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Impact of Agricultural Interventions on Nutritional Status in South Asia: A Review

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Abstract

The prevailing scenario of persistent malnutrition in many of the agricultural economies of South Asia is the motivation for this review paper. Using a systematic search approach and review, it brings forth main findings of empirical research on the linkages between agricultural interventions and nutritional outcomes. Validity assessments of the methodologies adopted in the studies found them to be weak in counterfactual analyses for internal validity, but sounder in terms of external validity attributes. In comparison to direct nutrition interventions, agricultural interventions for increasing productivity, with irrigation as an exception, are more effective in reducing malnutrition. The studies show that female empowerment is important for diet diversification and nutrition enhancement and that appropriate location and population specific biofortification interventions can help in alleviating malnutrition especially for the marginalized and vulnerable.

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1. INTRODUCTION

Agriculture can contribute towards the attainment of nutritional goals by increasing the availability and affordability of diverse foods, increasing the access to micronutrient rich foods and empowering women within the household (Hawkes and Ruel, 2006). As increase in food availability to the poorest in itself cannot solve the problem of malnutrition, it needs to be complemented with access to nutritious food (Das et al, 2014). Many sectors such as agriculture, education, health, water and sanitation, employment etc., play an important role in determining nutritional outcome at individual, household and societal levels (Shively et al, 2012; Gulati et al, 2012; Allendorf, 2007, Bhagowalia et al, 2012, Sraboni et al, 2013). Therefore, the prevailing scenario of persistent malnutrition, especially in predominantly agricultural economies of South Asia, needs to be seen from multiple angles and views.

There are seven key pathways connecting agriculture to nutrition: (i) agriculture as a source of food, (ii) agriculture as a source of income, (iii) agricultural policy and food prices, (iv) spending of agricultural income, (v) women's socioeconomic status and say in intra-household decision making, (vi) women's ability to manage the care, feeding, and health of

young children and (vii) women's own nutritional status (Gillespie et al, 2012). As these pathways evolve with changing agricultural policies, markets and consumer demand, there is a need for proper planning of programmes and policies including governance with indicators assigned to every step (IFPRI, 2011; FAO, 2013).

Current research on agriculture for improved nutrition includes evaluations of specific agricultural interventions and analysis of different datasets (Hawkes, Turner and Waage, 2012). In South Asia, agricultural strategies focusing on increasing food production at household level, particularly with irrigation facilities, have important implications on the nutritional health of women and children (Girard et al, 2012, Domenech & Ringler, 2013). When the agricultural interventions are targeted towards increasing household income through asset transfers, agro-based micro-enterprises and skill building for livelihoods, they are able to effectively and equitably address the nutritional needs of poor and marginalised households (Hillenbrand and Wald, 2010). 'Hidden hunger' can be tackled through forward looking food based approaches such as homestead gardens, animal or fish produce, etc. When these approaches are targeted at the most vulnerable groups and are combined with complementary feeding practices, they increase the nutritional status (Haddad and Meeker, 2013; World Bank, 2007; Tontisirin et al, 2002; Ruel, 2001). The literature shows that such approaches need to promote technologies for the production of nutritionally rich food varieties on small and marginal farms, and promote women as agents of change (Burchi et al, 2011; Ruel, 2001; Haider & Bhutta, 2008). Importance of female empowerment in agriculture in contribution to household food and nutrition security is well established (Sundberg, 2014). However, studies on impact of farmers' organisations, nutritional impact of access to markets for small landholders, and impact of programmes looking at nutrition improvement indicators are relatively few (van Dorp et. al, 2011).

Although research on the nutritional benefits of livestock production is limited in South Asia, studies in other agriculture dependent economies have shown significant correlation of nutrition with livestock rearing (Leroy & Frongillo, 2007). The nutritional benefits of fisheries and aquaculture in Africa show immense contributions to diversification of livelihoods, improving food security and supplementing dietary intakes for poor households (Kawarazuka, 2010). Increase in agricultural biodiversity through use of wild plant species contributes to improved livelihoods, health and nutritional outcomes (Frison et al, 2006). The biofortification of crops is complementary to measures such as fortification and

supplementation. It has benefits of good outreach to the poor and marginalised and ease of implementation at the household level (Zhao and Sewry, 2011; Potts and Nagujja, 2007; Gibson, 2011, Arimond et al, 2011).

While there have been several studies on the interconnectedness between agricultural interventions and nutritional outcomes, an empirical investigation of the linkages has not been accorded due emphasis. The aim of this paper is to conduct a systematic review of the empirical research in the South Asian context. It seeks to understand the existing literature to suggest policy intervention guidelines for the countries in this region, in order to combat food insecurity and malnutrition through agriculture. The next section presents the methodology for selection of the studies for review. The outcome indicators are discussed in the third section. The fourth section presents the main findings, followed by conclusions in the last section.

2. METHODOLOGY

This section deals with the process for selection of the studies reported in the literature and the criteria adopted for assessing the internal and external validity. Commencing from the year 2000, we undertake an in-depth literature review of the impact of interventions in agriculture and allied sectors (horticulture, livestock, fisheries and forestry) on nutritional outcomes for adults and children.

2.1 Paper search and screening

The search for empirical studies was conducted with agricultural interventions as the central concern. A systematic literature search was carried out using several search engines and websites: Google Scholar, International Food Policy Research Institute (IFPRI), Food and Agriculture Organization (FAO), World Bank, United Nations Children's Fund (UNICEF), EconLit, AgEcon Search, Government of India (Planning Commission, Ministry of Agriculture, Ministry of Women and Child Welfare), Leveraging Agriculture for Nutrition in South Asia (LANSA), Eldis-IDS, CAB abstracts, Ingenta Connect, Asian Development Review, and Harvest Plus. A range and combinations of catch phrases, using the terms impact/effects, agriculture/agricultural, interventions/programmes/production/growth, nutrition, nutritional outcomes, South Asia, were used for the period from January 2000 to

July 2014. As food diversity, homestead production, biofortification, livestock, aquaculture/fisheries, food policies, irrigation and land reforms hold importance in the South Asian nutritional context, the search was narrowed using apt phrases combined with terms such as impact/interventions, nutrition/nutritional outcomes/linkages etc. The term “health” was not included in the search process as it was resulting in many irrelevant results. Table 1 gives the number of search results for different search phrases.

Table 1: Search results

	Search phrase(s)	Search results
	Agriculture nutrition	1170625
	Agriculture intervention nutrition	79528
	Impact agriculture nutrition	640223
	Agriculture nutrition linkages	26247
	Agriculture nutrition South Asia	72514

Note: Cumulative numbers from all search engines

As the first step of screening, the search results were scanned until the relevance of the search title diminished. In the next step, papers examining the linkages between agricultural interventions and nutrition outcomes in the overall context, without any country or region specificity were selected. Out of these, only the empirical papers with statistical or econometric analysis were retained for the review exercise. The impact of the agricultural interventions was analysed on the basis of two outcome indicators viz., anthropometric measures and the Disability Adjusted Life Years (DALYs) and two intermediate development outcome (IDO) indicators viz., changes in consumption pattern and female empowerment.

2.2 Systematic Review

For conducting a systematic review, a small set of twenty five studies was finalised. The studies were not homogenous in terms of a common outcome indicator, and made use of different metrics for the linkage under consideration. While some papers looked at nutritional outcomes by using stunting and wasting for children and adolescent, others studied the Body Mass Index (BMI) for capturing adult malnutrition, or varying levels of micronutrients such as Vitamin A, haemoglobin etc. In a few papers, changes in consumption patterns were captured by constructing dietary diversity indices or examining intakes of certain foods. Such differences in techniques and indicators made comparisons across studies difficult and

limited the scope of aggregation of results into a single metric. As also observed by other researchers (Webb & Kennedy, 2012; Masset et al, 2011), lack of appropriate investment in measuring the impact, shortcomings in study designs and lack of methodological rigour are important gaps in the literature. There is a need for timely collection of data to investigate and understand the drivers of the linkages between agriculture, food security and nutrition (Haen et al, 2011) and for improving research methods to facilitate investigations of specific mechanisms, contextual counterfactuals and appropriate metrics (Webb, 2013; Turner et al, 2013, Masset et al, 2011).

2.2.1 Assessing model validity

Model validity was assessed by scoring the empirical analysis for internal validity on the basis of counterfactual analysis. For external validity, the papers were assessed on the basis of programme theory and heterogeneity of impact as shown in Table 2.

