Department for International Development

UKaid from the British people

Can agriculture interventions promote nutrition?

Agriculture and nutrition evidence paper

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Any errors or omissions remain those of the authors.

Every effort has been made to give a fair and balanced summary. In some areas where the evidence base is not clear-cut there is inevitably a subjective element. If readers consider that the evidence on any issue is not accurately described or misses important studies which may change the balance, please let us know by emailing EvidenceReview@dfid.gov.uk so that we can consider this when correcting or updating the paper.

Acronyms

BMI	Body Mass Index
EXP	Experimental
GDP	Gross Domestic Product
OBS	Observational
QEX	Quasi-experimental
OFSP	Orange-Fleshed Sweet Potato
QPM	Quality Protein Maize
UNICEF	United Nations Children's Fund
WHO	World Health Organisation

Executive summary

Burden of undernutrition and the potential role of agriculture

Despite some recent progress, the global burden of undernutrition remains high and falls disproportionately on women and young children. In Asia and Africa approximately 10% of women have a low body mass index (a measure of body thinness), an estimated 165 million children under the age of five years are stunted (too short for their age) and 52 million children under the age of five years are wasted (dangerously thin). Undernutrition is a cause of 3.1 million child deaths annually, equivalent to 45% of all child deaths in 2011. It has lifelong negative consequences on the health, development and wellbeing of children, and cripples the economic growth and development of nations.

Current expert consensus suggests that a set of specific nutrition interventions if delivered at scale could reduce the rate of stunting by 20% and the rate of child mortality by 15%. There is a growing interest in identifying whether agricultural interventions can reduce the burden of undernutrition.

A developed agriculture sector can improve nutrition and health outcomes directly, for example, through the production and consumption by small-scale farmers of an energy sufficient and nutritionally diverse diet, or indirectly, for example through changing the price of foods through increased market supply, or through enhanced household and national income by means of increased agricultural productivity. Agriculture may also have negative impacts on health and wellbeing, for example through higher work-loads (especially for women), raised risks of environmental contamination, and increased potential for infection with diseases which are transferable from animals to humans.

Evidence paper scope

This evidence paper provides a critical review of the strength and quality of the evidence base linking agriculture-based interventions and nutrition outcomes. In total, 38 studies published over the period 1980-2013 are included: 15 on home gardens, five on aquaculture, six on livestock, eight on cash crops and eight on biofortified crops (some studies address more than one intervention). The evidence base is derived roughly equally from Africa and Asia with one study from Latin America.

The primary nutrition outcomes of interest are biochemical measures of micronutrient (vitamin and mineral) status and measures of physical growth in childhood. The review also reports on multiple secondary outcomes including dietary consumption, income and morbidity.

Summary of findings

In general, the agricultural interventions reviewed in this evidence paper have inconsistent or mixed effects on nutritional outcomes in women and children, although there is evidence for a positive impact of biofortified crops on micronutrient status in children[1]. The review recognises that the evidence base on which these conclusions are drawn is limited in both size and quality. Significant research efforts are currently underway that may provide robust evidence further to inform these conclusions.

Specific findings on primary outcomes

- **Home garden interventions:**
  - effect on micronutrient status is inconsistent (7 studies)
  - effect on child growth is inconsistent (7 studies)
- **Aquaculture interventions:**
  - effect on maternal iron status is mixed (1 study)
  - effect on child growth is inconsistent (2 studies)
- **Livestock interventions:**
  - no evidence of an effect on micronutrient status (2 studies)
  - effect on child growth is inconsistent (4 studies)
- **Cash cropping:**
  - no studies report effect on micronutrient status
  - effect on child growth is inconsistent (7 studies)
- **Biofortified crops:**
  - evidence of positive effect on micronutrient status in children (3 studies)
  - effect on micronutrient status in women is mixed (2 studies)
  - moderate evidence of positive effect on child growth (3 studies).

[1] *Inconsistent*: similar studies with findings that do not concur. *Mixed*: dissimilar studies on the same topic that do not concur, or a variable pattern of impacts within the same study

1. Introduction: the potential role of agriculture in improving nutrition outcomes

Burden of undernutrition

The global burden of undernutrition remains large and falls disproportionately on young children and women. Current estimates suggest that low body-mass index, indicative of maternal undernutrition, affects over 10% of women in Asia and Africa, and globally, undernutrition is a cause of 3.1 million child deaths annually, equivalent to 45% of all child deaths in 2011 (Black et al. 2013). Undernutrition cripples economic growth and development. Future global prosperity and security are directly linked to the ability of the health and development communities adequately to respond to this challenge.

The two immediate causes of undernutrition are inadequate intake of an appropriate diet containing sufficient macronutrients (carbohydrates, protein and fat) and micronutrients (vitamins and minerals), and repeated illness especially with infectious diseases such as diarrhoea.

There are three main forms of undernutrition:

1. Acute undernutrition is a term used for short-term (days to weeks) deficits in dietary energy leading to body thinness. Acute undernutrition in children (also known as low weight-for-height or wasting) results in significantly increased risk of morbidity (illness) and mortality (death). Approximately 52 million children under five years of age currently suffer from acute undernutrition (UNICEF 2012).

2. Chronic undernutrition is a term used to denote long-term (months to years) insufficiency in dietary nutrient intake (dietary energy, vitamins and minerals) coupled with regular and repeated bouts of infectious diseases such as diarrhoea. Chronic undernutrition in children (also known as low height-for-age or stunting), especially during the first two years of life, leads to poor height growth and results in stunted physical growth as well as long-term reduced educational achievement, work capacity and economic productivity. Approximately 165 million children under five years of age currently suffer from chronic undernutrition (UNICEF 2012).

3. Micronutrient undernutrition denotes insufficient dietary consumption of essential vitamins (especially vitamin A) and minerals (especially iron, iodine, zinc). The consequences of insufficient intake of micronutrients vary from

irreversible blindness (xerophthalmia caused by chronic vitamin A deficiency) to lethargy and reduced cognitive function (caused by iron deficiency anaemia). The scale of micronutrient undernutrition is vast with more than 30% of children under five years of age thought to be vitamin A deficient and approximately 25% of the global population thought to be iron deficient (UNICEF 2009).

There are several other ways to assess nutritional status apart from weight-for-height (wasting), height-for-age (stunting) and clinical and biochemical measures of micronutrient and mineral deficiencies. One frequently used measure used in children is underweight (also known as weight-for-age) which assesses a child's weight relative to their age. Underweight is a composite measure that combines weight and height – an underweight child may be thin, short or both – and as such is difficult to interpret. A second measure of nutritional status that is used widely in both children and especially adults is the Body Mass Index (BMI – calculated as weight measured in kilograms divided by the square of height measured in metres). The BMI is a measure of body thinness and body fatness that is largely independent of height. In adults there are defined BMI cut-offs for underweight ($BMI<18.5kg/m^2$) and overweight ($BMI>25.0kg/m^2$) (WHO 1995). In children the BMI cut-offs for underweight and overweight are age-specific (Cole et al. 2007).

To date, much of the effort to address the global burden of undernutrition has focused on interventions that are designed directly to address the immediate causes of undernutrition. These interventions, termed 'nutrition specific' interventions, include such things as support for breastfeeding, food fortification and dietary supplementation, and many of these interventions have been rated as highly cost-effective for tackling undernutrition (Copenhagen Consensus 2012). Recently, a package of ten nutrition specific interventions has been identified that, at 90% coverage, are estimated to reduce by 15% the current total of deaths in children younger than five years (one million lives saved), reduce stunting by 20.3% (33.5 million fewer stunted children) and reduce prevalence of severe wasting by 61.4% (Bhutta et al. 2013).

Considerably less attention has been given to interventions that are designed to tackle the underlying or distal causes of undernutrition, including food security, care and health environments. These 'nutrition sensitive' interventions, including those related to agriculture, education, water, sanitation and hygiene, address the underlying determinants of nutrition and may also serve as delivery platforms for nutrition-specific interventions, increasing their scale, coverage, and effectiveness (Ruel et al. 2013).

There is a strong evidence base that demonstrates that nutrition specific interventions are critical to improve nutrition outcomes and child survival. Increased attention is now also being given to the evidence that interventions designed to tackle the underlying determinants of poor nutrition and health outcomes are able to reduce the burden of undernutrition (Ruel et al. 2013).

Tackling undernutrition through nutrition sensitive agriculture

This evidence paper focuses on one form of nutrition sensitive intervention: nutrition sensitive agriculture. The links between agriculture and health are complicated, bi-directional and sometimes counter-intuitive (Dangour et al. 2012). Multiple frameworks have been developed to identify critical pathways between agriculture and nutrition[2]. One of the latest frameworks, developed for a DFID-funded study (Hawkes et al. 2012), identified the principle pathways that link agricultural practices or interventions with nutrition-related outcomes either directly or indirectly (figure 1).

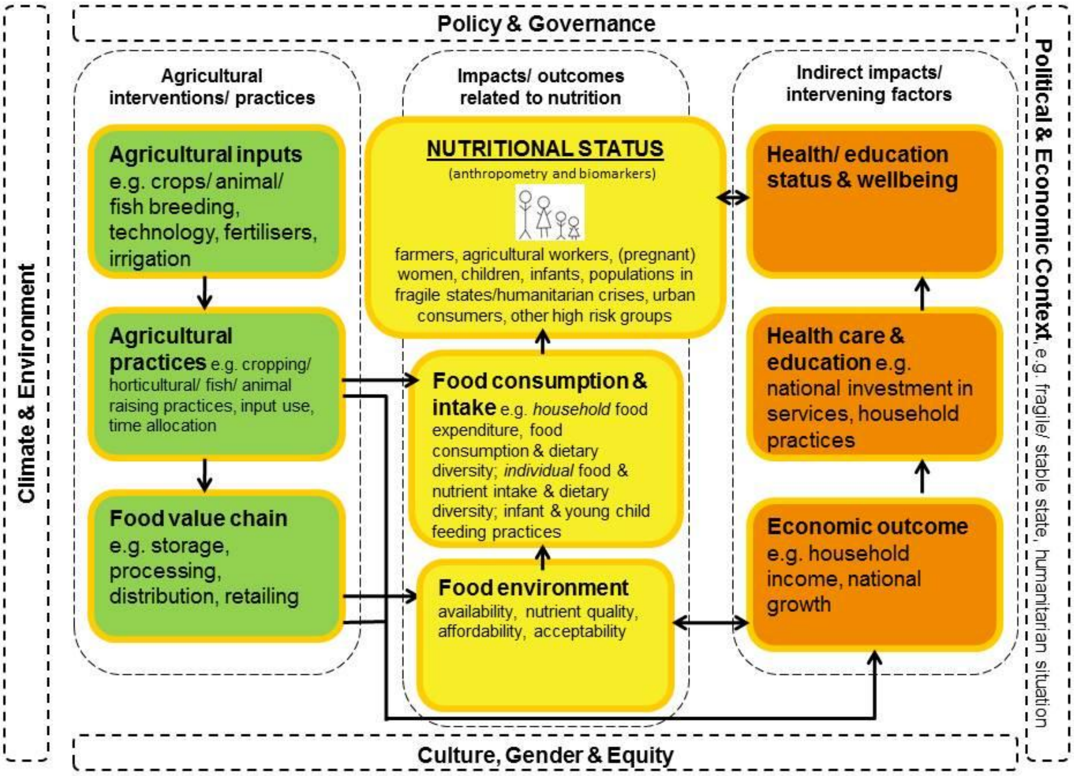

Figure 1: Pathways that link agricultural practices or interventions with nutrition-related outcomes.

The pathways start with agricultural practices or interventions that may relate to changes in agricultural inputs such as new crop varieties, agricultural practices such as home gardening, or the food value chain (the mechanisms by which agricultural outputs reach the consumer in the form of nutritious food products via storage, processing, distribution and retail systems). The direct effects of changes in agricultural practices or interventions are captured in the central (yellow) boxes that link changes in the food environment and food consumption and intake to nutrition and health outcomes in populations.

The indirect effects in the right hand (orange) boxes identify the impact of changes in agricultural practices and the food environment on agricultural employment and farm incomes, and the knock-on effect of changes in livelihoods on the ability to purchase foods and services that can be both beneficial and harmful to health. The role of agricultural growth in contributing to national economic growth which might improve population-wide access to health care and education is also identified. Macro-level factors that can influence agricultural practices and nutritional outcomes are presented in the borders of the framework. These factors include: policy and governance; culture, gender and equity; climate and environment; and the political and economic context.

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[2] Webb (2013) gives an overview of proposed pathways connecting pathways from agriculture to nutrition.

The relative lack of research emphasis on the potential of agriculture to improve nutrition outcomes is surprising given the importance of the agriculture sector in many poor countries. In many low-income countries, agriculture is the largest productive sector, contributing 29% of GDP, engaging 65% of the total labour force, and providing a livelihood for more than 86% of the rural population (World Bank 2007). Even in rapidly developing regions such as South Asia, agriculture contributes 20% of GDP and engages 50% of the total labour force (Hazell 2011). Growth in agriculture typically generates substantial demand for non-farm products, which in turn generates demand from non-farm enterprises thereby stimulating broader economic growth.

