-household trade-offs may exist
3.	Cunningham *et al.* [46]	Association between women's empowerment in agriculture and nutritional status among children under 2 years of age	Rural Nepal; cross-sectional survey of 4080 households from 240 rural communities across 16 districts of Nepal, in 2012. (Evaluation of Suaahara, a multi-sectoral maternal and child health and nutrition intervention funded by the USAID)	• The overall WEAI in 5 dimensions was positively associated with LAZ (Length-for-age) • Three component indicators were also positively associated with LAZ: satisfaction with leisure time, access to and decisions regarding credit and autonomy in production. • No indicator of women's empowerment in agriculture was associated with WHZ.
4.	Komatsu *et al.* [47]	Association between women's time use and their dietary diversity and children's dietary diversity	Bangladesh; 2012 data from the Bangladesh Integrated House-hold Survey (BIHS); and baseline survey of a USAID-funded nutrition programme – Suaahara in Nepal	• Women in Nepal have the heaviest work burden among all five countries, spending a total about 11 h a day on productive and reproductive work • Poor women face heavier workloads in Bangladesh and Nepal, particularly due to their substantial involvement in agricultural activities • Women's time in domestic work increases their dietary diversity in Nepal • Women who spent more time cooking had improved diets in Bangladesh and Nepal • In poor households, reductions in women's reproductive work time are

Table A3 (Continued)

S.No	Study	Outcome measure	Geographical area of research and data source	Main findings
				detrimental to nutrition, especially for children • Owning small livestock has a positive effect on women's dietary diversity in Nepal and on children's diets in Bangladesh and Nepal
5.	Malapit *et al.* [43]	Children's well-being using nutritional status for younger children (0–5 years) and education outcomes for older children (6–10 and 11–17 years); Women's Empowerment in Agriculture Index	Bangladesh; nationally representative data from the 2012 Bangladesh Integrated Household Survey (BIHS)	• Gender gaps in empowerment are only weakly linked to children's nutrition, although significant differences exist between boys and girls depending on the empowerment measures used • Increasing women's decision making over credit and assets is associated with improvements in girls' nutritional status (HAZ, WHZ), while increasing women's life satisfaction and participation in groups are associated with improvements in boys' nutritional status (WHZ, WAZ) • Household head's (father's) education is significantly associated with better nutrition and education outcomes for children, but younger girls (6–10 years) and older boys and girls (11–17 years) are more likely to receive more education when mothers are more educated
Intervention study				
6.	Rao and Raju [48]	Women's time use and child nutrition, energy stress and women's BMI	India; primary data from 12 villages in two Indian districts, Wardha (Maharashtra) and Koraput (Odisha), collected as part of the Farming System for Nutrition (FSN) study under LANSA. Detailed baseline livelihood, anthropometric and dietary surveys were conducted with 150 households in each district in early 2014. Thirty households in each district were selected from these 150 households, for the conduct of time use and anthropometry surveys over three seasons	• Overall, women's work in agriculture seems to have a negative effect on household nutrition through two pathways: lack of adequate time for care work in peak agricultural seasons and seasonal energy with consequent losses in body weight • The lack of time to ensure proper feeding and hygiene of the children adversely affects their health and hampers normal growth • Allowing for exceptions among different social groups, women in general experience more seasonal weight loss compared with men

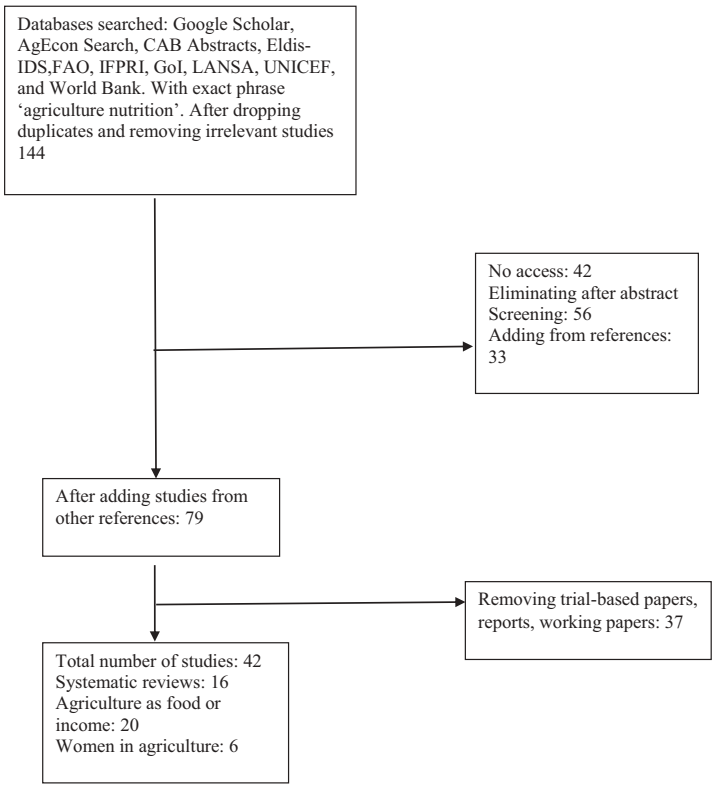

Figure A1 Literature search and study selection.