Table 2: Scoring criteria for internal and external validity

INTERNAL VALIDITY			
Criteria used	Low	Medium	High
Counterfactual analysis	<ul style="list-style-type: none"> •Weak or no comparisons of participants to unmatched non participants •No control group 	<ul style="list-style-type: none"> • Control group may have been used •No difference in difference analysis 	<ul style="list-style-type: none"> • Control group vs. non control group carried out • Difference in difference analysis conducted
EXTERNAL VALIDITY			
Programme theory	<ul style="list-style-type: none"> •No programme theory presented •No intermediate outcomes analysed 	<ul style="list-style-type: none"> •Programme theory presented •Intermediate outcomes considered but not analysed Or •No intermediate outcomes considered 	<ul style="list-style-type: none"> •Programme theory presented •Intermediate outcomes estimated and analysed
Heterogeneity of impact	<ul style="list-style-type: none"> •No heterogeneity of impact undertaken 	<ul style="list-style-type: none"> •Heterogeneity of impact mentioned but no analysis undertaken 	<ul style="list-style-type: none"> •Heterogeneity of impact analysis undertaken

Internal validity

Most of the empirical studies under review analysed data from secondary datasets and they had large sample sizes. Others were primary baseline surveys and had much smaller sample sizes. As power test for the sample size selection was not reported in these studies, they could not be scored on the basis of their power calculations in our analysis. With the studies showing large variations in sample sizes and many not adhering to sampling procedures, a direct comparison of the results is not feasible.

These papers under review establish an association between various agricultural interventions and outcome indicators via empirical techniques. However, they are not adequate in their soundness and therefore the results cannot be interpreted as a concrete evidence of nutritional impact of agricultural interventions. As pointed out by Masset et al (2011), the lacunae in model design and empirical testing could be possible reasons for the statistical techniques not being able to bring forth substantial linkages.

External validity

External validity is established to bring forth causal relationships which can then be extrapolated to other areas, states, regions, countries, having different geographic, socio-economic characteristics (Pelletier, 2002). In other words, the heterogeneity of impact based on population characteristics including socio-economic attributes of the population and intermediate outcomes are important in understanding the underlying causal relationships. In terms of scoring for external validity, only the papers pertaining to nutritional outcomes, viz., anthropometric and DALYs, were scored for both programme theory and intermediate outcome analysis. Papers pertaining to changes in consumption patterns and female empowerment were scored only for programme theory and not for intermediate outcome analysis, as these indicators themselves are intermediate development outcomes in the pathways that connect agriculture and nutrition. These papers were also scored for heterogeneity of impact.

3. VALIDATION ANALYSIS AND DISCUSSION OF OUTCOME INDICATORS

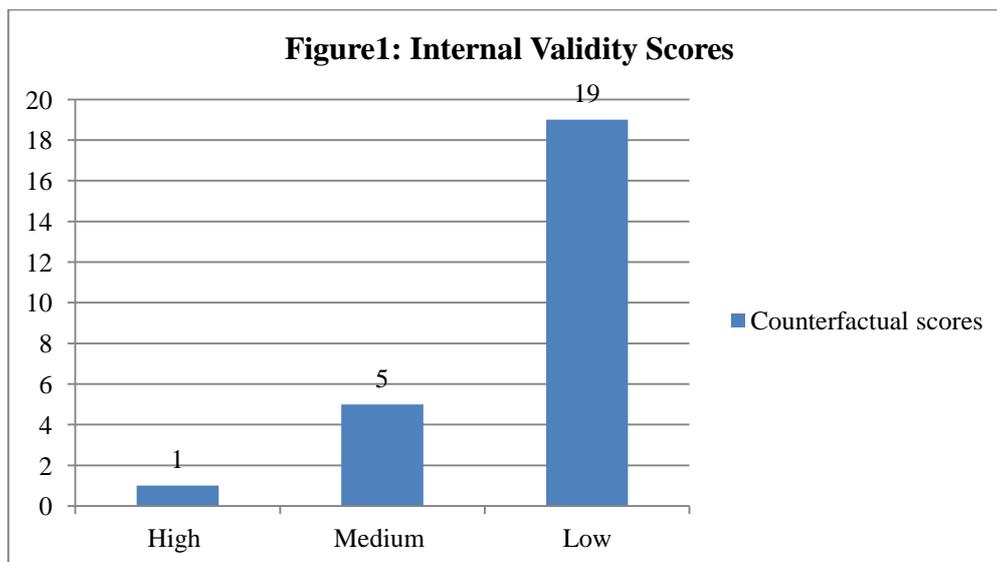
In the following subsections, we present the findings from review of the identified 25 empirical papers. First, internal and external validity of the papers is assessed. The papers are

then categorised on the basis of the outcome indicators and IDO indicators. Papers studying nutritional impact with more than one outcome indicator are discussed in more than one subsection.

3.1 Validity of the studies

3.1.1 Internal validity

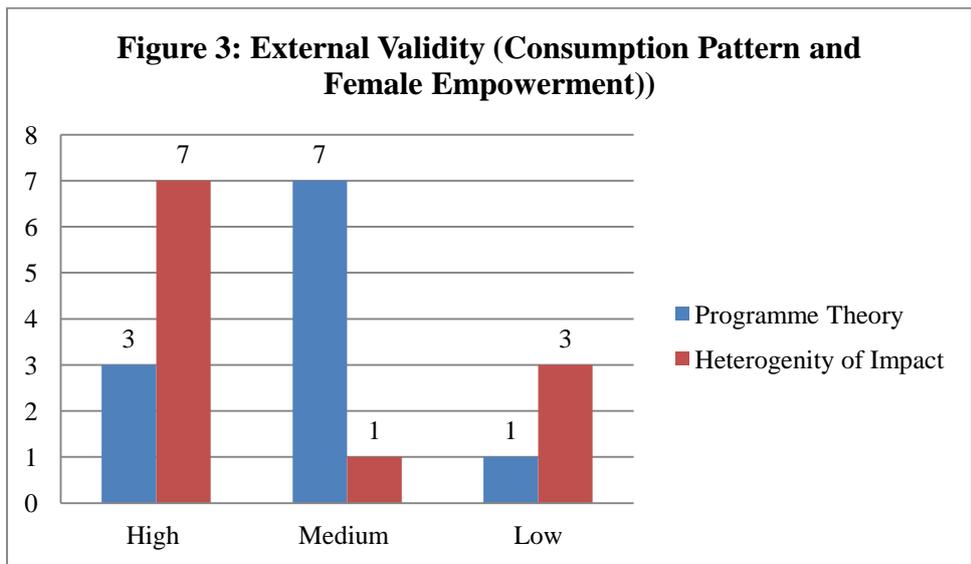
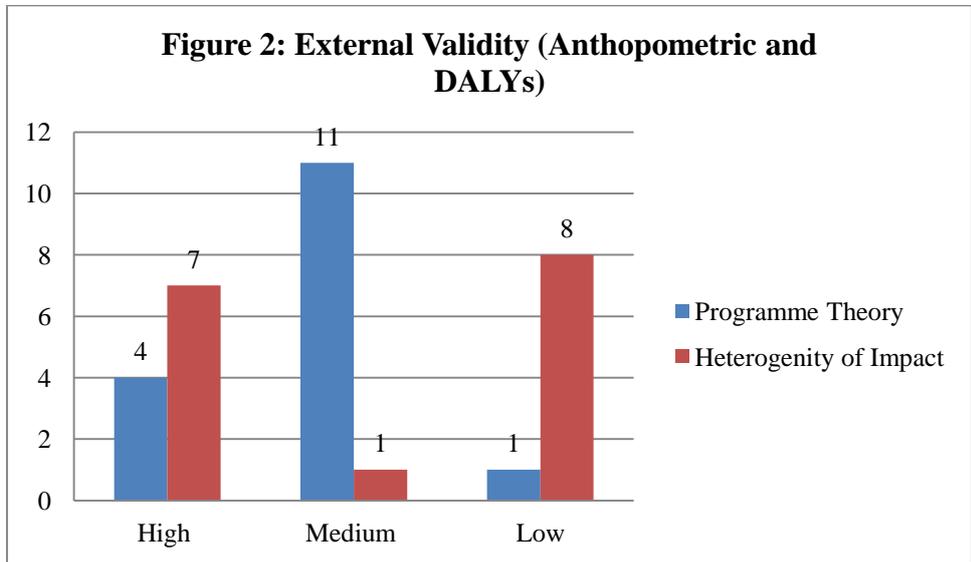
Based on our scoring criteria for counterfactual methods, only one study (Ogle et al, 2001) was scored high, while five studies were scored as medium (Ghosh, 2007; Hanji, 2006; Murshed-e-Jahan and Pemsal, 2011; Weinberger, 2005; Kiersur et al, 2010), the remaining 19 studies were scored as low. As the meeting point for counterfactuals was very thin, ex-post power calculations to assess the ability of the identified papers to bring forth nutritional impacts of agricultural interventions was not possible (Fig. 1).