Some efforts have been made to evaluate whether increasing the size and efficiency of the agriculture sector will in itself lead to enhanced nutrition outcomes. Generally, these efforts rely on statistical analysis of existing datasets or modelling of future scenarios to assess the association of growth in the agriculture sector with nutrition outcomes, usually in children. The associations are assumed to work along multiple pathways including increased food availability at the household and community level, increased farm and non-farm incomes, and more indirect linkages between increased agricultural sector productivity and measures of national economic development. The principal challenge in such work is that inferring a causal link between agricultural growth and improved nutritional status is not straightforward, especially given that any relationship will be highly context-specific.

For example, using a mixture of statistical and modelling approaches for a variety of country settings, some studies have suggested that there is a positive relationship between agricultural sector growth and nutrition outcomes in children (Webb and Block 2012; Ecker et al. 2011). This finding has however not been supported by other studies for single countries (Pauw and Thurlow 2011; Headey et al. 2012), or in analysis using multiple country datasets (Hoddinott et al. 2012; Headey 2013). The lack of concordance in findings is likely due to different methodological approaches and significant methodological challenges, and to the long results chain between agricultural sector growth and improvements in nutrition outcomes. The relationship between agricultural sector growth and undernutrition is heterogeneous, context dependant and unlikely to be measurable without considerable error. Overall the findings of such studies are mixed.

There is growing interest in the suggestion that specific agricultural interventions delivered at the household and village level are able to improve nutrition outcomes. Several reviews that assess the evidence linking agriculture interventions with maternal and child nutrition outcomes have been published in the last ten years (Berti et al. 2004, Girard et al. 2012, Masset et al. 2012, Ruel et al. 2013). The reviews are broadly consistent in their conclusions. First, that there is relatively consistent evidence that the production and consumption of specific crops rich in certain micronutrients is linked to improved micronutrient status in women and children. Second, that there is inconsistent or no evidence for most other agricultural interventions. Third, that the available evidence base is currently very small, and that most studies have substantial methodological limitations that limit their ability to identify any true effect. Finally, each review states that more rigorous and better designed studies are needed.

The evidence base is however expanding fast. Hawkes et al. (2012) mapped current and planned research projects on agriculture for improved nutrition and identified 151 research projects, of which 66 projects concerned increasing production and availability of nutritious foods, including 11 on home gardening and homestead production. Hawkes et al. did not appraise the quality of current and planned research projects, and did not identify gaps arising from inadequate quality.

Objectives of this evidence paper

This evidence paper aims to inform decisions related to programming in the area of nutrition-sensitive agriculture by providing a critical review of the strength and quality of the evidence base. It extends existing reviews by applying DFID's approach to assessing the strength of evidence to a wide range of agriculture-based interventions, systematically reporting data related to a wide range of nutrition and other relevant outcomes (e.g. cost-effectiveness, sustainability, knowledge), and reporting on data relevant to children, women and men. Additionally, no study is excluded from review based on quality criteria; rather, quality issues are raised when reporting studies.

Scope and structure of this evidence paper

Scope

This review focusses on the following direct agricultural interventions that have been evaluated for their effectiveness to improve nutrition outcomes:

- Home gardening for fruit and vegetables
- Aquaculture (household fish-farming)
- Livestock production
- Cash cropping
- Biofortified crops.

This focus on agricultural interventions with direct links to nutrition outcomes necessarily excludes some interventions in agriculture such as irrigation, mechanisation and agricultural extension which may result in benefits for nutrition outcomes but through a complicated causal pathway that would limit inference of causality. Some other related areas of evidence were also excluded, such as evidence for the relative nutritional value of different foods included in interventions.

For the purposes of this paper, the definition of agriculture includes the production of crops, livestock and fish. Outcomes of interest, disaggregated by gender and age when possible, are in table 1. Annex 1 indicates which studies reported which outcomes.

Nutrition outcomes	Primary	• Nutritional status measured by:
		  ○ Micronutrient status (clinical signs of deficiency and biochemical analysis)
		  ○ Physical growth (anthropometry)

	Secondary	• Agricultural production
		• Dietary intake
		  ○ Consumption
		  ○ Macro- and micro-nutrients
		  ○ Dietary diversity indicated by dietary diversity score
		• Household income

		• Household expenditure • Relevant morbidity outcomes (especially adverse events)
Other outcomes		• Cost-effectiveness • Sustainability, defined as the continuation of an intervention or its effects three or more years beyond the end of project input • Gender roles and responsibilities • Impact on care practices • Nutrition related knowledge

Table 1: Outcomes of interest

Structure

The paper is structured as follows:

- Chapter 3 presents the methods employed to construct this review. It includes details on the literature search method, and how we selected and quality appraised the research that we discuss.
- Chapter 4 discusses nutrition outcomes for five intervention strategies: home gardening for fruit and vegetables; aquaculture; livestock production; cash-cropping; and biofortified crops. This section also presents a detailed pathway analysis between these interventions and nutrition outcomes.

Chapter 5 provides an overall conclusion, a commentary on the strength and quality of the existing evidence base, and identifies areas with expanding research interest as well as significant evidence gaps.

2. Methods

Basic principles

The literature search and screening process was designed so that:

- The review comprehensively covered the total evidence base.
- The evidence included is representative of the total evidence base (that is, the inclusion of any further studies would not affect the balance of evidence or argument).
- The review focused on evidence that best demonstrates the impacts of interventions on nutrition outcomes, or best describe the relations between key variables of interest.
- Clear boundaries were set for the review.

Literature search and screening

A structured literature search for each chapter of the paper was undertaken using the following databases and repositories:

- Scopus
- Web of Knowledge
- Google Scholar
- Research for Development (R4D), DFID's research repository
- International Initiative for Impact Evaluation (3ie) systematic review and impact evaluation databases.

The following general inclusion criteria were applied for the database search:

- Only papers in peer-reviewed journals
- Only papers in English language
- Any date
- Only studies conducted in low or middle income countries.

Theoretical, conceptual, review and systematic review papers identified in the search process were hand searched for additional studies, but were not formally included. The analysis presented included only empirical research.

Papers identified in the search process were screened for relevance and papers that were not relevant were excluded. The remaining papers were then screened according to specific research design and outcome inclusion criteria. Outcomes criteria are presented in table 1. Research design criteria are in table 2.

	Include	Exclude
Design	Experimental and non-experimental study designs that include a comparison group, including randomised controlled trials (RCTs) and repeat cross-sectional or longitudinal studies (and others) that have contemporary (or historical) comparisons groups (that can be matched or not).	Experimental and non-experimental study designs that do not include a comparison group. Ex-ante modelling i.e. projections of impact of real or hypothetical interventions.

Table 2: Research design inclusion and exclusion criteria

The papers that remained after all screening stages constitute the body of evidence synthesised in the present paper: any conclusions made with respect to the evidence base refer to this body, or a smaller sub-set used in a specific section.

Assessing the strength of evidence and evidence synthesis

This section summarises the process adopted for describing the research design and assessing the quality of retained studies, and assessing the overall strength of bodies of evidence. The full process is described in detail in the DFID note *Assessing the strength of evidence*[3].

I. Describing research designs

Following screening, all studies were categorised according to their broad research design: Experimental (EXP) studies including randomised controlled trials that randomly assign individuals, households or communities to receive an intervention or not to receive an intervention; Quasi-experimental (QEX) studies that similarly compare intervention and control groups, but do not assign subjects at random to either group; or observational (OBS) studies in which the effect of an intervention in a population over time is observed and contrasted with outcomes in other populations that did not receive the intervention. Experimental studies provide the most robust evidence on the impact of interventions. Study design categorisations are noted in the main text of the review when discussing individual studies, and noted in Annex 2 for all included studies. These categories are provided to give the reader an initial, general indication of the research study design.

II. Assessing quality

Studies were graded 'high', 'moderate' or 'low' according to the quality of the evidence presented, as assessed against the principles of credible research taken from the DFID note *Assessing the strength of evidence*. The grade definitions are summarised in table 2. For each included study annex 2 summarises reviewer judgements against each principle. A full explanation of the principles and method according to which papers were graded are available in the DFID note *Assessing the strength of evidence*.

[3] Available at: https://www.gov.uk/government/publications/how-to-note-assessing-the-strength-of-evidence.

Study quality	Text notation	Defined
High	↑	Demonstrates adherence to principles of appropriateness/rigour, validity and reliability; likely to demonstrate principles of conceptual framing, openness/transparency and cogency
Moderate	→	Some deficiencies in appropriateness/rigour, validity and/or reliability, or difficulty determining these; may or may not demonstrate principles of conceptual framing, openness/ transparency and cogency
Low	↓	Major and/or numerous deficiencies in appropriateness/rigour, validity and reliability; may/may not demonstrate of conceptual framing, openness/transparency and cogency

Table 3: Study quality category definitions.

Quality grades were used to enable a standardised assessment of the degree of confidence in study findings and interpretations. All relevant studies were included in the review, irrespective of quality.

III. Assessing the strength of bodies of research

For the body of evidence considered in each chapter or sub-section, the synthesis of evidence and our conclusions were based on assessing three factors:

- the overall quality of that body of evidence (high, moderate or low) based on the ratings of individual studies
- the size of the body of evidence assessed (small, medium, large)[4]
- the consistency of the findings produced by the studies constituting the body (consistent or inconsistent).

The context or contexts in which this evidence is set (global, regional or country specific) is also indicated in the text.

General characteristics of retained studies

In total, 38 studies (published over the period 1980-2013) are included in this Evidence Paper. Some of these studies address more than one study. Table 4 gives the total number of studies included within each section, as well a summary of the quality, research design and geographical coverage.

[4] In this paper, small = <10 studies, medium = ≥10 studies, large = ≥20.

	Total number of studies[5]	Quality assessments	Research design	Geographical coverage
Home gardening	15	High: 1 Moderate: 7 Low: 7	EXP: 0 OBS: 10 QEX: 5	Sub-Saharan Africa: 7 Asia: 8
Aquaculture	5	High: 0 Moderate: 4 Low: 1	EXP: 0 OBS: 2 QEX: 3	Bangladesh: 3 Malawi: 1 Vietnam: 1
Livestock production	6	High: 0 Moderate: 1 Low: 5	EXP: 0 OBS: 6 QEX: 0	Kenya: 2 Ethiopia: 1 Cambodia: 1 Thailand: 1 Bangladesh: 1
Cash-cropping	8	High: 0 Moderate: 4 Low: 4	EXP: 0 OBS: 8 QEX: 0	Sub-Saharan Africa: 7 Sri Lanka: 1 Nepal: 1 Guatemala: 1
Biofortified crops	8	High: 1 Moderate: 6 Low: 1	EXP: 6 OBS: 0 QEX: 2	Sub-Saharan Africa: 6 India: 2

Table 4: General characteristics of retained studies.

[5] This may be different to the total number of papers reviewed in each section because in some cases more than one paper discusses the same intervention study, or more than one study is reported within a paper.

3. Nutrition sensitive agricultural interventions

Pathways between agricultural interventions and nutrition outcomes

This chapter reviews evidence for the effect of agricultural interventions on nutrition outcomes. The overarching pathways linking agriculture and nutrition outcomes have been presented (figure 1). Figure 2 (p20) concentrates in greater detail on agricultural interventions and paths between these interventions and nutrition outcomes, principally in mothers and children.

The pathways start with household allocation of resources. This review focuses on agriculture but two other possible recipients of resources – employment, and time for caring and nurturing – are included because they may affect nutritional status and may impact on, or be impacted upon, by resources given over to agriculture.

Three main pathways between agriculture and nutrition are described:

- Path A concerns food production primarily for household consumption. The direct path between this and improved nutrition is through increased production of food, increased food availability, and increased consumption of (nutrient rich) foods.
- Path B concerns food production primarily for sale (cash cropping). The direct path between cash cropping and nutritional status is through using the income generated through crop sales to buy nutritious food for consumption.
- Path C offers an indirect route from cash-cropping to nutrition, where income from cash-cropping is used for non-food expenses such as health care and education which may in turn be associated with nutrition outcomes.

These simplified paths may be complicated in multiple ways and some examples are indicated by dashed lines. First, in practice there is often no hard distinction between production for household consumption and production for sale. For example, surplus food intended for household consumption may be sold for cash, food cash crops may be consumed directly by the household, and food production for household consumption and sale may be maintained together by the same household or community. However, in this review, the cash crop section focuses on interventions designed specifically to increase cash crop production and measure the effects of this strategy on nutrition outcomes. In other sections, when production for household consumption and commercial production have been combined, efforts are made to disentangle their contribution to nutrition outcomes.

Second, biofortified crops may mediate between nutrition outcomes and agriculture by being chosen for home production or locally available for purchase. As a growing area of research, this review dedicates a separate section to biofortified crops.

Third, the effect of relative distribution of women's labour and time across agriculture, employment, and time for care and nurturing may be particularly relevant to nutrition outcomes. More generally, women's social status, empowerment, control over resources, time allocation, and health may mediate in the pathways between agriculture inputs, intra-household resource allocation and child nutrition (Ruel et al. 2013). We report findings on these issues when it is available in included studies.

Finally, some other mediating variables are discussed through the main text when relevant. These variables include:

- nutrition education and/or agriculture skills training
- labour demands
- food acceptability
- food/crop choice
- type of agricultural method or methods employed, or intervention set-up.

The rest of the chapter is structured around five classes of intervention as follows:

- Home gardening for fruit and vegetables
- Aquaculture
- Livestock production
- Cash cropping
- Biofortified crops.