3.1.2 External validity

Out of the sixteen papers examining anthropometric outcomes and DALYs, four papers (Allendorf, 2007; Headey et al, 2011; Ghosh, 2007; Hanji, 2006) scored high and eleven scored medium for programme theory. For heterogeneity of impact, the scores were high for seven papers and medium for one. Out of the eleven papers considering IDO indicators, three scored high on programme theory (Headey et al, 2011; Murshed-e-Jahan and Pemsal, 2011;

Murshed-e-Jahan et al, 2009), while seven scored medium. Heterogeneity of impact scores for IDO were high for seven papers showing that a fair amount of literature has focused on analysis of causal effects over varying population characteristics (Tables 3-6).



The empirical studies under consideration scored better for external validity vis-a-vis internal validity. A large number of them presented sound programme theory in terms of conceptual frameworks and pathways of impact. Some studies also undertook analysis of intermediate outcomes, making their external validity sound. In terms of heterogeneity of impact, many studies undertook analysis of causal effects over varying population characteristics such as socio-economic conditions and regional variations etc., lending more credibility to their

Table 3 : Details of empirical papers studying anthropometric outcomes

Paper	Outcome measure	Area of research	Internal Validity	External Validity		Results
				Counterfactual score	Programme theory	
1. Shively, et al, (2012)	Anthropometric outcomes (children <5 years). HAZ and HWZ by agro ecological zones	Nepal, Demographic and Health Survey 2001, 10,793 women, 4,397 men (age 15-59) and 5,464 children <5 yrs	Low	Medium	High	<ul style="list-style-type: none"> • Agriculture is important to child nutrition. • Agricultural intensification including fertilization, irrigation and use of improved seeds leads to lower HAZ and WHZ scores. • Satellite remote sensing variables (NDVI) have a very useful role in understanding patterns of nutrition risk and early warning of household food insecurity.
2. Gulati, et al, (2012)	Normalized malnutrition index using anthropometric outcomes (children <5 years and adults) WAZ, HAZ, WHZ, and BMI	India, NFHS - III, 2005-06	Low	Medium	High	<ul style="list-style-type: none"> • Improvements in agricultural productivity can be a powerful tool to reduce under nutrition. • Malnutrition is a multidimensional problem: access to sanitation facilities and women's literacy are strong factors affecting malnutrition.
3. Webb and Block (2012)	Anthropometric – children less than 5 years of age HAZ, WAZ, and WHZ	Panel for 29 developing countries, 1980-2007	Low	Medium	Low	<ul style="list-style-type: none"> • When there is support for agriculture, poverty reduction strongly supports reductions in child under-nutrition (stunting and wasting). • Agriculture support increases rural incomes faster and decline in under-nutrition is more pronounced in rural settings.
4. Bhagowalia et al (2012)	Anthropometric outcomes (HAZ and WHZ for children 0-5 and 8-11 years)	India, India Human Development Survey 2005,	Low	Medium	High	<ul style="list-style-type: none"> • Stunting and wasting rates are marginally higher for agricultural households vis-à-vis non-agricultural households • Children belonging to the highest income quintiles have higher HAZ vis-à-vis the poorest quintile, this effect is stronger for non-agricultural households • Income gradient for under-nutrition is weak while non-income factors such as child vaccinations and female secondary education

						have strong significant effects on reducing malnutrition
5. Headey (2011)	Anthropometric outcomes (children - stunting) WAZ, HAZ and BMI (<i>and diet diversification</i>)	cross-country dataset	Low	Medium	Low	<ul style="list-style-type: none"> Relationship between agricultural growth and malnutrition is heterogeneous. Agricultural growth has insignificant effect on malnutrition in Indian states but a highly negative effect for other developing countries (specifically for stunting).
6. Headey, et al (2011)	Anthropometric (BMI for women and HAZ and WAZ)	India, DHS 2009, Indiatat, RBI (2010, FAO (2009), NFHS - II	Low	High	High	<ul style="list-style-type: none"> Ceteris paribus, BMIs for female agricultural workers are lower than for female non-agricultural workers with livelihood characteristics having an important negative bearing on adult BMIs. Female employment in agriculture has significant but small positive effect on HAZ scores for children Evidence doesn't corroborate the hypothesis that child care practices are poorer in agricultural households or by agriculturally employed mothers
7. Parasuraman et al (2011)	Anthropometric for children HAZ, WAZ (<5 years) and BMI for adolescent girls and women	Vidarbha region, Maharashtra, primary survey, 6990 households in six high distress districts	Low	Medium	High	<ul style="list-style-type: none"> Cultivation of food crops contributes towards improvements in child nutrition. Ceteris paribus, higher the expenditure on food items, lower the proportion of undernourished children, adolescents and ever married women. Visible changes in agricultural cropping patterns cannot be taken as indicators of better nutritional status of households.
8. Allendorf (2007)	Anthropometric – children (severely underweight)	Nepal, Demographic and Health Survey 2001, 8,633 households, agricultural workers	Low	High	High	<ul style="list-style-type: none"> Women's empowerment is important for the agriculture nutrition link. Women's land rights empower women, benefit family welfare and child health and nutritional status.
9. Ghosh (2007)	Anthropometric – women's height and HAZ	NFHS - II 1998-99	Medium	High	Low	<ul style="list-style-type: none"> Land reforms, especially reforms targeting the abolition of intermediaries and imposition of land ceilings lead to significant

	for children	sample size of 67,600 women, 16 major states				improvements in women's long term nutritional status (or height) and also have a bearing on child nutritional attainments.
10. Hanji (2006)	Anthropometric – adolescent girls and adult BMIs	India, 192 households from 8 villages in 3 talukas of Belgaum district, Karnataka,	Medium	High	Low	<ul style="list-style-type: none"> • Irrigation facilities leads to a shift in cropping patterns in favour of high value crops and nutritional cereal crops got replaced with commercial crops reducing the availability of nutrients to population.
11. Hallman, et al (2003)	Anthropometric- height for age- HAZ, adult female BMIs and calorie intakes	Bangladesh, 955 Rural households	Low	Medium	High	<ul style="list-style-type: none"> • Vegetable technology targeted to women in households with small landholdings has positive impacts on female empowerment and child nutritional status. • Group fishpond technology is highly beneficial for poor households leading to higher off farm incomes and improved nutritional status. • Regressions for nutritional status for adults and children show no effects of fishpond technologies in the pooled sample but the access towards technological advancements has strong significant effects on pre-schooler HAZ.
12. Adhiguru, et al (2003)	RDA for women and children using 24 hour recall method	India, Primary survey data – 180 households from Dharmapuri district, TamilNadu,	Low	Medium	Medium	<ul style="list-style-type: none"> • Vegetable cultivation has immense potential in supplying vitamin rich foods and micronutrients to weaker sections.

Table 4 : Details of empirical papers studying DALYs

Paper by	Outcome measure	Area of research	Statistical analysis			Results
			Counterfactual	Programme theory	Heterogeneity of impact	
1. Stein et al (2006)	Disability Adjusted life years (DALYs)	Iron biofortification in India	Low	Medium	Low	<ul style="list-style-type: none"> • Under pessimistic assumptions iron biofortification of rice and wheat could save 0.8 million DALYs annually. • Under optimistic assumptions the DALYs saved could be 2.3 million • Sizeable health benefits can be reaped when iron content of rice and wheat is enhanced and its coverage increased. • Iron biofortification of rice and wheat is a very cost effective agricultural intervention
2. Meenakshi et al (2007)	Disability Adjusted life years (DALYs)	12 countries in Asia, Africa & Latin America	Low	Medium	Low	<ul style="list-style-type: none"> • Biofortification can have positive effects in terms of reducing micronutrient deficiencies and is a cost-effective intervention. • It is also more cost effective than supplementation or fortification • In South Asian countries biofortification is more effective since these countries are predominantly rural and have effective seed distribution systems in place.
3. Asare-Marfo et al (2013)	Biofortification Prioritization Index (BPI)	7 staple crops across 127 countries in Asia, Africa, Latin America and the Caribbean (LAC)	Low	Medium	Low	<ul style="list-style-type: none"> • Biofortification Priority Indices (BPIs) <p>Comparisons of country rankings of unweighted BPIs:</p> <ul style="list-style-type: none"> • In African countries, biofortification of cassava, sweet potato and maize with vitamin A and beans and pearl millet with iron has the largest effect. • For Asian countries zinc rich cereals (rice and wheat) have the largest effect • LAC countries call for a food basket approach wherein biofortification of all key crops is the essential requirement.