Some studies have elements of more than one of these interventions. When data is sufficiently disaggregated, the same study is used in all relevant sections.

The evidence associated with each intervention is organised around the outcomes in table 1.

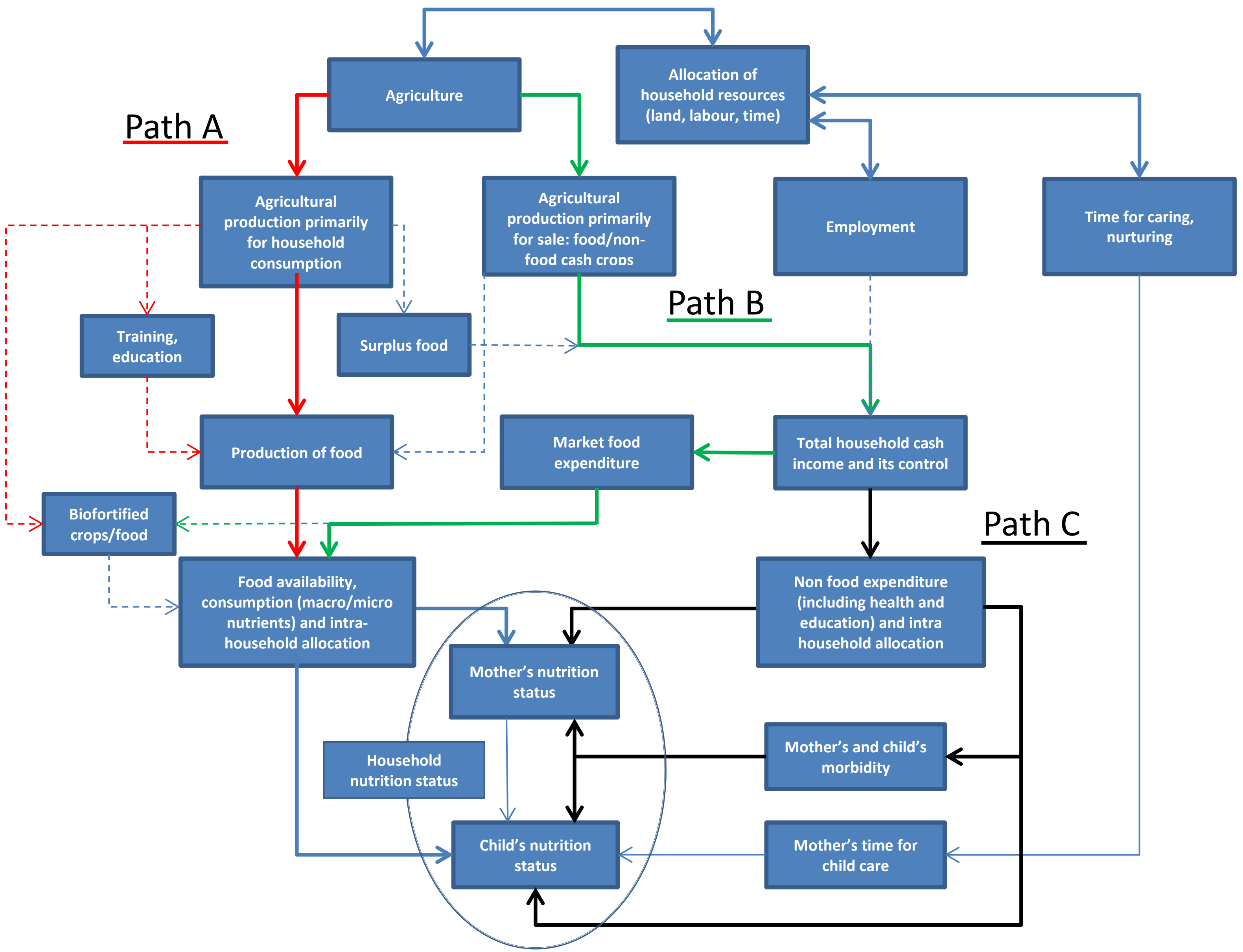

Figure 2: Pathways between agriculture interventions and nutrition outcomes (modified from Sharma 1999)

A. Home gardening for fruit and vegetables

This section considers fruit and vegetable production as a strategy for improving household or individual nutrition outcomes. Home garden interventions may involve the direct establishment of a household garden or provision of materials to improve a garden, home garden and/or nutrition education and/or skills training, or a mix of both.

The basic pathway between home gardening and improved nutrition is as follows: establishing or improving a home garden leads to an increase in household production and diversity of nutrient rich fruit and/or vegetables, which leads to increased consumption of these foods, which in turn leads to improved nutrition outcomes. This simple model may be complicated. For example, the link between increased production and consumption is not necessarily direct: consumption may be direct from the garden, or surplus fruit or vegetables produced may be sold, and this income may be spent on food, or relevant inputs such as health services.

Overview of the evidence base

17 reports of 15 studies are included (English and Badcock 1998 and English 1997 discuss the same project and intervention, as do Faber et al. 2002 and Faber et al. 2002a). Overall, the evidence base is of moderate quality, with one high quality, seven moderate quality, and seven low quality studies. These studies are a mix of quasi-experimental (five studies) and observational studies (10 studies). Several studies report small sample sizes and/or difficulties establishing or maintaining a true comparison group. Home garden studies have been undertaken in Africa and Asia, but the evidence for some aspects of home gardening has a geographical bias which is reported below when relevant.

Summary

The evidence base for the link between home gardening and micronutrient status is small (seven studies) and findings are inconsistent.

A small number of studies (two quasi-experimental, five observational) report on the impact of home gardening on height-for-age, weight-for-age, and weight-for-height in children (age range 1-13 years). Four studies record no impact whilst three studies record statistically significant positive associations in some measures. The lack of wider evidence of impact may be due to research design issues rather than the absence of a true effect.

A medium sized (11) body of mostly observational evidence shows that home gardening is associated with increased household production of fruit and/or vegetables, and increased consumption of vegetables and/or fruit at household and individual level (children (age range 1-13 years), and women). This finding is broadly consistent of moderate quality overall and from Africa and Asia.

A medium sized body (10 studies) of observational and quasi-experimental evidence shows that home gardening is associated with an increase in the intake of vitamin A rich foods. Five of these studies record an increase in intake in children ≤6 years. The evidence is broadly consistent and of moderate quality overall. The majority of studies have been undertaken in Asia, with some from Africa. The evidence base for the impact of home gardening on intake of other micro and macro nutrients is small (four and five studies respectively) and inconsistent.

Overall, a small body (three studies) of moderate quality observational studies link home gardening with a reduction in childhood morbidity. However, the results are mixed with no consistent pattern of effect on any particular form of morbidity.

The evidence base for the sustainability of home gardening impacts is small (three studies) and of moderate or low quality. The studies consistently suggest sustainable positive impacts on several outcomes including consumption, production and nutrition knowledge.

A small body (four studies) of moderate quality observational and quasi-experimental studies from Africa suggest education and/or training in home gardening increased home gardening activity and had a positive impact on secondary nutrition outcomes.

Evidence on home gardening and nutrition outcomes

1. Primary nutrition outcomes

I. Micronutrient status

The evidence base for the link between home gardening and vitamin A status is small (five studies) and findings are inconsistent. Two studies report a positive association. A third study records a negative association, although this was likely due to helminth infestation. Two other studies record no association between home gardening and vitamin A status.

The evidence base for the impact of home gardening on biochemical status of other micronutrients is small (three studies). One study reports a positive impact on haemoglobin in women, whilst a second study records no impact on haemoglobin in women or children. One study reports a positive impact on vitamin E in children.

Vitamin A status

Five studies investigated the link between home gardening and biochemical vitamin A status. The findings are inconsistent.

Two studies report a positive relationship between home gardening and vitamin A status (de Pee et al. 1998 [OBS; ↑], Faber et al. 2002/2002a [QEX;→]), although only Faber was designed specifically to test the impact of home gardening on vitamin A status. de Pee used a multiple logistic regression model and survey data to determine correlates with serum retinol levels in women in Central Java, Indonesia, recording significant positive relationships between ownership of a home garden, vitamin A intake and serum retinol concentrations.

Faber et al. (2002/2002a [QEX;→]) implemented a home gardening programme in a village in KwaZulu-Natal, South Africa. The programme was linked to a primary health care activity (community based growth monitoring system) and accompanied by a nutrition education programme. Serum retinol concentrations were collected at baseline and 20 months after implementation, and compared with a control group with no household promotion or production programme. At follow-up, children aged 2-5 years from the experimental village had significantly higher serum retinol concentrations than children from the control village.

Three studies report no impact of home gardening on vitamin A status. One low quality study undertaken in South Africa reported no significant difference in vitamin A status between children aged 6-13 years whose parents participated in communal vegetable garden programme compared to children of parents who did not (Schmidt and Vorster 1995 [OBS;↓]). Schipani et al. (2002 [OBS ↓]) recorded no significant difference in vitamin A status in children aged 1-7 years between ‘mixed-gardening families’ compared to ‘non gardening families’ in Thailand. However, ‘nongardening families’ did not provide a true control group for comparison (for example, ‘nongardening’ families also produced food for home consumption).

A study undertaken in Tanzania (Kidala et al. 2000 [QEX;→]) found significantly lower serum retinol in children aged 12-71 months in the intervention group. However, this group also had a significantly higher proportion of children with helminth infestation. Overall, children with helminths had lower levels of serum retinol than those without, and it is reasonable to conclude that helminth infestation was a confounder.

<u>Status of other micronutrients</u>

Three studies report data on the impact of home gardening interventions on the status of micronutrients other than vitamin A.

Two studies investigated impact on haemoglobin levels. Kumar and Quisumbing (2011 [QEX;→]) reported significantly better long-term haemoglobin levels in women amongst early adopters of improved vegetable varieties for home gardening in Bangladesh. Olney et al. (2009 [OBS;→]) however, in a homestead food production programme primarily targeting women’s groups in Cambodia, found no significant differences for haemoglobin in children and mothers between intervention and control groups, and there was no impact on prevalence of anaemia in children under five years of age.

Schmidt and Vorster (1995 [OBS;↓]) reported significantly higher vitamin E status amongst children aged 6-13 years whose parents participated in a communal vegetable garden programme in South Africa compared to children of parents who did not.

II. Anthropometry

A small number of studies (two quasi-experimental, five observational) report on the impact of home gardening on height-for-age, weight-for-age, and weight-for-height in children (age range 1-13 years). Four studies record no impact whilst three studies record statistically significant positive associations in some measures.

The lack of evidence of impact may be due to research design issues (e.g. small sample sizes, insufficient time between baseline and follow-up) rather than the absence of a true effect. Of the two quasi-experimental studies that reported positive impacts, one did so over a long period of time (10 years) and the other only amongst the longest and most intensely involved villages.

The evidence base for the impact of home gardening on anthropometric measures is inconsistent and suffers from design weaknesses.

Four studies record no impact on height-for-age, weight-for-age, and weight-for-height in children. Of these four, Schipani et al. (2002 [OBS↓; Thailand]) recorded no increase in consumption patterns between intervention and control group children aged 1-7 years, Schmidt and Vorster (1995 [OBS↓; South Africa]) lacked a true control group for comparison whilst Faber et al. (2002/2002a [QEX; →]) and Olney et al. (2009 [OBS →; Cambodia]) were unable to distinguish between a true lack of effect and design issues precluding measurement of effect (e.g. length of intervention).

One study from Cambodia reports data on anthropometric measures in women, and records no significant impact on weight or body mass index (Olney et al. 2009 [OBS; →).

Three other studies report some positive nutrition outcomes. English and Badcock 1998 ([OBS→; Vietnam]) recorded a decrease in stunting in children aged six years and under in the intervention group compared to control, but no difference in incidence of wasting, or those stunted and wasted. Two further studies suggest that insufficient time between adoption of the intervention and recording impacts may account for the absence of more widespread recorded effects on anthropometric measures.

In a study of the long-term (10 year) impacts of a programme supporting the adoption of improved vegetable varieties for home gardening in Bangladesh, Kumar and Quisumbing (2011 [QEX→]) recorded increased BMI for children and women, but not for men, and a reduction of stunting in girls. In a quasi-experimental study undertaken in Malawi, Kerr et al. (2010 [QEX→]) recorded improvement in weight-for-age in children under three years old in the longest and most intensely involved intervention villages. Kerr et al. showed that a simple comparison between control and experimental groups shows no impact of a participatory agricultural and nutrition intervention on nutritional status, but that simple comparison is confounded by natural variation and difficulty maintaining a pure control. When length of time and intensity of involvement were considered, the effect of the intervention on weight-for-age was statistically significant.

2. Secondary nutrition outcomes

No studies reported data on dietary diversity.

I. Production and consumption of vegetables and fruit

A medium sized (10) body of mostly observational evidence shows that home gardening is positively associated with increased production and consumption of vegetables and/or fruit at household and individual level (women and children). This finding is broadly consistent, of moderate quality overall and from Africa and Asia.

Together, four of these studies with relevant data suggest that the majority of the increased volume of vegetables consumed by households came direct from their home garden.

Production

Six studies report data on the impact of home gardening on production of fruit and vegetables.

Five studies show that home gardening is positively associated with increased production of vegetables (Bushamuka 2005 et al. [OBS↓; Bangladesh], English and Badcock 1998 [OBS→; Vietnam], Faber et al. 2002/2002a [QEX→; South Africa], Laurie and Faber 2008 [OBS↓; South Africa]) Olney et al. 2009 [OBS→; Cambodia]). Three of these studies also recorded data on production of fruit and each study shows an increase in fruit production in the intervention group (Bushamuka et al. 2005; English and Badcock 1998; Olney et al. 2009).

One study undertaken in Bangladesh recorded no greater household production of fruit or vegetables within project versus non-project areas, although the study lacked baseline data and a true control group (Greiner and Mitra 1995 [OBS↓]).

Consumption

10 studies show that home gardening is associated with increased consumption of vegetables. The evidence is broadly consistent and includes low and moderate quality quasi-experimental and observational research from Asia and Africa.

Three studies report increased household vegetable consumption amongst intervention households compared to control groups (Bushamuka et al. 2005 [OBS↓; Bangladesh]; Jones et al. 2005 [OBS↓; Nepal]; Olney et al. 2009 [OBS→; Cambodia]), although English and Badcock 1998 [OBS→; Vietnam] recorded no significant increase at household level.

Eight studies report increased vegetable consumption amongst children in intervention households (English and Badcock 1998 [OBS→; Vietnam]; Faber et al. 2002/2002a [QEX;→]); Hagenimana et al. 2001 [QEX→; Kenya]; Kerr et al. 2007 [OBS↓; Malawi]; Kidala et al. 2000 [QEX;→]; Laurie and Faber 2008 [OBS↓; South Africa]; Olney et al. (2009 [OBS→; Cambodia]); Schmidt and Vorster 1995 [OBS;↓]). One of these studies also reports data on mother's consumption of vegetables (Olney et al. 2009). The study reports that mothers in the intervention group were less likely than mothers in the control group to have eaten carrots in the week prior to the endline survey. However, among the mothers who had consumed dark-green leafy vegetables in the previous week, those in the intervention group consumed them more frequently than those in the control group.

The evidence that home gardening increases consumption of fruit is more limited. Four studies report data on this. Three studies report an increase in fruit consumption by intervention households compared to control households (Bushamuka et al. 2005 [EXP ↓; Bangladesh]; English and Badcock 1998 [OBS→; Vietnam]; Jones et al. 2005 [OBS↓; Nepal]). English and Badcock (1998) also recorded an increase amongst intervention group children. A fourth study reports no increased consumption by children under five years old in intervention households, and no increase in the proportion of mothers who had consumed fruit (Olney et al. 2009 [OBS→; Cambodia]). However, among the mothers who had consumed fruit in the previous week, those in the intervention group more frequently consumed fruit than those in the control group, and this study also reported an increased consumption in the intervention group over the control group at household level.

Two plausible pathways link increased production from home gardening with increased consumption: consumption direct from the garden, and sale of surplus garden produce with the income spent on food. A small number of studies plausibly confirm that both pathways operate, but suggest that production for direct consumption is most likely in home garden interventions.

In two studies, home gardeners reported greater consumption from their garden and less purchase of food relative to controls (Jones et al. 2005 [OBS↓; Nepal], Laurie and Faber 2008 [OBS↓; South Africa]). In a third study, when asked what difference the project gardens had made to the household, a third of respondents said that they appreciated the fact that they did not have to buy vegetables; 8% of the households with project gardens sold some of the produce for cash (Faber et al. 2002/2002a [QEX→; South Africa]). A further study shows increased production, increased consumption and increased sale of vegetable produce in home gardening project households (Bushamuka et al. 2005 [OBS↓; Bangladesh]). However, the majority of the increased produce was eaten rather than sold. In a three month period, project participants produced a median 135kg of vegetables and consumed 85kg. Income generated from sale of produce was mainly spent on food. Control households produced a median 46kg and consumed 38kg.

II. Intake of micro and macro nutrients

A medium sized body (11 studies) of observational and quasi-experimental evidence shows that home gardening is associated with an increase in the intake of vitamin A rich foods. The evidence is broadly consistent and of moderate quality overall. The majority of studies have been undertaken in Asia, with some from Africa.

The evidence base for the impact of home gardening on intake of other micro and macro nutrients is small (four and five studies respectively) and inconsistent. There is some evidence that home gardening has a positive impact on the intake of some nutrients.

<u>Vitamin A intake</u>

11 studies report data on the impact of home gardening on the intake of vitamin A. This evidence base consists of quasi-experimental and observational studies undertaken in Asia (seven studies) and Africa (four studies), is of moderate quality overall, and is broadly consistent.

10 studies show higher intake of vitamin A rich foods at household or individual level in households that participated in a home garden programme compared to households that did not. Six of these studies record an increase in intake in children aged six years or under (Faber et al. 2002/2002a [QEX→; South Africa], English and Badcock 1998 [OBS→; Vietnam], Hagenimana et al. 2001 [QEX→; Kenya], Laurie and Faber 2008 [OBS↓; South Africa]), Olney et al. 2009 [OBS→; Cambodia], Kidala et al. 2000 [QEX→; Tanzania]). Three studies record an increase vitamin A intake at household level (Jones et al. 2005 [OBS↓; Nepal], English and Badcock 1998 [OBS→; Vietnam], Olney et al. 2009 [OBS→; Cambodia]). One study undertaken in Bangladesh records an increase in vitamin A intake in men and women members of project households, but not children in these households (Kumar and Quisumbing 2011 [QEX→]).

One study reported higher consumption of carotene-rich (yellow) foods by children aged 1-6 years in beneficiary and non-beneficiary groups in a home gardening intervention (Greiner and Mitra 1995 [OBS↓; Bangladesh]). However, consumption of green leafy vegetables was higher in the beneficiary group.

One further study from Indonesia showed ownership of a home garden was positively associated with vitamin A intake from plant sources amongst women (de Pee et al.1998 [OBS↑;]).

One study undertaken in Thailand showed no increase in vitamin A intake in households defined as 'mixed-gardening families' compared to 'nongardening families' (Schipani et al. 2002 [OBS;↓). However, 'nongardening families' did not provide a true control group for comparison (for example, 'nongardening' families also produced food for home consumption).

<u>Intake of other micronutrients</u>

Four studies report data on the impact of home gardening on intake of micronutrients other than vitamin A. The evidence is inconsistent.

Three studies link home gardens to increased intake of some, but not all, micronutrients.

English and Badcock (1998 [OBS; →]) recorded significantly higher iron intake but not vitamin C intake in children six years and under and households (average per person) amongst beneficiaries of a home gardening intervention in Vietnam. Faber et al. (2002/2002a [QEX; →]) recorded increased intake by children from households with project gardens of riboflavin, vitamin B6 and ascorbic acid, but not calcium, magnesium, zinc, thiamine, niacin, vitamin B12, folic acid or vitamin C in South Africa. Neither study measured biochemical status for any micronutrient.

Kumar and Quisumbing (2011 [QEX;→]) reported increased iron intake amongst men and women, but not children, and recorded significantly better long-term haemoglobin levels (the only biochemical analysis undertaken) in women amongst early adopters of improved vegetable varieties for home gardening in Bangladesh.

Schipani et al. 2002 [OBS; ↓) recorded no significant difference in intake of micronutrients and no difference in micronutrient status between 'mixed-gardening families' and 'nongardening families' in a study from Thailand. However, 'nongardening families' did not provide a true control group for comparison.

<u>Macronutrient intake</u>

The evidence on intake of macronutrients is small (five studies) and inconsistent. Faber et al. (2002/2002a [QEX; →]) recorded no impact of home gardening on total energy intake by children aged 2-5 years, or intake of protein, fat and carbohydrate in a study from South Africa. In Vietnam, English and Badcock (1998 [OBS; →]) recorded significantly higher intake of energy and protein but not fat in children from households that participated in a home gardening intervention compared to children from households that did not. At household level, average consumption per person of fat, but not total energy or protein, was higher in project households. Kumar and Quisumbing (2011 [QEX;→]), in a study undertaken in Bangladesh, recorded no increase in household energy availability, and women in the intervention group had significantly lower energy intake and less protein intake (no explanation for this finding is offered). Schmidt and Vorster (1995 [OBS; ↓]) recorded no significant difference between intervention and control groups in protein intake and biochemical indicators of protein status in a study from South Africa. The same study recorded higher energy and fat intake amongst children in the control group (statistical significance not tested). Schipani et al. (2002 [OBS; ↓) recorded no significant difference in intake of energy, protein and fats amongst children aged 1-7 years from ‘mixed-gardening families’ and ‘nongardening families’ in Thailand.

III. Household income and expenditure

Three studies report that project participants sold some home produced vegetables or fruit (English and Badcock (1998 [OBS; →]; Bushamuka et al. 2005 [OBS↓; Bangladesh]; Kerr et al. 2007 [OBS↓; Malawi]). For example, from a project promoting cultivation of legumes for improved soil fertility, food security and child nutrition in Malawi, Kerr et al. (2007) reported that 10 of 24 farmers reported selling from $US4-46 worth of groundnuts and soybeans, with an average income of $US13 reported. Eight of these farmers were older women.

Bushmaku et al. (2005) reported that significantly more household beneficiaries of a homestead gardening programme generated income by selling part of their garden produce compared to households in the control group. Food was the item most frequently purchased by intervention and control groups, but amongst households that managed a garden, significantly more households in the intervention group than in the control group purchased food or paid for education, clothing, productive assets, and health care from their gardening activities. In one further study, home gardeners reported less purchase of food relative to the control group (Laurie and Faber 2008 [OBS↓; South Africa]).

IV. Morbidity

A small body (three studies) of moderate quality observational studies link home gardening with a reduction in childhood morbidity. The results are inconsistent and the evidence base too small to identify a consistent pattern of effect on any particular form of morbidity.

A quasi-experimental study in South Africa showed that a programme to promote home gardening and production of high vitamin A vegetables, combined with nutrition education and community based growth monitoring, was associated with significantly lower reported experience of vomiting, fever, sores on the skin, continuous runny nose, diarrhoea and poor appetite in children 1-5 years old (Laurie and Faber 2008 [QEX; ↓]). An observational study in Vietnam reported significantly reduced incidence and severity of acute respiratory infections and incidence of diarrhoeal disease in preschool children compared to controls following promotion of home gardening and nutrition education (English et al. 1997 [OBS; →]). However, an observational study from Cambodia (Olney et al. 2009 [OBS; →), whilst recording a decrease in childhood fever, recorded no impact of home gardening on diarrhoea in children under five years of age or mothers.

3. Other outcomes

No studies report on the cost effectiveness of home gardening.

I. Sustainability

The evidence base for the sustainability of home gardening impacts is small (three studies) and of moderate or low quality. The studies consistently suggest sustainable positive impacts on several outcomes including consumption, production and nutrition knowledge.

Three studies (Bushamukaku et al. 2005 [OBS↓; Bangladesh], Kidala et al. 2000 [QEX→; Tanzania], Jones et al. 2005 [OBS↓; Nepal]) carried out an impact assessment 3-5 years after the end of the intervention period. These studies consistently suggest positive impacts on the number of households having a home garden; nutrition and home gardening knowledge; and the consumption and production of fruit and vegetables.

A fourth compared data collected in 1996/1997 and 2006/2007 and also reported positive impacts on some secondary nutrition outcomes (Kumar and Quisumbing 2011 [QEX→; Bangladesh). However, this may not be a true test of sustainability because it is not clear that all intervention activities had ceased by follow-up data collection.

II. Gender roles and responsibilities

One low quality study undertaken in Bangladesh has data on women's influence in household decision-making (Bushamuka et al. 2005 [OBS; ↓]). Women beneficiaries of a homestead gardening programme reported greater power in household decision-making than they had before the introduction of the programme, and a greater increase than that reported by women in the control group.

III. Impact on care practices

One study reports data on care practices. The nutrition education element of a home garden intervention in Nepal included information on the need to consume more energy and higher-quality foods products during pregnancy, and promoted exclusive breastfeeding and feeding of colostrum (Jones et al. 2005 [OBS↓; Nepal]).

More caregivers in project households reported adjusting their diet to consume 'special foods' during pregnancy. There were no differences between intervention and control households in the percentage of caregivers who reported feeding colostrum to newborns, or in the reported length of exclusive breastfeeding.

IV. Nutritional knowledge and impact of nutrition education and agriculture/garden training on secondary nutrition outcomes

For a small body (four studies) of moderate quality observational and quasi-experimental studies from Africa, education, promotion and/or training in home gardening was the main intervention. These studies consistently show that these activities increased home gardening activity and had a positive impact on secondary nutrition outcomes.

All studies that included a home gardening or agricultural intervention had an element of education or training attached to the intervention. Five studies gathered data on nutritional knowledge and each showed an increase in this knowledge amongst intervention groups compared to controls (Faber et al. 2002/2002a [QEX→; South Africa]; Jones et al. 2005 [OBS↓; Nepal]; Kidala et al. 2000 [QEX→; Tanzania], Laurie and Faber 2008 [OBS ↓; South Africa]; English and Badcock 1998 [OBS; →]). For example, in a project from South Africa promoting cultivation of carotene rich vegetables and providing nutrition education, compared to control households, more caregivers from project households thought that yellow fruit and vegetables were good for their children, were familiar with the term 'vitamin A', knew that vitamin A is a nutrient in food, and could name three food sources rich in vitamin A.