Table 5 : Details of empirical papers studying changes in consumption pattern

Paper by	Outcome measure	Area of research	Internal Validity	External Validity		Results
				Programme theory	Heterogeneity of impact	
			Counterfactual score			
1. Yu (2012)	Consumption pattern change	Bangladesh, IFPRI Chronic Poverty and Longer Term Impact Study, 1,237 households, 50 villages in 2005/06	Low	Medium	High	<ul style="list-style-type: none"> • Nutrition is governed by household size, characteristics of household head, asset ownership, consumption of own produce • Female headed households face difficulties in meeting their nutrition needs. • Increases in rice yields through agricultural research and development an effective way of improving nutrition. • Specific policies needed to address the food and nutrition needs of vulnerable.
2. Bhagowalia et al (2012)	Diet diversification	India, using the India Human Development Survey 2005	Low	High	High	<ul style="list-style-type: none"> • Agricultural income and production conditions have significant influence on household dietary diversity • Agricultural programs aimed at irrigation, livestock ownership and crop diversification significantly enhance dietary diversity.
3. Gaiha et al (2012)	Diet diversification	India, 1993-2009, NSS 50th, 61st and 66th Rounds unit record data over 3 NSS years	Low	Medium	High	<ul style="list-style-type: none"> • 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 life-style play important roles in diet diversification and nutritional outcomes.
4. Headey (2011)	Diet Diversification	cross-country dataset	Low	Medium	High	<ul style="list-style-type: none"> • Agricultural growth has a strong effect on daily energy supply (calorie consumption) but a weak effect on dietary diversity.
5. Murshed-e-Jahana and Pemsil (2011)	Consumption pattern change	The impact of long-term IAA training provided to small-scale farmers in Bangladesh is assessed	Medium	High	High	<ul style="list-style-type: none"> • Integrated Agriculture Aquaculture (IAA) has a positive impact on fish consumption. • The significant positive effect on fish consumption could perhaps result from either a higher level of fish farming inputs purchased using the grant money, or a general higher overall interest in fish farming or the project activities.
6. Kiresur et al (2010)	Consumption pattern change	Balgalkot district, Karnataka, 120 farm	Medium	Low	Low	<ul style="list-style-type: none"> • Nutritional security of respondents is significantly influenced by agricultural income per consumer unit per annum, literates/

		households, 2005-06				household, total consumer units per household. <ul style="list-style-type: none"> Enhancements in agricultural productivity through transfer of productive assets to poor households and increased access to agricultural credit by rural households would contribute towards enhancing nutritional status
7. Murshed-e-Jahan et al (2009)	Consumption pattern change	Bangladesh, 2002-03 and 2003-04, 225 farmers	Low	High	Medium	<ul style="list-style-type: none"> Aquaculture interventions have positive effect on consumption and household nutrition Aquaculture interventions can bring about reductions in poverty and improvements in nutritional status of resource poor households Women's effective participation and access to nutritional benefits can be facilitated through gender sensitive approaches in aquaculture
8. Weinberger (2005)	Consumption pattern change	Pakistan, primary survey around Lahore area, industries employing females on a piece rate basis, June 2001-February 2002	Medium	Medium	Low	<ul style="list-style-type: none"> Increase in mung bean productivity has substantial impact on nutrition, iron intake, and human productivity
9. Roos et al (2003)	Diet diversification	Bangladesh, 84 poor rural households in Kishoreganj district (June 1997- January 1998)	Low	Medium	Low	<ul style="list-style-type: none"> No difference in fish intake in the fish producing and non-fish producing control households. Fish consumption contributed to <10% of the required protein intakes Production of Vitamin A dense SIS (small indigenous fish species) can make important nutritional contributions
10. Ogle et al (2001)	Diet diversification	Vietnam, two villages Rural 217 women	High	Low	Low	<ul style="list-style-type: none"> Wild vegetables make a significant contribution to overall micronutrient intakes viz., carotene, vitamin C and calcium. Analysis of food variety helps in bringing forth the benefits of wild vegetables

Table 6 : Details of empirical paper studying female empowerment

	Paper by	Outcome measure	Area of research	Internal validity	External validity		Results
					Counterfactual score	Programme theory	
	1. Sraboni et al, (2013)	Per adult equivalent calorie availability and dietary diversity	Bangladesh, BIHS data, 3944 households	Low	Medium	High	<ul style="list-style-type: none"> • Positive associations between household calorie availability and dietary intakes and women's empowerment score, number of groups in which women participate, women's control over assets. • Leadership in community and control over resources are areas where women have lower empowerment.
	2. Malapit et al, (2013)	Anthropometric – mother's BMI and children <5 years HAZ, WAZ, HWZ,	Household survey data conducted in 4,080 households in Nepal across 16 districts	Low	Medium	High	<ul style="list-style-type: none"> • Production diversity at household level determines maternal nutrition outcomes, mother's dietary diversity and BMI; for children this effect seems to be facilitated through the age of the child. • Autonomy in agricultural production decisions as a measure of female empowerment is a key determinant of almost all mother and child outcomes with the exception of maternal BMI.

findings on the external validity front. Thus, the studies on linkages between agricultural interventions and nutritional outcomes have given due emphasis to the underlying programme theory, analysing intermediate outcomes and heterogeneity of impact.

3.2 Outcome indicators

3.2.1 Anthropometric measures

A majority of the studies have considered anthropometric measures as the outcome indicators, to study the linkages between agricultural interventions and nutrition outcomes. Out of the twelve such studies, seven were based on India (3 using primary datasets and 4 using secondary datasets), two on Nepal, one on Bangladesh and two on cross-country datasets including countries from outside the South Asian region (Table 3).

Most of the studies used the prevalence rates of malnutrition in terms of anthropometric indicators, including BMIs for adults and three indicators for child malnutrition (WAZ, HAZ and WHZ¹). The authors except Ghosh (2007) have not reported observed differences and none including Ghosh (2007) carried out power tests. Only four of the studies using anthropometric outcomes as impact indicators reported the overall significance of the model (F or chi-squared statistics) and the test statistic was significant (significance level: 1% – 10%). These results indicate existence of a relationship between agricultural interventions and anthropometric outcomes.

The studies indicate that the household occupation affects status of nutrition. Bhagowalia et al (2012), using the IHDS² 2005 dataset for India, show that agricultural households have marginally higher stunting (HAZ) and wasting (WHZ), as compared to non-agricultural households. The income-nutrition relationship disaggregated by agricultural and non-agricultural households reveals that HAZ scores for children belonging to higher income quintiles are higher than those belonging to the lowest income quintiles and this effect is more pronounced in non-agricultural households. Non-income factors such as child vaccination, female education, etc., have higher impact on improving nutrition outcome than

¹WAZ = weight for age, HAZ= height for age (Stunting), WHZ = weight for height (Wasting), the three anthropometric measures used as indicators of child malnutrition

² India Human Development Survey 2005

the income. Mother's BMI has a statistically significant effect on HAZ scores and WAZ scores of children under the age of three. There is no conclusive evidence to indicate that women's employment in agriculture is a possible reason for neglect of care of children. In fact women employed as other unskilled labour are more likely to leave their children in the care of older children or other family members (Headey et al, 2011).

Rapid economic and agricultural growth has contributed significantly in reducing stunting rates in many developing countries, but it is not a sufficient condition for reducing the rates of malnutrition. In India, high agricultural growth rates in the states such as Gujarat, Rajasthan and Bihar have not been accompanied by decrease in under-nutrition. Although agricultural growth was found to have strong effects on increasing energy supply particularly at low levels of daily energy, non-agricultural growth was found to have large and significant effects on dietary diversity (Headey, 2011).

The performance of the agricultural sector can also be captured by the levels of production. The increase in agricultural food production especially of grains and pulses shows more conclusive evidence on improving the nutrition outcome, as compared to overall agricultural growth rates (Parasuraman and Rajeratnam, 2011). Increased food supplies facilitate increased calorie intakes and improved diet diversity. A negative and significant relationship between the improvements in agricultural productivity and under-nutrition in India has been reported (Gulati et al, 2012; Shively et al, 2012). Increased food production was found to be associated with reduction in underweight and low BMI prevalence. However, it is not very clear as to whether the pathway taken is direct food consumption by infants/mothers or increased income (Headey, 2011).

Parasuraman and Rajeratnam (2011) have also shown that higher the per capita expenditures on food by households, lower are the rates of undernourishment amongst children (as indicated by stunting), adolescents (as indicated by energy deficiency) and ever-married women (as indicated by energy deficiency). The size of land holding did not have a significant impact on nutritional status. The study also reported that changes in cropping patterns leading to crop diversity towards commercial crops may not lead to changes in the nutritional status of households.

The study by Shively et al (2012) has shown a negative correlation between agricultural intensification and child nutrition outcome for districts in Nepal, using satellite remote sensed Normalized Difference Vegetation Index. Districts with higher rates of agricultural intensification (as measured in terms of average rates of irrigation, fertilization and use of improved seeds) reported high stunting rate which could be due to preference towards production of cash crops vis-à-vis food crops, larger cash expenses on inputs and high labour demands on households, which work against the nutrition. Hanji (2006) studied the impact of irrigation on cropping pattern change in the Malprabha, Ghatprabha region of Karnataka, India. The study showed a shift in cropping pattern away from nutri-cereals such as ragi, pulses, bajra, sorghum etc., towards cash crops such as sugarcane, tobacco, cotton etc. due to improved irrigation facilities, reducing the availability of nutrients to people. It led to adolescent girls in these areas being significantly shorter and lighter in weight compared to the standards as set by the National Center for Health Statistics.

Agricultural interventions intended to promote women's land rights and autonomy in agricultural production through land redistribution may have implications for female and child nutrition status. Empowerment of women, coupled with female friendly agricultural technologies, results in increased intra-household bargaining power and larger say in household resource allocation decisions. This eventually may lead to provision of nutritious food for them and their children. There is a positive effect of land reforms on the long-term nutritional status of women measured through height. For children whose mothers benefitted from land reform in India, there is an inter-generational benefit in terms of improved height for age (Ghosh, 2007). In Nepal, women are engaged in farming in high proportions but with limited land rights. A multivariate analysis showed that if a mother owns land, probability that her child is severely underweight reduces by half (Allendorf, 2006). These studies lend a clear validity to the female empowerment pathway.

Empowering women through interventions of improved vegetable technology targeted especially for them in small farm holding households in Bangladesh, had positive implications for child nutrition. School age children, adolescents and adults in vegetable technology adopted households had higher intakes of calories from green leafy vegetables as compared to likely-adopter households (Hallman et al, 2003). School-age children and adolescents in adopted households were slightly taller than their non-adopted counterparts. In

one area (Saturia), pre-schooler HAZ scores were positively affected by access to technology, more so for boys. In the other area (Jessore), it had a positive effect on female BMIs.

Adhiguru and Ramasamy (2003) studied linkage between agricultural production systems for rice, vegetable and sugarcane and malnutrition for the rural poor in Dharmapuri district, Tamilnadu, India. They considered the Recommended Daily Allowance (RDA) as the outcome indicators to measure nutritional deprivation. Shortages in the RDA were higher for fruits and green leafy vegetables for both males and females and were the lowest for pulses and cereals. Vegetable production systems had lower RDA deficits in the consumption of vitamin A, iron and vitamin C for adults and for children vis-à-vis non-vegetable production systems. An important finding of the study is that agricultural interventions are found to be more sustainable than the direct nutrition enhancing once in tackling malnutrition for the rural poor.

The paper by Webb and Block (2012) looks at the trends in poverty and nutrition, using anthropometric indicators, which take place during economic transformation and the consequent impacts on agriculture. It is a cross-country study of datasets from 29 developing countries, many from outside the South Asian region. Its findings support the hypothesis that structural transformation of economy leads to improvements in agriculture and facilitates improvement in nutrition especially in rural areas. Statistically significant results for the effect of economic transformation (as measured by a declining share of rural population) in reducing stunting for countries supporting agriculture is shown. Such an effect is explained by rising agricultural incomes, one of the benefits of structural transformation which favour agriculture, thereby reducing poverty and enhancing nutrition.

3.2.2 Disability Adjusted Life Years (DALYs)

The Disability Adjusted Life Years method is an attempt that facilitates the possibility of measuring the burden of disease. It is an index enabling the measurement of morbidity and mortality related to a disease (Stein et al, 2005). Here we present the main findings from three papers which have undertaken estimations of DALYs and brought forth usefulness of

biofortification in combating micronutrient deficiencies and facilitating health benefits (Table 4).

An ex-ante impact assessment of iron biofortification in India using the DALYs framework finds that the annual burden of disease due to iron deficiencies, in aggregate terms, amounts to 4.0 million DALYs lost (Stein et al, 2006). It is further estimated that the biofortification of rice and wheat can save 0.8 million DALYs annually, reducing the prevailing disease burden by 19% under pessimistic assumptions. Under an optimistic assumption, DALYs saved would be 2.3 million reducing the disease burden by 58%. Iron biofortification is reported to be more cost effective than fortification and supplementation. With a clear possibility of large health benefits of biofortification of staples, it needs to be given due cognizance in policy formulations as an intermediate measure to reduce iron deficiencies in India.

A cross-country estimation of the DALYs for 12 countries in Asia, Africa and Latin America (Meenakshi et al, 2007) also supports the cost effectiveness of biofortification in combating micronutrient deficiencies with the results differing by country, crop and micronutrients. Biofortification has a clear cost advantage over supplementation and fortification, more specifically in South Asia, which could be because of the predominantly rural population and the effective working of seed distribution systems in these countries. Country and crop specific biofortification prioritization indices (BPIs) for 7 staple crops for 127 countries in Asia, Africa, Latin America and the Caribbean (LAC) also indicate that the biofortification of staple crops does hold the potential to reduce micronutrient deficiencies (Asare-Marfo et al, 2013). Comparisons of the estimated unweighted BPIs reveal that the biofortification of rice and wheat with zinc would be most beneficial for Asian countries, and a food basket approach where all key food crops are biofortified would be more advisable for the LAC countries.

3.3 Intermediate development outcome indicators

3.3.1 Changes in consumption patterns

This section deals with the empirical findings from nine papers (listed in Table 5) which have examined the effects of agricultural interventions on consumption pattern changes. Although

patterns of food consumption are indicators of dietary quality and the intakes of macro and micro nutrients, they may not directly reflect dietary intakes in the case of children. Changes in the diets over the period of 1993 – 2009 show a shift towards fruits, vegetables, oils and livestock products in India (Bhagowalia et al, 2012). The effects of consumption pattern change on nutrition outcomes can be attributed more to changes in consumer tastes, dietary diversification, reduced calorie requirements and price fluctuations rather than to decline in calorie consumption. Household and regional level regression estimates show a weak relationship between calorie consumption and nutrition outcomes. However, there was a strong cross-sectional effect of wealth on the dietary diversification of children, thereby impacting their nutrition status (Headey et al, 2011). The adoption of Integrated Agriculture Aquaculture (IAA) in countries like Bangladesh was found to lead to higher consumption of food and particularly of fish, due to higher farm productivity as well as farm incomes (Murshed-e-Jahan & Pemsil, 2011). Improvement in the consumption were also significantly impacted by household income, farm size and family size.

The nutritional status of agricultural households is largely dependent on food supplies from their own farm which in turn depend upon crop productivity. Estimates of the impact of modern varieties of pulses (mung bean) on nutrition via increased productivity were found to be substantial in the case of Pakistan (Weinberger, 2005). This effect can be attributed to agricultural research targeted towards improving productivity of the pulses. In Bangladesh, per capita nutrition intakes in terms of energy, protein, fat, calcium, iron, riboflavin and beta-carotene were found to be affected by the household size, age of household head, assets and consumption of own production (Yu, 2012). Increase in rice production at household level had a positive impact on intake of nutritious food through consumption of own produce and increase in household incomes. It has been proposed that nutrition intakes can be improved by increasing rice yields by providing timely access to inputs, improvement of rural infrastructure and adherence to other timelines.

Change in consumption pattern in India, as measured using a Food Diversity Index (FDI), had a slowing down of the dietary transition during 2004 – 2009 and no concrete links between food diversity and improved nutrition intakes were found (Gaiha et al, 2012). There were mixed effects of dietary diversity on nutritional outcomes i.e., dietary shifts led to lower calorie intakes but increased intakes of fats and proteins. Lowering of calorie intakes are not desirable in case of poor households as it makes them more vulnerable to acute malnutrition.

At higher income levels, decreased calorie intakes coupled with increased intakes of proteins and fats could have large implications in terms of the risk of some non-communicable diseases. Some of the plausible factors underlying these dietary shifts have been identified as urbanization, demographic changes, lifestyle and eating habit changes.

Kiresur et al (2010) studied the inter-linkages between agricultural productivity, rural poverty and nutritional security (measured as the ratio of calorie intake to the RDA for energy in kcal/day/CU as recommended by the ICMR) by using primary data collected across 120 farm households in Bagalkot district of Karnataka, India. Nutritional security was found to vary across income categories with the highest security for the richest category. Poverty alleviation programmes aimed at transferring productive assets to poor farm households led to increases in agricultural productivity and consequently to nutrition security.