In four studies, education, promotion and/or training in home gardening was the primary intervention (Kidala et al. 2000 [QEX→; Tanzania], Laurie and Faber 2008 [OBS ↓; South Africa], Hagenimana et al. 2001 [QEX→; Kenya], Faber et al. 2002/2002a [QEX→; South Africa]). In one of these studies (Hagenimana et al. 2001) the beneficiaries were exclusively women's groups.

These studies reported an increase in nutrition knowledge (Laurie and Faber 2008, Faber et al. 2002/2002a, Kidala et al. 2000), production of vegetables (Laurie and Faber 2008, Faber et al. 2002/2002a, Kidala et al. 2000) and consumption of vegetables (Kidala et al. 2000, Laurie and Faber 2008, Hagenimana et al. 2001, Faber et al. 2002/2002a), and reduced childhood morbidity (Laurie and Faber 2008).

A study by Faber et al. (2002/2002a [QEX; →]) undertaken in South Africa demonstrates the kind of approach taken in these studies. Demonstration gardens located at growth monitoring points (*Isizinda)* served as training centres for all mothers attending the *Isizinda*. Mothers received skills training, nutrition education promoting the production of yellow fruit/veg and dark-green vegetables at household level, and information explaining the importance of these foods. Children were introduced to foods prepared from the garden when attending growth monitoring days. The only direct household level support was the planting in household gardens of vegetables not already locally consumed.

At the end of the project, children aged 2-5 years old in project and non-project households consumed significantly more vitamin A compared to baseline, but children in project households consumed significantly more vitamin A than those in non-project households. The increased intake from children in the control group may be explained by raised knowledge and awareness of the importance of vitamin A in those households, increased availability of butternuts in local shops and project mothers trading fruit and vegetables with non-project mothers. All these activities were attributed to the project gardens.

B. Aquaculture

Fish are an important source of essential nutrients and in certain settings may provide an effective contribution to nutrition security (DFID 2013). This section considers evidence on the contribution of fish-farming to improved household or individual nutrition outcomes.

The basic pathway between home aquaculture and improved nutrition is similar to that for home gardening (see p21). Essentially, fish produced may be: directly consumed; sold, with the income generated spent on food (or relevant inputs such as health services); or a mix of both.

Overview of the evidence base

Five studies on the relationship between small-scale fish-farming and nutritional outcomes have been reviewed. Four are moderate quality, while the remaining one is of low quality. Three quasi-experimental studies were undertaken in Bangladesh. Of two observational studies, one was undertaken in Malawi and one in Vietnam.
Summary

There is a small body (five studies) of evidence on the impact of small-scale fish-farming on nutrition, with most of the research having been conducted in Bangladesh. It is difficult to draw general conclusions from these studies. For most outcomes of interest, three or fewer studies report relevant data, and findings are often inconsistent.

Two studies report data related to nutritional status. One study reported improved weight-for-age, but not weight-for-height or height-for-age amongst children aged 6-59 months in fish farming households in Malawi. The other study reported a complex mix of positive and adverse results across long term and short term outcomes, dependent on nutrition outcome, gender, and whether fish ponds were managed by groups of households or owned by individual households.

Two studies show an increase in fish consumption amongst fish farming households, although a third study found no increase.

Two studies record increased income in fish-farming households compared to non-fish-farming households.

One study reports some positive long-term outcomes for secondary nutrition outcomes, particularly from individual pond fish-farming.

Evidence on aquaculture and nutrition outcomes

1. Primary nutrition outcomes

I. Micronutrient status

One study from Bangladesh reports data on haemoglobin levels for women (Kumar and Quisumbing 2011 [QEX;→]). The study examined short and long-term nutrition outcomes for early and late adopters (defined, respectively, as those that had adopted the technology as of the initial survey (the treatment group), and those that had not (the comparison group) within two forms of household fish production: group pond fish-farming and individual pond fish-farming. The group ponds were managed by groups of women (ranging in number from five to 20) whilst the individual ponds were managed by a mix of men and women.

The fraction of women with anaemia in early adopting households of individual fish ponds decreased significantly in the 10 years between initial and final data collection. There was no significant long term change in the fraction of women with anaemia in group-pond fishing households.

II. Anthropometry

Two studies consider associations between anthropometric measures of nutritional status and household fish-farming. The findings are inconsistent. One study from Malawi of moderate quality reported improved weight-for-age, but not weight-for-height or height-for-age amongst children aged 6-59 months in fish farming households. The other study, of high quality and conducted in Bangladesh, reported a complex mix of positive and adverse results.

A cross-sectional study in rural Malawi (Aiga et al. 2009 [OBS; →]) showed a significant difference in the prevalence of underweight in children aged 6-59 months between fish-farming (24%) compared to non-fish-farming households (42%). Significant differences between the prevalence for severe underweight between fish-farming (5%) compared with non-fish-farming households (17%) were also observed. No statistically significant difference was observed between fish-farming and non-fish-farming households in stunting and wasting. The study suggests that the lower prevalence of underweight in children of fish-farming households was likely to be due to increased purchasing power for obtaining other types of food as a result of increased income from fish-farming, rather than through increased consumption of fish. However, the study design is too weak to confirm this.

The study from Bangladesh comparing examining short and long-term nutrition outcomes for early and late adopters of group pond fish-farming and individual pond fish-farming reports a mixed set of results and lacks data with which to explain findings (Kumar and Quisumbing 2011 [QEX;→]). The group fish-pond approach did not affect adult nutrition status. Amongst children of early adopters of group pond fish-farming, overall BMIs increased but the long term impacts on stunting were opposite for boys and girls: there was an increase in the proportion of stunted girls in group pond fishing households whilst there was a decline in the proportion of boys with stunting. Stunting rates for girls were higher among early-adopting families compared to late-adopters. No evidence is available to explain why the intervention had adverse impacts on some nutrition outcomes, particularly as the intervention did not significantly impact on expenditure outcomes in group-pond households (see below).

Overall, amongst children of early adopters of individual pond fish-farming, whilst overall BMI increased and the proportion of thin girls declined, the household proportion of stunted girls increased suggesting sustained impacts on long-term indicators of nutritional status did not occur.

One further study compared anthropometric measures for children aged under six from households that participated in a home gardening intervention which included promotion of fish ponds with children from households that did not (English and Badcock 1998 [OBS→; Vietnam]). Stunting in children from intervention households decreased compared to children in control households, but there was no difference between groups in incidence of wasting, or those stunted and wasted. However, it is not possible to separate the effects of fish ponds from gardens as they were both being promoted at the same time.

2. Secondary nutrition outcomes

No studies report data on dietary diversity or morbidity.

I. Production and consumption of fish

Three studies documented the impact of household fish-farming on the overall consumption of fish. Two studies of moderate quality (one each from Bangladesh and Vietnam) observed an increase in consumption in households where fish farming was introduced compared to non-fish-farming households. One of these studies showed increased consumption again if women were the principal producers. A third low quality study from Bangladesh showed no increased consumption in fish producing households.

In a study from Bangladesh, Murshed-e-Jahan et al. (2010 [QEX;→]) reported an increase of 6.6% in annual per capita fish consumption in intervention households compared to a 2.3% in control households, and although fish consumption decreased as a proportion of total fish production in the intervention group, larger absolute volumes of fish were consumed. Total consumption of self-produced fish in intervention households was significantly higher than that of control households.

The study also suggested a positive effect of women's participation. In the small number (5%) of intervention fish ponds where women were principal producers, household production was 12% greater than male operated ponds and household fish consumption was also greater (1.84 vs. 1.79 kg/capita/month).

One moderate quality study examining the effectiveness of a homestead gardening project in Vietnam which included the promotion of fishponds found increased production and consumption of fish in the intervention group at follow-up (English et al. 1997/English and Badcock 1998 [OBS; →]). However, the statistical significance of this finding was not tested.

A low quality study in Bangladesh, which used a control group that was much smaller than the intervention group and did not describe how this group was matched to the intervention group, indicated that there was no difference in fish intake between fish-producing households and non-fish producing households (Roos et al. 2003 [QEX; ↓]).

II. Intake of micro and macro nutrients

One high quality study undertaken in Bangladesh examined the impact of household fish-farming on nutrient intake. It showed a negative impact of group fish-farming on overall nutrient intake compared to a positive impact on nutrient intake in those farming individual ponds. A second study showed increased consumption of macronutrients in children aged five years and under, but it is not possible to separate the effects of fish ponds from gardens.

The study examining the impact of group-fish farming and individual-pond-farming also investigated the effect on nutrient intake (Kumar and Quisumbing 2011 [QEX→; Bangladesh]). In households with group-fish ponds, adverse impacts on nutrient intake were noted. The number of household members consuming less than the recommended daily amount (RDA) of energy and protein increased, and the proportion of women consuming less than the RDA of iron increased.

In contrast, some positive impacts and no negative impacts on nutrient intake were noted in families with individual ponds. Whilst children's nutrient consumption did not significantly increase, total protein, iron and vitamin A consumption increased in men and total energy, protein and vitamin A consumption increased for women over the study period.

In part, these differences between group and individual fish pond farming households may be attributed to increased income and consumption expenditure amongst individual pond farming households compared to group-pond farming households (see below).

In Vietnam, English and Badcock (1998 [OBS; →]) recorded significantly higher intake of energy and protein but not fat in children five years of age and under from households that participated in a home gardening intervention that promoted fish ponds compared to children from households that did not. At household level, average consumption per person of fat, but not total energy or protein, was higher in project households. However, it is not possible to separate the effects of fish ponds from gardens.

III. Household income and expenditure

Two studies, one moderate and one high quality report data on household income and expenditure. Both studies report positive impacts of fish-farming on household income. The evidence comes from Bangladesh.

Following the introduction of an aquaculture development project in Bangladesh, significant increases in the average annual income of project farmers were observed when compared to a control group of fish farmers (Murshed-e-Jahan et al. 2010 [QEX; →]). Project farmers received three years of continuous training on aquaculture development while the control group of fish farmers did not receive this intervention. The annual income growth rate for farmers receiving the intervention was 8.1% year compared with 0.9% year for control farmers. The difference is mainly accounted for by increases in farm and fish income: increased productivity amongst intervention households led to a higher quantity of fish sold at market by intervention households, and no significant income increases were observed from other activities between project and control groups. An increase in the total number employed (family and hired labour) was significantly higher on project farms, and labour productivity and returns to family labour was significantly higher in the project households.

Despite an initial short-term increase, Kumar and Quisumbing (2011 [QEX→) reported no long-term increase in income amongst group fish pond farmers in a study undertaken in Bangladesh, probably because benefits from group ponds were shared across several families. The situation was the reverse for individual fish pond farmers. Despite short term decreases in consumption expenditure and asset holdings, they returned a significantly increased per-capita fish pond income in the long-run and showed substantial increases in consumption expenditure.

IV. Morbidity

An observational study in Vietnam reported significantly reduced incidence and severity of acute respiratory infections and incidence of diarrhoeal disease in preschool children compared to controls following promotion of home gardening and fish ponds (English et al. 1997 [OBS; →]). However, it is not possible to separate the effects of fish ponds from gardens.

3. Other outcomes

No studies report data on cost effectiveness, gender roles and responsibilities, or impact on care practices.

I. Sustainability

One study reports long-term impacts of fish-farming from ponds managed by groups of households or owned by individual households. Some positive long-term outcomes are recorded for secondary nutrition outcomes, particularly from individual pond fish-farming.

The evidence base for the long-term impacts of household fish-farming is limited to one study (Kumar and Quisumbing 2011 [QEX→; Bangladesh]). Kumar and

Quisumbing compared data collected in 1996/1997 and 2006/2007 and showed that long-term impacts are different across interventions and may differ from short-term impacts. However, this may not be a true test of sustainability because it is not clear that all intervention activities had ceased by follow-up data collection.

Kumar and Quisumbing reported some long-term impacts on primary and secondary nutrition outcomes of individually operated, household pond sites. Household consumption expenditure and income increased despite negative short term impacts from up-front costs of adopting the technology, and these households showed significant reductions in the proportion of members consuming less than RDA of protein, energy and vitamin A. However, long-term impacts on nutritional status amongst adults and children were mixed (see p32).

In contrast, no significant long-term outcomes were recorded for households participating in group fish pond sites on consumption expenditure or income, despite short-term income gains. Moreover, in the long-term the proportion of household members consuming less than the RDA of calories and protein increased, and the proportion of women consuming less than the RDA of iron increased. As reported above, long-term impacts on nutritional status were mixed (p32).

II. Knowledge

English et al. (1997 [OBS; →]) studied the effect of a programme promoting the establishment and improvement of household gardens combining horticulture, pond culture of fish and other aquatic animals and small-animal husbandry. The programme included nutrition education and small group activities for mothers of children five years of age and under. Mothers who had participated in the education programme demonstrated a better understanding of good nutrition and of vitamin A than those in the control commune.

C. Livestock production

This section considers evidence on the contribution of household livestock production as a strategy for improving household or individual nutrition outcomes.