A cross-country study showed agricultural growth to have a strong and significant impact on calorie consumption with a weak effect on dietary diversity (Headey, 2011). Agricultural programmes aimed at irrigation, crop diversity and livestock significantly affected household dietary diversity and nutrition outcomes of small and marginal farmers in India (Bhagowalia et al, 2012).

Ogle et al (2001) showed that the intake of some of the wild and traditionally grown vegetables led to diet diversification, facilitating higher micronutrient intakes and bringing about better nutritional outcomes. Using primary data from 84 poor households in Kishoreganj district in Bangladesh, Roos et al (2003) demonstrated the impact of farming of small fish species such as mola on diet diversification in terms of improving intake of vitamin A, calcium and iron and on household income. The clear income enhancing and increased micronutrient intake benefits of fish cultivation or aquaculture, for women and children especially in the poor and small landholding households in Bangladesh, point towards the usefulness of diet diversification effects of such interventions.

3.3.2 Female empowerment

Empowerment of women, as discussed in earlier subsections, is an undeniably important determinant of female and child nutritional outcomes. It also constitutes an important pathway from agriculture to nutrition in terms of employment, women's socio-economic

status, their own nutritional health and child rearing and caring practices (Gillespie et al, 2012). Female empowerment could be a by-product of agricultural interventions such as land reforms etc. In some studies, female empowerment has been captured using Women's Empowerment in Agriculture Index (WEAI) and its association with anthropometric outcomes, calorie availability and dietary diversity. The findings from two papers are presented here to highlight the impact of female empowerment in agriculture on nutritional outcomes (Table 6).

In Bangladesh, WEAI (a combination of 5 domains of empowerment sub-index and a gender parity index) showed a clear and positive association with per adult calorie availability and household dietary diversity (Sraboni et al, 2013). It implies that higher female empowerment in decision making within the household leads to improved nutritional outcomes for the household. Determinants of empowerment indicated that women's group membership and narrowing gender gaps had positive and significant effect on household food-security outcomes.

In Nepal, WEAI was used to assess the importance and impact of female empowerment in agriculture on anthropometric outcomes for children and adults (Malapit et al, 2013). Female empowerment had differing effects on dietary diversity and nutritional outcomes for women and children depending on the dimension of empowerment. Women's autonomy in agricultural production decisions was one of the main factors with enhancing effects on maternal and child nutritional outcomes, except for maternal BMIs. The number of hours for which women were engaged in paid and unpaid work had a positive impact on child diet diversity as well as children's WHZ and HAZ scores. It was further shown that that women's control over income improves child WAZ and maternal BMIs. The association with Women's Group had a positive impact on maternal BMIs.

4. MAIN FINDINGS FROM THE REVIEW

Based on assessments of the empirical papers studying the impact of agricultural interventions on nutrition outcomes, we find one study with high and five studies with medium counterfactual scoring and whose results can be taken as leading to useful conclusions about how agricultural interventions of various types impact nutritional and intermediate development outcomes in South Asia (Table 7).

Table 7 : Paper details for internal validity

Paper	Intervention/outcome indicator	Counterfactual score
Ogle et al (2001)	Consumption pattern change -Diet Diversity- <i>Edible wild/local vegetables</i>	High
Ghosh (2007)	Anthropometric - <i>Land reforms</i>	Medium
Hanji (2006)	Anthropometric - <i>Irrigation –</i>	Medium
Kiresur (2010)	RDA calorie intakes - <i>Poverty- alleviation through agricultural productivity increases</i>	Medium
Murshed-e-Jahan et al (2011)	Consumption pattern change- <i>Aquaculture</i>	Medium
Weinberger (2006)	Consumption pattern change- <i>Mung bean research</i>	Medium

Although we find heterogeneity in agricultural interventions and the nutritional impact outcomes, it is clear that agriculture holds the potential to improve nutritional outcomes. The agricultural interventions that clearly enhance nutrition outcomes for women and children are those which directly promote female empowerment and facilitate productivity enhancement. Irrigation on the other hand leads to a shift away from nutritious foods towards commercial crops, bringing forth shortfalls in nutrition outcomes.

Agricultural programmes promoting cultivation of local edible wild plant species, small indigenous fish species and production of pulses are found to facilitate diet diversity which then could be expected to bring about improved nutritional outcomes. Improved productivity of pulses and vegetables via agricultural research also holds the potential to enhance nutritional outcomes through increased micronutrient intakes. In the South Asian context, these agricultural interventions need to be supplemented by nutrition education and addressing of the socio-economic needs of small landholders to enable them to act as vehicles for nutritional enhancements of children, adolescents and women.

5. CONCLUSIONS

Our systematic search approach and review of the literature has shown malnutrition to be a complex issue that calls for interlinking of a range of conditional and complementary factors.

The studies were found to be generally weak in counterfactual analyses for internal validity, but were sounder in terms of external validity assessments.

In the South Asian region, effectiveness of the agricultural interventions in increasing the food supplies and consequent energy intakes is clearly seen. The programmes that promote agricultural productivity are found to significantly lead to reductions in malnutrition rates for adults and children vis-à-vis direct nutrition enhancing interventions. Irrigation is found to be an exception to this association and an important determining factor for nutritional outcomes. It enhances agricultural income through shifts in cropping patterns towards commercial crops and therefore, it impacts the food consumption basket adversely leading to poor nutritional outcomes.

Gender roles have important underlying interconnections in the agriculture to nutrition pathways when it comes to agricultural productivity, incomes and nutritional outcomes. In the South Asian context specifically, the female empowerment pathway highlights the nutrition enhancing and diet diversification possibilities of female friendly agricultural technologies such as improved vegetable technology and women's land rights which promote women's autonomy in agricultural production and household decision making. These in turn have a positive effect on female and child nutritional outcomes. An insightful finding is that different domains of female empowerment have differing impacts on maternal and child nutritional outcomes. It indicates a need for more in-depth studies on the role of the female empowerment in the agriculture-nutrition nexus.

Biofortification is seen to have the potential to reduce micronutrient deficiencies and bring about health benefits. Appropriate location and population specific biofortification interventions could contribute effectively towards alleviating malnutrition especially for the marginalised and vulnerable. As the reviewed studies were restricted to specific crops, further research is required for capturing the effects of multiple micronutrient enhancing biofortification techniques.

While there do exist pathways from agriculture to nutrition in the South Asian region, the evidence linking the agricultural interventions (technological and policy) and their impact on the nutritional status of women and children is still very scanty. There is need for well-designed studies with sound methodologies, integrated datasets and rigorous analytical

techniques, which can facilitate substantial inferences on the linkages between agriculture, intermediate outcomes and nutrition measures.

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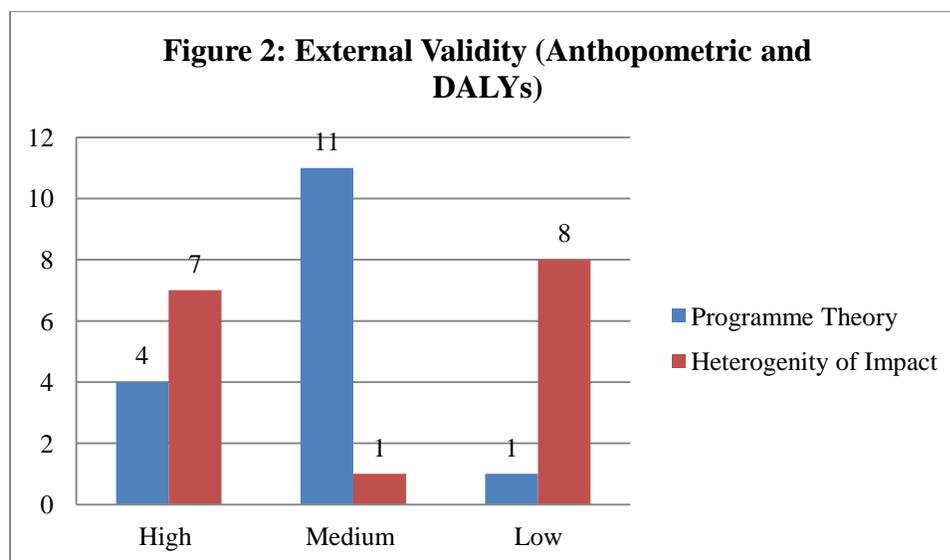
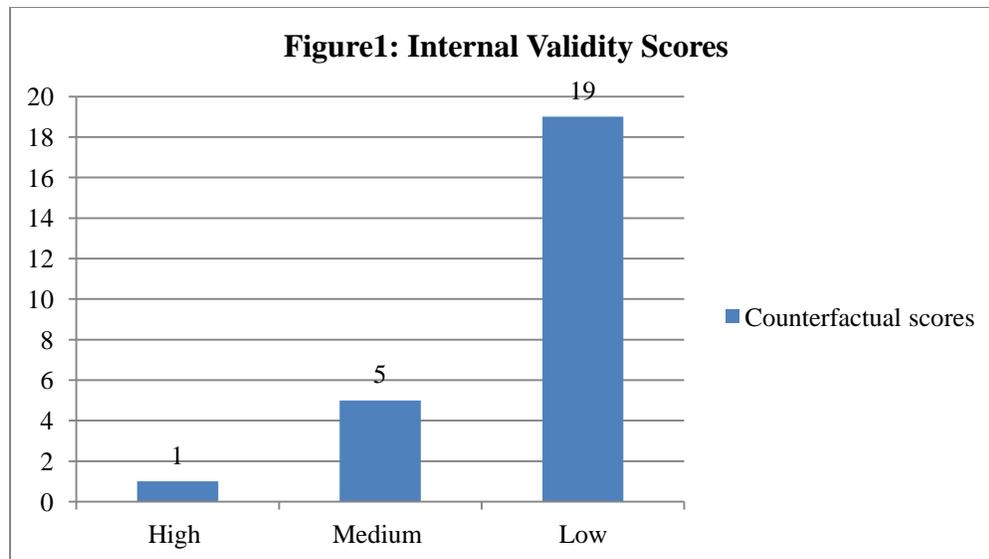