The basic pathway between home livestock production and improved nutrition is similar to that for home gardening (see p21). Essentially, livestock or livestock produce may be: directly consumed; sold, with the income generated spent on food (or relevant inputs such as health services); or a mix of both.
Overview of the evidence base

Six studies on the impact of household-level livestock interventions on nutritional outcomes are included. Overall, the evidence base is of low quality: of the six studies, one is rated moderate quality and five are rated low. All studies are observational. Two reports considered evidence from small-scale livestock interventions embedded in homestead gardening interventions. These studies were carried out in South East Asia (Cambodia and Thailand). The remainder were stand-alone interventions involving poultry, cows or goats taking place in Africa (Ethiopia, Kenya) and Bangladesh.

Summary

In order to have an impact on nutritional status, a livestock intervention must be successfully adopted by the target population, and animal-source foods must be produced and consumed, or sold to supplement income used to purchase nutritious foods. The included studies have reported outcomes relating to each of these.

Overall, a small body of evidence (five studies) found no consistent impact of livestock interventions on nutritional status. Three studies suggest that livestock interventions may have an impact on production of livestock among stand-alone livestock interventions. Overall, the evidence from six studies does not show that livestock interventions have an impact on consumption at the household level, with the exception of milk consumption in beneficiary households involved in dairy interventions. Four studies suggest a higher income for households participating in livestock interventions.

Evidence on livestock productivity, husbandry and restocking on nutrition outcomes

1. Primary nutrition outcomes

I. Micronutrient status and anthropometry

The impact of livestock interventions on micro-nutrient status and/or anthropometry was addressed by five reports. Two described livestock interventions embedded in household garden interventions, and three reported on stand-alone livestock interventions. Overall, there is no evidence for an effect of livestock interventions on nutritional status in women or children (age range six months to seven years). The finding is broadly consistent, although there are a few exceptions.

A homestead gardening intervention in Cambodia (Olney et al. 2009 [OBS →]) found no significant difference in weight or BMI of women in intervention and control groups. For children under five, there was no significant difference in haemoglobin, anaemia prevalence, or stunting, wasting or underweight.

In Thailand, no significant difference was recorded in height-for-age, weight-for-height and weight-for-age in children aged 1-7 years old from households defined as ‘mixed-gardening families’ compared to ‘non-gardening families’ (Schipani et al. 2002 [OBS;↓). There were also no significant differences in mean haemoglobin, ferritin, or retinol concentrations. However, ‘non-gardening families’ did not provide a true control group for comparison (for example, ‘non-gardening’ families also produced food for home consumption). Additionally, the disaggregated effect or absence of effect of livestock cannot be determined in these studies because the livestock aspect of the intervention was embedded in a home garden intervention.

Amongst standalone livestock studies, in a dairy goat development project in Ethiopia that identified women's groups and offered them training and goats (local breeds and/or crossbred dairy goats), there was no difference in adult BMI or prevalence of wasting in children under five years of age across intervention and control groups, but underweight and stunting in children were higher in the control group (Kassa et al. 2003 [OBS ↓]). However, whilst the highest percentages of stunting and underweight were observed in the control group, stunting and underweight were more severe amongst groups who received cross bred goats than those with only local goats. The study method could not determine the reason for the difference between these two groups. Moreover, the study design was too weak to attribute better outcomes in goat owning households to this intervention.

Two studies from Kenya report contrasting results. Walingo (2009 [OBS; ↓]) reported no statistically significant difference in BMI of women in dairy intervention and control groups, but Hoorweg et al. (2000 [OBS; ↓]) reported a better nutritional status (height-for-age, weight-for-height and weight-for-age) in pre-school children 6-59 months old among dairy development project farmers and customers compared to children in the comparison group. The difference remained after controlling for household income.

2. Secondary nutrition outcomes

No studies report data on household expenditure.

I. Production or ownership of livestock

The impact of livestock interventions on production was addressed by four reports. Three studies of low quality reported positive effects of stand-alone livestock interventions on production of the goods being promoted. One study of moderate quality showed no effect of a livestock intervention embedded in a homestead gardening intervention on production.

A moderate quality study, primarily working with women's groups in Cambodia to incorporate poultry and animal-production activities into a homestead gardening intervention, found no significant difference in the mean number of pigs, ducks or cows owned between intervention and control groups at end line (Olney et al. 2009 [OBS; →]).

A low quality study of the FARM-AFRICA dairy goat project in Ethiopia found that this programme increased milk production (Kassa et al. 2003 [OBS; ↓]). Mean milk production was also found to be higher in the beneficiary group of a cattle development programme focused on women in Kenya (Walingo 2009 [OBS; ↓]). A low quality cross-sectional study compared households taking part in a Participatory Livestock Development Project (PLDP) in Bangladesh with non PLDP-adopting households and found poultry stock and eggs produced and sold to be significantly higher in PLDP-adopting households (Nielsen et al. 2003 [OBS; ↓]).

II. Consumption, nutrient intake and dietary diversity

The impact of livestock interventions on consumption and nutrient intake was addressed by six reports. Overall, the evidence does not show that livestock interventions have an impact on consumption at the household level, with the exception of milk consumption in beneficiary households involved in dairy interventions.

Although a homestead gardening intervention in Cambodia was generally successful in increasing household poultry ownership, there appeared to be no impact on consumption of poultry amongst woman and children under five (Olney et al. 2009 [OBS; →]). A significantly higher proportion of children in the intervention group consumed eggs, liver, and meat (other than chicken) compared with the control group at the end of the intervention, but with the exception of egg consumption, the difference in consumption between groups was not significantly different from that at baseline. An intervention involving mixed gardens with small animals in Thailand reported no significant difference in nutrient intakes between groups (Schipani et al. 2002 [OBS; ↓]). No increase in consumption of animal-source foods rich in vitamin A was seen in the FARM-AFRICA dairy goat project in Ethiopia (Kassa et al. 2003 [OBS; ↓]), and the authors concluded that the intervention was not accompanied by a better use of foods of animal origin, especially milk. No difference in overall diet, and consumption of chicken and eggs specifically, was seen as a result of the PLDP poultry intervention in Bangladesh and consumption was negligible in comparison to other animal-source foods (Nielsen et al. 2003 [OBS; ↓]). However, consumption of fish was higher among PLDP-adopting women and girls aged 5-12 years. The authors suggest this may be because income gained from poultry production was used to buy fish. However, data was not available to confirm this.

There is some evidence that standalone dairy interventions may have more impact. Mean per capita milk consumption by preschool children and for family members was shown to be higher in the beneficiary group compared with the non-beneficiary group for a dairy intervention in Kenya (Walingo 2009 [OBS; ↓]). In the Kenyan DDP project, the average milk consumption of DDP-farmers and DDP-customers was much higher than among the control population (Hoorweg et al. 2000 [OBS; ↓]). The authors' suggest that this low milk consumption amongst control households was because milk was too expensive for these households, although direct data is not offered to support this suggestion. Overall energy and protein intake did not differ significantly between groups.

III. Household income

The impact of livestock interventions on income was addressed by four reports on stand-alone livestock interventions. The evidence suggests a higher income for participatory households as a result of the intervention.

Ethiopian households taking part in the FARM-AFRICA dairy goat project had an increased household income in comparison to control households (Kassa et al. 2003 [OBS; ↓]). In Kenya, the marketed surplus of milk was significantly higher in households of women beneficiaries of a livestock project over those of non-beneficiary women (Walingo 2009 [OBS; ↓]). The mean income from marketed surplus of milk in this study was KShs.181.40 in beneficiary households and KShs.56.19 in non-beneficiary households per day. An increased monthly income was reported in PLDP-adopting households in Bangladesh from the greater production of eggs (Nielsen et al. 2003 [OBS; ↓). A cross-sectional study of a dairy development project (DDP) in Kenya found dairy farmers had a higher income than a rural sample from non-intervention villages as a result of dairy activities (Hoorweg et al. 2000 [OBS; ↓]).

IV. Morbidity

One study reports data on child and maternal morbidity. In a homestead gardening intervention in Cambodia (Olney et al. 2009 [OBS →]), children under five years of age in the intervention group had a lower prevalence of fever in the two weeks prior to the end line survey than children in the control group. There was no significant difference between the two groups in prevalence of diarrhoea in the previous two weeks, and prevalence of measles symptoms in the previous six months. The study also reported no difference in prevalence between the intervention and control groups for maternal diarrhoea.

3. Other outcomes

No studies report data on cost effectiveness, sustainability, gender roles and responsibilities, impact on care practices, or nutrition knowledge.

D. Cash crops

This section reviews evidence for the impact on nutrition outcomes of cash cropping (production of food or non-food crops specifically for sale). The anticipated direct pathway between cash crops and household or individual nutritional status is through using the income generated through crop sales to buy nutritious food for consumption (path B, fig. 2). This path may be complicated by:

- consumption of food cash crops by the producing household
- maintenance or otherwise of food production for household consumption
- patterns of household income control
- increased labour demands made on individuals, notably women, which may in turn affect child feeding and care practices.

Allocation of cash-crop income to non-food expenditure (such as education and healthcare) offers an indirect path to nutrition outcomes (fig. 2, path C). The evidence base discussed has data on the direct path A and (to a lesser extent) on patterns of food versus non-food expenditure which may be used to infer relative expenditure on paths B and C. However, there is no date within these studies on path C between non-food expenditure and nutritional status[6].

Overview of the evidence base

Eight studies are reviewed, four moderate quality and four low quality. All studies are observational, and many analyse national nutrition survey data rather than data collected for the purposes of the study. Most of the studies are from sub-Saharan Africa (five studies), with two studies from Asia (Nepal, Sri Lanka) and one from Guatemala.

Of the eight studies, five concern food cash crops and one a mix of food and non-food crop. For the remaining two, the type of cash crop is not clear or not specified. The evidence base is insufficient to draw conclusions on the relative impacts of food and non-food cash cropping.

Summary

Of seven studies with relevant data, four studies report no overall difference in nutritional status between cash-cropping and non-cash cropping households or

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[6] Additionally, we have no data on possible nutrition impacts within employees/employee households from employment opportunities generated by cash cropping.

individuals. Two other studies report better nutrition outcomes (improved weight-for-age, reduction in stunting) in children ≤ 67 months in cash cropping households compared to non-cash cropping households, but neither study could show the association was a direct impact of cash cropping. One further study reported mixed results.

The evidence base for the impact of cash cropping on micro and macro nutrient intake is limited to three studies. These studies show no association between cash cropping and increased energy intake.

All seven observational studies with relevant data recorded higher income amongst households involved in cash cropping compared to households who were not. Three of these studies have data on household expenditure. These studies suggest that incremental increases in income from cash crops are not spent on food.

Most participants involved in cash-cropping across all studies continued food production for home consumption. Two studies report little or no increased labour demands from cash-cropping.

Evidence on cash crops and nutrition outcomes

1. Primary nutrition outcomes

No studies report data on the impact of cash cropping on micronutrient status.

I. Anthropometry

Seven studies report data on the impact of cash-cropping on anthropometric measures of nutritional status. Four studies report no overall difference in nutritional status between cash-cropping and non-cash cropping households or individuals. Two studies report better nutrition outcomes (improved weight-for-age, reduction in stunting) in children ≤ 67 months in cash cropping households compared to non-cash cropping households, but neither study could show the association was a direct impact of cash cropping. One further study reported mixed results.

Four studies report no overall impact of cash cropping on improved child nutritional status (Haaga et al. 1986 [OBS↓; Kenya], Sharma 1999 [OBS→; Nepal], Immink and Alarcon 1991 [OBS→; Guatemala], Kurth 1989 [OBS↓; Malawi]) or adult nutritional status (Immink and Alarcon 1991).

One study compared four groups: non rice-growers; resident tenants at a large-scale irrigation scheme; non-resident tenants who also farmed elsewhere; and individual rice growers (Neimeijer et al. 1988 [OBS;↓]). Rice production was primarily produced for cash purposes. Overall, children aged 6-47 months of resident tenants had the poorest nutritional status. Resident tenants had higher levels of stunting than the other three groups, which were broadly similar. Average weight-for-height was relatively high amongst non-resident tenants and there were no wasted children in this group. Among the three other groups the percentage of wasted children varied between 5% (non-rice growers and resident tenants) and 15% (individual rice growers). Incidence of underweight was highest amongst children of resident tenants. Adverse outcomes for resident tenants may be explained by their almost total reliance on a rice cash crop (see below).

Two studies report improvements in nutrition outcomes in children in cash-cropping households, compared to children from households not involved in cash-cropping. In these two studies it is difficult to determine the pathway between cash crops and nutritional status. A study from Sri Lanka recorded significant improvement in pre-school children's weight-for-age in households involved in a paddy development scheme (Holmboe-Ottesen et al. 1989 [OBS;→]). However, the project design could not exclude impact on improved nutritional status of project children from factors other than the intervention. In the second study, using cross-sectional survey data collected in Swaziland, commercial maize farming was associated with a reduction in stunting in children 67 months old and under compared to subsistence maize farming, but so were rainfall, homestead size and adult employment (Huss-Ashmore and Curry 1989 [OBS; →]). This study could not assess the relative contribution of these factors to nutrition outcomes. Additionally, commercial production was not associated with improved weight-for-age or other anthropometric indicators for children or anthropometric measures for women.