Figure 3: External Validity (Consumption Pattern and Female Empowerment))

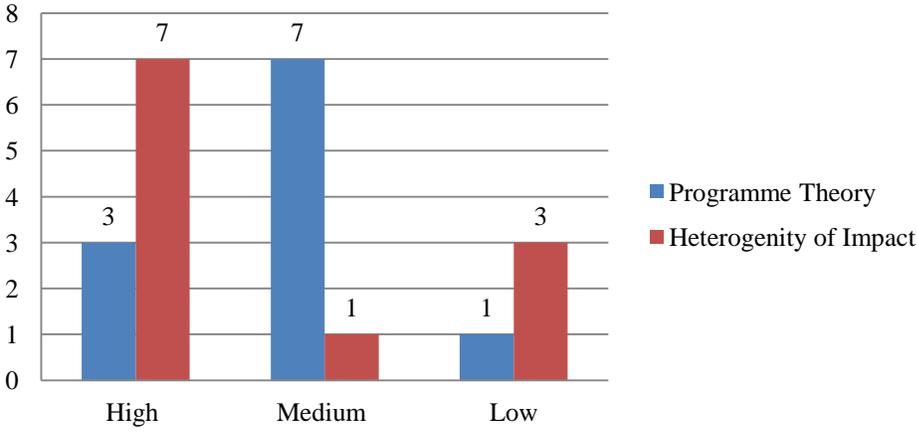


Table 1: Search results

Search phrase(s)	Search results
Agriculture nutrition	1170625
Agriculture intervention nutrition	79528
Impact agriculture nutrition	640223
Agriculture nutrition linkages	26247
Agriculture nutrition South Asia	72514

Note: Cumulative numbers from all search engines

Table 2: Scoring criteria for internal and external validity

INTERNAL VALIDITY			
Criteria used	Low	Medium	High
Counterfactual analysis	<ul style="list-style-type: none"> •Weak or no comparisons of participants to unmatched non participants •No control group 	<ul style="list-style-type: none"> • Control group may have been used • No difference in difference analysis 	<ul style="list-style-type: none"> • Control group vs. non control group carried out • Difference in difference analysis conducted
EXTERNAL VALIDITY			
Programme theory	<ul style="list-style-type: none"> •No programme theory presented •No intermediate outcomes analysed 	<ul style="list-style-type: none"> •Programme theory presented •Intermediate outcomes considered but not analysed Or •No intermediate outcomes considered 	<ul style="list-style-type: none"> •Programme theory presented •Intermediate outcomes estimated and analysed
Heterogeneity of impact	<ul style="list-style-type: none"> •No heterogeneity of impact undertaken 	<ul style="list-style-type: none"> •Heterogeneity of impact mentioned but no analysis undertaken 	<ul style="list-style-type: none"> •Heterogeneity of impact analysis undertaken

Table 3 : Details of empirical papers studying anthropometric outcomes

Paper	Outcome measure	Area of research	Internal Validity	External Validity		Results
				Counterfactual score	Programme theory	
1. Shively, et al, (2012)	Anthropometric outcomes (children <5 years). HAZ and HWZ by agro ecological zones	Nepal, Demographic and Health Survey 2001, 10,793 women, 4,397 men (age 15-59) and 5,464 children <5 yrs	Low	Medium	High	<ul style="list-style-type: none"> • Agriculture is important to child nutrition. • Agricultural intensification including fertilization, irrigation and use of improved seeds leads to lower HAZ and WHZ scores. • Satellite remote sensing variables (NDVI) have a very useful role in understanding patterns of nutrition risk and early warning of household food insecurity.
2. Gulati, et al, (2012)	Normalized malnutrition index using anthropometric outcomes (children <5 years and adults) WAZ, HAZ, WHZ, and BMI	India, NFHS - III, 2005-06	Low	Medium	High	<ul style="list-style-type: none"> • Improvements in agricultural productivity can be a powerful tool to reduce under nutrition. • Malnutrition is a multidimensional problem: access to sanitation facilities and women's literacy are strong factors affecting malnutrition.
3. Webb and Block (2012)	Anthropometric – children less than 5 years of age HAZ, WAZ, and WHZ	Panel for 29 developing countries, 1980-2007	Low	Medium	Low	<ul style="list-style-type: none"> • When there is support for agriculture, poverty reduction strongly supports reductions in child under-nutrition (stunting and wasting). • Agriculture support increases rural incomes faster and decline in under-nutrition is more pronounced in rural settings.
4. Bhagowalia et al (2012)	Anthropometric outcomes (HAZ and WHZ for children 0-5 and 8-11 years)	India, India Human Development Survey 2005,	Low	Medium	High	<ul style="list-style-type: none"> • Stunting and wasting rates are marginally higher for agricultural households vis-à-vis non-agricultural households • Children belonging to the highest income quintiles have higher HAZ vis-à-vis the poorest quintile, this effect is stronger for non-agricultural households • Income gradient for under-nutrition is weak while non-income factors such as child vaccinations and female secondary education

						have strong significant effects on reducing malnutrition
5. Headey (2011)	Anthropometric outcomes (children - stunting) WAZ, HAZ and BMI (<i>and diet diversification</i>)	cross-country dataset	Low	Medium	Low	<ul style="list-style-type: none"> Relationship between agricultural growth and malnutrition is heterogeneous. Agricultural growth has insignificant effect on malnutrition in Indian states but a highly negative effect for other developing countries (specifically for stunting).
6. Headey, et al (2011)	Anthropometric (BMI for women and HAZ and WAZ)	India, DHS 2009, Indiatat, RBI (2010, FAO (2009), NFHS - II	Low	High	High	<ul style="list-style-type: none"> Ceteris paribus, BMIs for female agricultural workers are lower than for female non-agricultural workers with livelihood characteristics having an important negative bearing on adult BMIs. Female employment in agriculture has significant but small positive effect on HAZ scores for children Evidence doesn't corroborate the hypothesis that child care practices are poorer in agricultural households or by agriculturally employed mothers
7. Parasuraman et al (2011)	Anthropometric for children HAZ, WAZ (<5 years) and BMI for adolescent girls and women	Vidarbha region, Maharashtra, primary survey, 6990 households in six high distress districts	Low	Medium	High	<ul style="list-style-type: none"> Cultivation of food crops contributes towards improvements in child nutrition. Ceteris paribus, higher the expenditure on food items, lower the proportion of undernourished children, adolescents and ever married women. Visible changes in agricultural cropping patterns cannot be taken as indicators of better nutritional status of households.
8. Allendorf (2007)	Anthropometric – children (severely underweight)	Nepal, Demographic and Health Survey 2001, 8,633 households, agricultural workers	Low	High	High	<ul style="list-style-type: none"> Women's empowerment is important for the agriculture nutrition link. Women's land rights empower women, benefit family welfare and child health and nutritional status.
9. Ghosh (2007)	Anthropometric – women's height and HAZ	NFHS - II 1998-99	Medium	High	Low	<ul style="list-style-type: none"> Land reforms, especially reforms targeting the abolition of intermediaries and imposition of land ceilings lead to significant

	for children	sample size of 67,600 women, 16 major states				improvements in women's long term nutritional status (or height) and also have a bearing on child nutritional attainments.
10. Hanji (2006)	Anthropometric – adolescent girls and adult BMIs	India, 192 households from 8 villages in 3 talukas of Belgaum district, Karnataka,	Medium	High	Low	<ul style="list-style-type: none"> • Irrigation facilities leads to a shift in cropping patterns in favour of high value crops and nutritional cereal crops got replaced with commercial crops reducing the availability of nutrients to population.
11. Hallman, et al (2003)	Anthropometric- height for age- HAZ, adult female BMIs and calorie intakes	Bangladesh, 955 Rural households	Low	Medium	High	<ul style="list-style-type: none"> • Vegetable technology targeted to women in households with small landholdings has positive impacts on female empowerment and child nutritional status. • Group fishpond technology is highly beneficial for poor households leading to higher off farm incomes and improved nutritional status. • Regressions for nutritional status for adults and children show no effects of fishpond technologies in the pooled sample but the access towards technological advancements has strong significant effects on pre-schooler HAZ.
12. Adhiguru, et al (2003)	RDA for women and children using 24 hour recall method	India, Primary survey data – 180 households from Dharmapuri district, TamilNadu,	Low	Medium	Medium	<ul style="list-style-type: none"> • Vegetable cultivation has immense potential in supplying vitamin rich foods and micronutrients to weaker sections.