Some studies show that factors other than cash-cropping have a stronger relationship with nutritional status than cash-crops. For example, a study of a cash crop programme in Western Nepal, Sharma (1999 [OBS→]) showed that households that participated in the programme showed improvements in children's weight-for-age and weight-for-height. However, multivariate regression showed that these improvements were not a consequence of the programme, but were associated with household, mother and child characteristics (e.g. mother and child's age, mother's education, household size). A general survey of such factors that contribute to nutritional status is beyond the scope of the present paper, but it is worth noting that several other retained studies show associations between non-agriculture and non-cash crop variables and nutrition outcomes (e.g. Kennedy and Cogill 1988 [OBS;↓]).

2. Secondary nutrition outcomes

No studies report data on general consumption or dietary diversity.

I. Production

Most participants involved in cash-cropping across all studies continued food production for household consumption. Two studies report little or no increased labour demands from cash-cropping.

One study has data on comparative production between beneficiaries and non-beneficiaries in a cash crop project. This study reports data on rice yield following a paddy cultivation project in Southern Sri Lanka (Holmboe-Ottesen et al. 1989 [OBS;→]). Farmers participating in the project had almost double the yield of those who did not participate.

Further studies consider resource allocation between cash and subsistence crops within cash cropping households. Most participants involved in cash-cropping across all studies continued food production for household consumption. Two studies report data on the relative household resources allocated to cash crop and subsistence crop production, and one further study reports data on an almost wholesale shift to cash cropping away from subsistence agriculture amongst some participants.

Sharma (1999 [OBS; →]) reported that among project households in a study in Nepal, cash crops accounted for 25% of cultivated land and 25% of household labour allocated to agriculture, suggesting that 75% of these resources were spent on agriculture for home consumption. Kennedy and Cogill (1988 [OBS;↓]) in a study undertaken in Kenya reported that the area of land used for staple food production was very similar for commercial sugar farmers as it was for non-sugar farmers, although the total area of land under crops was significantly higher amongst sugar growers.

Neimeijer et al. (1988 [OBS;↓]) reports data from Kenya on adverse effects from almost total reliance on a rice cash crop. As described above, this study compared non rice-growers, resident tenants at a large-scale irrigation scheme, non-resident tenants who also farmed elsewhere and individual rice growers. The resident tenants who had the lowest food production for home consumption had the narrowest resource base, and depended almost totally on the income earned from rice. This group had the worst nutrition outcomes in terms of child stunting and household and child energy intake. Other groups had a more diverse resource base, including production of other crops and livestock, including for home consumption, and income from off-farm employment. Non-resident tenant farmers had the most favourable nutrition outcome and the most diverse resource base, which suggests that it is not cash-cropping as such that had detrimental nutritional effects for the resident tenants, but almost exclusive reliance on it to support household nutrition needs. However, the study could not exclude alternative explanations for poor outcomes amongst resident tenant farmers (such as insufficient purchase of food, or purchase of food of low nutrition value).

II. Intake of micro and macro nutrients

The evidence base for the impact of cash cropping on micro and macro nutrient intake is limited to three moderate or low quality studies. These studies show no association between cash cropping and increased energy intake.

Three studies report data on energy consumption. Kennedy and Cogill (1988 [OBS↓; Kenya]) report no significant differences between commercial sugar farmers and non-sugar farmers in the number of days of calories in storage or the mean energy intake per adult equivalent in the household. Holmboe-Ottesen et al. (1989 [OBS;→]) evaluated a rural development programme focused on raising the productivity of paddy cultivation. Overall, project farmers and farmers outside the project area recorded no significant difference in energy intake from the three recorded staple foods (rice, coconut, sugar). In the study comparing different categories of rice farmer in Kenya (Neimeijer et al. 1988 [OBS;↓]), at compound level and amongst children aged 6-47 months in those compounds, resident tenants had the lowest energy intake with the other three groups recording substantially higher energy intakes (statistical significance not tested). This pattern is repeated for protein and iron intake in children, with children of resident tenants having the lowest recorded intake. Calcium intake differed slightly from this pattern, with children of resident tenants and non-rice growers recording low intake levels compared to individual rice growers and non-resident tenants.

III. Household income and expenditure

All seven studies with relevant data recorded higher income amongst households involved in cash cropping compared to households who were not. The evidence is observational, of moderate or low quality, consistent and from Asia and sub-Saharan Africa (plus one study from Latin America). Three of

these studies have data on household expenditure. These studies suggest that incremental increases in income from cash crops are not spent on food.

Seven studies recorded higher income amongst households involved in cash cropping compared to households who were not (Holmboe-Ottesen et al. 1989 [OBS→; Sri Lanka]), Immink and Alarcon 1991 [OBS→; Guatemala]), Neiemeijer et al. 1988 [OBS↓; Kenya], Kennedy and Cogill, Haaga et al. 1986 [OBS↓; Kenya]), Kurth 1989 [OBS↓; Malawi], Sharma 1999 [OBS→; Nepal]).

Three studies have data on cash crop income spending decisions (Kennedy and Cogill 1988 [OBS↓; Kenya], Sharma 1999 [OBS→; Nepal], Immink and Alarcon 1991 [OBS→; Guatemala]). These studies suggest that incremental increases in income from cash crops are not spent on food. For example, in Kenya, commercial sugar cane producing families had incomes 2 to 2.5 times higher than non-sugar farmers and 73% of the difference in agricultural sales between sugar and non-sugar farmers was attributed to sugar production (Kennedy and Cogill 1988 [OBS↓]). For sugar farmers, 36% of their total income came from agricultural sales compared to 20% for non-sugar farmers. But household expenditure on food was not statistically significantly different between the two groups and for all farmers an annual income increase of 100 KSh (6.25 USD) resulted in household caloric intake increase of two calories, equivalent to 18 calories per equivalent adult per day in sugar farming households. Similarly, Sharma (1999 [OBS→; Nepal]) and Immink and Alarcon (1991 [OBS→; Guatemala) record no significant increase in food expenditure amongst cash-cropping versus non cash-cropping households. This suggests that the additional income is allocated to non-food expenses, although none of the included studies had data to show what these other expenses were.

IV. Morbidity

One observational study from Sri Lanka reports data on disease patterns (Holmboe-Ottesen et al. 1989 [OBS;→]). Holmboe-Ottesen et al. evaluated a rural development programme focused on raising the productivity of paddy cultivation. The percentage of households reporting a pre-school child with cold and fever symptoms and diarrhoea rose in project and non-project areas, with project households showing the greatest increase. However, only project households reported a decrease in intestinal-worm infections. There was no difference between project and non-project households in reported malaria and abscess.

3. Other outcomes

No studies report data on cost effectiveness, sustainability or nutrition knowledge.

I. Gender roles and responsibilities

Income from cash crops may be spent differently depending on who in the household controls that income (Kurth 1989). One study reports some data on gender spending responsibilities. In Kenya, 79% of respondents participating in a sugar-growing scheme reported that men controlled income from sugarcane production, and 76% reported that women were responsible for food expenditure (Kennedy and Cogill 1988 [OBS;↓]).

II. Impact on care practices

No study has data on direct impacts of cash-cropping on care practices. However, two studies report data on impacts on household labour allocation. Both studies report little or no increased labour demands from cash-cropping.

It is plausible that labour invested in cash cropping reduces time available for child care, or is otherwise detrimental to individual (mother, child) nutrition outcomes, mitigating the potential benefit of increased income on nutrition intake. Two studies report data on the direct impact of cash-cropping on household labour allocation (Sharma 1999 [OBS→; Nepal], Kennedy and Cogill 1988 [OBS↓; Kenya]). Both studies report little or no increased labour demands from cash-cropping, although neither study has direct data on care practices.

The situation reported by Kennedy and Cogill (1988) undertaken in Kenya is quite specific. Kennedy and Cogill showed that the amount of household labour supplied for all crops was not significantly different between sugar and non-sugar farmers, despite significantly greater land under crops in former group. This was because sugar was produced under contract for a sugar factory, and the factory supplied labour to the farmer. This enabled an increase in the proportion of land in production without additional demands on household labour.

In the second study undertaken in Nepal, Sharma (1999) showed that for the whole sample, mother's time spent in agriculture was negatively associated with children's weight for age and weight for height. However, cash crop project and non-project mothers spent a similar time in all agriculture activities, and cash crop activities accounted for 10% of women's time in agriculture. This suggests the negative association cannot be attributed to cash cropping alone.

Although there is no evidence available that cash-cropping increased labour demands in a manner detrimental to nutrition outcomes, two studies recorded a positive association between household size and child nutrition outcomes (Sharma 1999 [OBS→; Nepal], Huss-Ashmore and Curry 1989 [OBS→; Swaziland]). Sharma (1999) suggests this positive association can be attributed to a larger amount of time available for child care in large families.

E. Biofortified crops

Biofortification (improving the nutritional quality of food crops) is a strategy to address households' poor access to nutritious food (Gunaratna et al. 2010). Biofortified crops may be produced for home consumption or as a cash crop.
Overview of the evidence base.

This section has reviewed eight studies relating to the impact on nutrition outcomes of the introduction of three biofortified crops: orange-fleshed sweet potato (OFSP – varieties of sweet potato particularly rich in beta-carotene or pro-vitamin A; three studies); quality protein maize (QPM – a variety of maize containing protein of improved amino acid composition than that present in normal maize; three studies); and iron, or iron and zinc biofortified pearl millet (two studies).

Two of the reports (Low 2007 et al. and Low et al. 2007a) consider the same intervention and have been treated as one study. One report (Akalu et al. 2010) considers two separate intervention studies. The evidence base is of moderate quality overall. Of the eight studies, one was high quality, six are moderate quality and one is low quality. Six of the studies are experimental and two are quasi-experimental. Six studies were undertaken in sub-Saharan Africa (Mozambique, Uganda, Ethiopia, Benin) and two in India.

Four of the studies target household production and consumption of biofortified crops, one study targets both household production and commercial production, and three studies use biofortified foods as food supplements.

Summary

There is a small body (three studies) of moderate quality evidence that biofortified crops improve nutritional status of children (age range 22 months-5 years). Two studies on OFSP reported a positive effect of OFSP consumption on vitamin A status among children. One study on biofortified millet reports increased absorption in children of iron and zinc from millet biofortified with both micronutrients.

Two studies report on the impact of biofortified crops on women's micronutrient status. A study on biofortified millet records increased iron absorption rates compared to regular millet. The other study records no reduction in prevalence of vitamin A deficiency among women consuming OFSP.

All three studies on QPM reported a positive effect of QPM intake on weight and height growth.

Three OFSP studies measured dietary intake of biofortified crops and/or nutrient intakes. These studies report increased OFSP consumption and greater dietary intake of pro-vitamin A in children (≤ 5.5 years) and adults.

In the OFSP studies, OFSP was promoted in rural populations commonly consuming white-fleshed sweet potato (WFSP). These studies reported good uptake and acceptability of the crops by producers and consumers. None of the QPM studies reported findings related to the impact of the intervention on the adoption or consumption of QPM.

Evidence on biofortification and nutrition outcomes

1. **Primary nutrition outcomes**

   I. **Micronutrient status**

There is a small body (three studies) of moderate quality evidence that biofortified crops improve nutritional status of children (age range 22 months-5 years). Two studies on OFSP reported a positive effect of OFSP consumption on vitamin A status among children. One study on biofortified millet reports increased absorption of iron and zinc from millet biofortified with both micronutrients in children.

Two studies report on the impact of biofortified crops on women's micronutrient status. A study on biofortified millet records increased iron absorption rates compared to regular millet. The other study records no

reduction in prevalence of vitamin A deficiency among women consuming OFSP.

In Uganda, increased vitamin A intake from OFSP significantly increased vitamin A status at follow up in children aged 3-5 years, but no change in mean serum retinol was observed among women (Hotz et al. 2012 [EXP; →]). The intervention also significantly reduced the prevalence of marginal vitamin A status in children. The intervention did not reduce the prevalence of vitamin A deficiency among women. An OFSP intervention in Mozambique (Low et al. 2007 and Low et al. 2007a [QEX; →]) identified a fall in the prevalence of low serum retinol concentrations from 60% at baseline to 38% at endline in children in the intervention group with no change in control group (mean age 13 months at baseline).

Two studies report positive impact on nutritional status from consuming biofortified millet. A randomised crossover trial involving women in Benin with marginal iron status reported a doubling of total iron absorbed from meals with iron-biofortified millet compared to regular millet (Cercamondi et al. 2013 [EXP; →]). A double-blind randomised controlled trial involving children aged 22-35 months in India recorded iron and zinc absorption from pearl millet biofortified with both micronutrients (Kodkany et al. 2013 [EXP; ↑]). Absorption of both iron and zinc from test meals was significantly higher than from non-biofortified millet, and exceeded estimated physiological requirements.

II. Anthropometry

All three studies on QPM reported a positive effect of QPM intake on weight and height growth in populations with mild to moderate undernutrition at baseline who habitually consumed maize-based diets.

Two randomised controlled studies (one a cluster RCT and one a RCT) of QPM seed dissemination and promotion in Ethiopia are reported by Akalu et al. (2010 [EXP →]). In the first study (cRCT), height-for-age and weight-for-age of children aged 5-29 months did not differ significantly between children from QPM (intervention) and conventional maize (control) growing households. However, mean weight-for-height decreased significantly in the control group over the course of the 13-month study, but did not differ significantly from baseline in the intervention group. In the second study, weight-for-height and BMI of children aged 7-56 months did not differ significantly between children from intervention and control households. Mean height-for-age and weight-for-age decreased significantly in the control group but did not change significantly in the intervention group over the course of the study.