Table 4 : Details of empirical papers studying DALYs

Paper by	Outcome measure	Area of research	Statistical analysis			Results
			Counterfactual	Programme theory	Heterogeneity of impact	
1. Stein et al (2006)	Disability Adjusted life years (DALYs)	Iron biofortification in India	Low	Medium	Low	<ul style="list-style-type: none"> • Under pessimistic assumptions iron biofortification of rice and wheat could save 0.8 million DALYs annually. • Under optimistic assumptions the DALYs saved could be 2.3 million • Sizeable health benefits can be reaped when iron content of rice and wheat is enhanced and its coverage increased. • Iron biofortification of rice and wheat is a very cost effective agricultural intervention
2. Meenakshi et al (2007)	Disability Adjusted life years (DALYs)	12 countries in Asia, Africa & Latin America	Low	Medium	Low	<ul style="list-style-type: none"> • Biofortification can have positive effects in terms of reducing micronutrient deficiencies and is a cost-effective intervention. • It is also more cost effective than supplementation or fortification • In South Asian countries biofortification is more effective since these countries are predominantly rural and have effective seed distribution systems in place.
3. Asare-Marfo et al (2013)	Biofortification Prioritization Index (BPI)	7 staple crops across 127 countries in Asia, Africa, Latin America and the Caribbean (LAC)	Low	Medium	Low	<ul style="list-style-type: none"> • Biofortification Priority Indices (BPIs) <p>Comparisons of country rankings of unweighted BPIs:</p> <ul style="list-style-type: none"> • In African countries, biofortification of cassava, sweet potato and maize with vitamin A and beans and pearl millet with iron has the largest effect. • For Asian countries zinc rich cereals (rice and wheat) have the largest effect • LAC countries call for a food basket approach wherein biofortification of all key crops is the essential requirement.

Table 5 : Details of empirical papers studying changes in consumption pattern

Paper by	Outcome measure	Area of research	Internal Validity	External Validity		Results
				Programme theory	Heterogeneity of impact	
			Counterfactual score			
1. Yu (2012)	Consumption pattern change	Bangladesh, IFPRI Chronic Poverty and Longer Term Impact Study, 1,237 households, 50 villages in 2005/06	Low	Medium	High	<ul style="list-style-type: none"> • Nutrition is governed by household size, characteristics of household head, asset ownership, consumption of own produce • Female headed households face difficulties in meeting their nutrition needs. • Increases in rice yields through agricultural research and development an effective way of improving nutrition. • Specific policies needed to address the food and nutrition needs of vulnerable.
2. Bhagowalia et al (2012)	Diet diversification	India, using the India Human Development Survey 2005	Low	High	High	<ul style="list-style-type: none"> • Agricultural income and production conditions have significant influence on household dietary diversity • Agricultural programs aimed at irrigation, livestock ownership and crop diversification significantly enhance dietary diversity.
3. Gaiha et al (2012)	Diet diversification	India, 1993-2009, NSS 50th, 61st and 66th Rounds unit record data over 3 NSS years	Low	Medium	High	<ul style="list-style-type: none"> • 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.
4. Headey (2011)	Diet Diversification	cross-country dataset	Low	Medium	High	<ul style="list-style-type: none"> • Agricultural growth has a strong effect on daily energy supply (calorie consumption) but a weak effect on dietary diversity.
5. Murshed-e-Jahana and Pemsil (2011)	Consumption pattern change	The impact of long-term IAA training provided to small-scale farmers in Bangladesh is assessed	Medium	High	High	<ul style="list-style-type: none"> • Integrated Agriculture Aquaculture (IAA) has a positive impact on fish consumption. • The significant positive effect on fish consumption could perhaps result from either a higher level of fish farming inputs purchased using the grant money, or a general higher overall interest in fish farming or the project activities.
6. Kiresur et al (2010)	Consumption pattern change	Balgalkot district, Karnataka, 120 farm	Medium	Low	Low	<ul style="list-style-type: none"> • Nutritional security of respondents is significantly influenced by agricultural income per consumer unit per annum, literates/

		households, 2005-06				household, total consumer units per household. <ul style="list-style-type: none"> Enhancements in agricultural productivity through transfer of productive assets to poor households and increased access to agricultural credit by rural households would contribute towards enhancing nutritional status
7. Murshed-e-Jahan et al (2009)	Consumption pattern change	Bangladesh, 2002-03 and 2003-04, 225 farmers	Low	High	Medium	<ul style="list-style-type: none"> Aquaculture interventions have positive effect on consumption and household nutrition Aquaculture interventions can bring about reductions in poverty and improvements in nutritional status of resource poor households Women's effective participation and access to nutritional benefits can be facilitated through gender sensitive approaches in aquaculture
8. Weinberger (2005)	Consumption pattern change	Pakistan, primary survey around Lahore area, industries employing females on a piece rate basis, June 2001-February 2002	Medium	Medium	Low	<ul style="list-style-type: none"> Increase in mung bean productivity has substantial impact on nutrition, iron intake, and human productivity
9. Roos et al (2003)	Diet diversification	Bangladesh, 84 poor rural households in Kishoreganj district (June 1997- January 1998)	Low	Medium	Low	<ul style="list-style-type: none"> No difference in fish intake in the fish producing and non-fish producing control households. Fish consumption contributed to <10% of the required protein intakes Production of Vitamin A dense SIS (small indigenous fish species) can make important nutritional contributions
10. Ogle et al (2001)	Diet diversification	Vietnam, two villages Rural 217 women	High	Low	Low	<ul style="list-style-type: none"> Wild vegetables make a significant contribution to overall micronutrient intakes viz., carotene, vitamin C and calcium. Analysis of food variety helps in bringing forth the benefits of wild vegetables

Table 6 : Details of empirical paper studying female empowerment

	Paper by	Outcome measure	Area of research	Internal validity	External validity		Results
					Counterfactual score	Programme theory	
	1. Sraboni et al, (2013)	Per adult equivalent calorie availability and dietary diversity	Bangladesh, BIHS data, 3944 households	Low	Medium	High	<ul style="list-style-type: none"> • Positive associations between household calorie availability and dietary intakes and women's empowerment score, number of groups in which women participate, women's control over assets. • Leadership in community and control over resources are areas where women have lower empowerment.
	2. Malapit et al, (2013)	Anthropometric – mother's BMI and children <5 years HAZ, WAZ, HWZ,	Household survey data conducted in 4,080 households in Nepal across 16 districts	Low	Medium	High	<ul style="list-style-type: none"> • Production diversity at household level determines maternal nutrition outcomes, mother's dietary diversity and BMI; for children this effect seems to be facilitated through the age of the child. • Autonomy in agricultural production decisions as a measure of female empowerment is a key determinant of almost all mother and child outcomes with the exception of maternal BMI.

Table 7 : Paper details for internal validity

Paper	Intervention/outcome indicator	Counterfactual score
Ogle et al (2001)	Consumption pattern change -Diet Diversity- <i>Edible wild/local vegetables</i>	High
Ghosh (2007)	Anthropometric - <i>Land reforms</i>	Medium
Hanji (2006)	Anthropometric - <i>Irrigation –</i>	Medium
Kiresur (2010)	RDA calorie intakes - <i>Poverty- alleviation through agricultural productivity increases</i>	Medium
Murshed-e-Jahan et al (2011)	Consumption pattern change- <i>Aquaculture</i>	Medium
Weinberger (2006)	Consumption pattern change- <i>Mung bean research</i>	Medium