A non-randomised intervention study compared diets supplemented with QPM, conventional maize or milk with control diets for children in low-income families in India. Children aged 18-30 months who received QPM supplementation had increased weight growth compared to children in other intervention arms and the control arm, and QPM supplementation was comparable to milk supplementation and superior to conventional maize and no intervention in its beneficial effects on weight-for-height and length growth (Singh et al. 1980 [QEX ↓]). Average gain in head, chest and mid-arm circumferences was greater for the QPM group than conventional maize and control groups, but not as great compared to milk supplementation.

2. Secondary nutrition outcomes

No studies report data on production, dietary diversity, household income and expenditure, or morbidity.

I. Consumption and nutrient intake

Three studies (all on OFSP) measured dietary intake of biofortified crops and/or nutrient intakes. These studies report that interventions that increased access to OFSP resulted in increased OFSP consumption and greater dietary intake of pro-vitamin A in children (≤ 5.5 years) and adults.

A significant net increase in the consumption of OFSP was reported in women and children aged 6 months to 5 years in intervention groups relative to control groups in Uganda (Hotz et al. 2012 [EXP, →]). In the intervention group 31-38 % of all sweet potato eaten (across age-groups) was OFSP, compared with 4% in control group. An increased intake of vitamin A was recorded for women and children. In Mozambique (Hotz et al. 2011 [EXP, →]) OFSP consumption was reported at baseline (approximately 14% of all sweet potato consumed). After the intervention, OFSP consumption was significantly greater in intervention groups relative to the control groups. An increase in vitamin A intakes in women and children aged 6 months to 5.5 years was demonstrated in the intervention groups compared with control groups. OFSP was the dominant source of pro-vitamin A in the diets of intervention households. Energy intake did not differ between intervention and control groups at baseline or follow-up.

Finally, over the course of the study, Low et al. (2007 [QEX →]) identified an increase in consumption by children (mean age 13 months at baseline) of OFSP in Mozambique in both intervention and control groups but the size of the increase was significantly greater in the intervention group (54% of intervention children vs. 4-8% of control children had consumed OFSP on three or more days in the previous week). The vitamin A intakes of children in the intervention group were nearly eight times higher than those in the control group. Dietary diversity was also significantly greater amongst the intervention group, with 32% consuming food from more than four groups compared with 9% in the control group.

Uptake and acceptance of biofortified crops

Uptake and acceptability of biofortified crops were addressed by four reports: three on OFSP (one in Uganda and two in Mozambique) and one on QPM in Ethiopia. All three OFSP studies reported good uptake and acceptability of the crops by producers and consumers. The evidence on the acceptability of QPM primarily supported its favourable growing and storage traits.

In a cluster randomised controlled trial comparing the effectiveness of two models of agricultural extension, demand creation and behaviour change (one intensive, one reduced) in Uganda, there was no evidence to indicate that the change of colour of sweet potato from white to orange was met with resistance by rural farming households (Hotz et al. 2012 [EXP; →]). OFSP replaced one-third of usual sweet-potato intake and OFSP was widely produced and consumed at the household level after two years. This study found no additional advantage from a more intensive period of agricultural extension on adoption and intake of OFSP (see below). A second cluster randomised controlled trial, conducted in Mozambique, reported that the orange colour of the new sweet potato variety was not a barrier to adoption (Hotz et al. 2011 [EXP; →]). An average of 77% of households across the intervention groups adopted OFSP for cultivation by the end of the study, and by the end of the study among all households growing sweet potato 56% were OFSP.

OFSP was found to be acceptable to farmers when introduced using an integrated approach in a quasi-experimental study in Mozambique (Low et al. 2007 and Low et al. 2007a [QEX →]). 90%of intervention households were found to be cultivating OFSP in the second year of the intervention compared with 5% at baseline and of these, 86% reported higher yields with OFSP than previous sweet potato cultivars. The percentage of intervention households selling sweet potatoes increased from 13% at baseline to 30% at follow-up and a consumer survey of 114 individuals in two markets found 43% had purchased OFSP.

Farmers who took part in two randomised controlled studies in Ethopia (Akalu et al. 2010 [EXP →]) reported favourable traits of QPM over conventional maize varieties such as resistance to weevils, and earlier maturity. Early maturity led to increased yields during earlier harvests, but decreased yields during a normal rainy season. Families and children also responded positively to QPM for its taste and cooking qualities.

3. Other outcomes

No studies report data on gender roles and responsibilities, impact on care practices, or nutrition knowledge.

I. Cost effectiveness and sustainability

Hotz et al. (2011 [EXP→; Mozambique]) and Hotz et al. (2012 [EXP→; Uganda]) report data related to sustainability and cost-effectiveness. Both studies compared intensive and less intensive intervention designs within a randomised, controlled effectiveness study.

In both studies, the intervention comprised three components: an agricultural component consisting of agricultural training and the distribution of OFSP vines and planting material; a demand creation/behaviour change component including education on child and maternal health and nutrition targeted at women and a public campaign to raise awareness of the benefits of OFSP; and a marketing and product development component including training for traders and development of a market for OFSP.

In year one, all groups received all three components; for the following year (Hotz et al. 2011) or two years (Hotz et al. 2012) the agriculture training and health and nutrition education components, as well as support from agriculture and nutrition extentionists, continued only in intensive programme groups.

Both studies reported no difference in adoption and intake of OFSP between the intensive and less-intensive groups. The authors suggest that the additional cost of maintaining direct, community-level contact by project staff beyond the 1st year of intervention is not justified.

One further study has data on relative costs of diets supplemented with QPM, conventional maize or milk (Singh et al. 1980 [QEX ↓]). OPM was 80% cheaper than milk per gram of utilizable protein. OPM also had lower production costs.

4. Evidence gaps and current, planned and emerging research areas

1. Evidence gaps

Overall, the evidence base on nutrition sensitive agricultural interventions is small with few high quality studies. This observation is in line with other recent reviews (Girard et al. 2012, Masset et al. 2012, Ruel et al. 2013). Over and above the general call for more high quality studies in all areas, some more specific evidence gaps emerged through the present review. Evidence gaps that relate to specific interventions are noted in the main text, and throughout we have noted when there is a paucity of studies, a lack of high quality studies, or limited geographical or contextual spread. Ruel et al. (2013) and Girard et al. (2012) also give summaries of specific evidence gaps and priorities for future research, including nutrition-sensitive agricultural interventions in combination with other forms of nutrition-sensitive or nutrition-specific interventions. Therefore in this section we note some gaps in the evidence base that emerged across interventions and which, if filled, would inform policy and programming decisions:

- **Cost effectiveness:** Our retained evidence base contains only two studies with data on cost effectiveness, both on biofortified crops.
- **Comparative data across nutrition-sensitive agriculture interventions:** We divide direct agricultural interventions into five categories (home gardening, aquaculture, livestock production, cash cropping and biofortification). Some studies reviewed combined different interventions. Often, data on primary nutrition outcomes could not be disaggregated by intervention type to assess the contribution of each intervention (this issue is less pronounced for some secondary outcomes, notably consumption patterns). At the same time, the majority of studies reviewed implemented a single form of intervention. Overall therefore, there is little data with which to make meaningful, comparative assessments across our five classes of intervention.
- **Sustainability:** Few studies report data on the sustainability of intervention impacts, in terms of the continuation of an intervention or its effects.
- **Role of women:** No studies compare the relative effects of targeting women versus men, and few studies report data of effects on issues such as women’s labour, time for caring, and empowerment, and how these might mediate in pathways between agricultural interventions and maternal or child nutrition.
- **Qualitative data:** Few studies report comprehensive qualitative data that might help explain barriers and incentives for adoption of different

interventions, throw light on why interventions did or did not improve nutrition outcomes.

2. Current and planned research areas

Hawkes et al. (2012) reviewed current and planned research projects on agriculture for improved nutrition. Whilst they did not appraise the quality of these research projects, the review does show in broad terms the evidence that is in the pipeline (although no timeframe for release of results is given). A total of 151 projects and programmes were identified that met the exclusion criteria. Main findings relevant to topics covered in the present review are:

- A strong emphasis on sub-Saharan Africa (n=93), followed by South Asia (n=36) and South East and East Asia (n=17)
- 66 projects concern increased production and availability of nutritious foods as a means to improving nutrition outcomes
- 73 projects focus on improving production and consumption of nutritious foods
- 27 projects are biofortification projects, either crop breeding programmes (n=17) or concerned with introducing biofortified crops into the food value chain (n=10)
- 46 projects target children, and 46 target women

Hawkes et al. also noted four projects that explore the impact of aflatoxin contamination on nutrition, and another set of studies concerned with agricultural growth generally and its effect on development, the food environment and nutrition (n=21), and agriculture nutrition alongside other policy areas such as the economy (n=7). As part of the present review we looked at two of these areas of emerging evidence: the impact of aflatoxin contamination on nutrition, and on links between food prices and nutrition outcomes.

3. Emerging research areas

I. Aflatoxin control

The United Nations Food and Agriculture Organisation estimates that 25% of the world's food crops are contaminated with toxins produced by fungi (mycotoxins), especially those produced by Aspergillus and Fusarium species, affecting up to 4.5 billion people (Williams 2004). These toxin-producing fungi are abundant in agricultural soils, and food crops such as maize and groundnuts are susceptible to fungal infection during harvest and storage especially in Africa and Asia.

Agricultural practices including timely planting, maintaining optimal plant densities, proper plant nutrition, avoiding drought stress, controlling other plant pathogens, weeds and insect pests, crop rotation and management of crop residues can reduce mycotoxin levels in crops. Breeding crops specifically to reduce the risk of fungal infestation (Widstrom, Guo and Wilson, 2003; Cary et al. 2011; Brown et al. 2010), and biocontrol strategies including the application of competitive non-toxigenic strains of Aspergillus (Dorner 2009) are primary areas of mycotoxin control research.

Aflatoxins are among the most potent naturally occurring liver carcinogen and chronic exposure to aflatoxins is directly linked to a significant global burden of liver cancer

(Liu and Wu 2010). However, there is now also an emerging body of evidence on the link between mycotoxin exposure and childhood nutritional status.

Pregnant and lactating women exposed to mycotoxins in their diet appear to transmit these toxins to their infants in utero and via breastmilk and this has been identified as a risk factor for reduced birth weight and birth length and growth in early childhood (Khlangwiset et al. 2011; Turner et al. 2007; Shuaib et al, 2010; Sadeghi et al. 2009; Mahdavi et al. 2010). Significant negative associations between blood markers of aflatoxin exposure and measures of child growth were identified in a cross-sectional study of 480 children aged under five years in Benin and Togo (Gong et al. 2002 in BMJ and Gong et al. 2003 in IJE). However a cross-sectional study in the Gambia among 472 children aged 6 to 9 years found that aflatoxin exposure was only weakly negatively associated with weight for height and not associated with either height for age or weight for age (Turner et al. 2003). Finally, a longitudinal study that followed 200 children aged 16-37 months in Benin for eight months found a strong negative correlation between aflatoxin exposure and height growth (Gong et al. 2004). Children in the highest quartile of aflatoxin-albumin adduct concentrations grew 1.7cm less over the eight month period than those with the lowest levels.

The current body of observational studies is suggestive of an association between aflatoxin exposure in utero and early childhood and reduced child growth and there is little robust evidence demonstrating a direct impact of mycotoxin exposure on nutrition outcomes. The underlying biological mechanisms for these effects of aflatoxins are largely unknown and are the subject of significant current research interest.

II. Agriculture-related food-price policies

Food prices are a key driver of dietary intake patterns, and high food prices are likely to have a significant impact on nutrition outcomes and health especially among poor people (Green et al. 2013). Estimates from the United Nations Food and Agriculture Organization (FAO) suggest that the global food price crisis of 2007-2008 pushed an additional 40 million people into hunger, and also negatively affected the diversity of diets (FAO 2008). In contrast, in some wealthy countries fiscal measures to change relative food prices are being attempted to promote the consumption of healthy diets. Simulation studies suggest that taxes on sugar-sweetened beverages, saturated fats and salt may reduce obesity and cardiovascular mortality (Andreyeva 2011, Allais 2010).

Agricultural policies have the potential to change food prices and thereby nutrition outcomes. Particularly relevant are agricultural policies broadly labelled output market interventions, including policies that influence the price of food production, and policies that affect trade liberalisation and public food distribution systems. In theory, these policies have the ability to act on measures of both undernutrition and over-nutrition, and given their national scale if they can be designed to be more sensitive to nutrition outcomes, the potential for benefits may be significant.

However, there is currently very little information on their ability to modifying nutrition outcomes and this is an area where more evidence is urgently needed. A systematic review of the published and unpublished evidence evaluating the impact of agricultural price policies on nutritional outcomes identified only four relevant papers (Green et al. 2013). Only one of these studies focussed on undernutrition and reported an *ex post* evaluation from the Indian state of Andhra Pradesh on the impact of a public distribution system on children's nutritional status (Tarozzi 2005). This analysis investigated the impact of a sharp increase in subsidised rice prices and found no evidence for an association between length of time spent in a high-rice price regime and child nutritional status as assessed by weight-for-age.

Three studies focused on the impact of agricultural output price policies on nutrition-related chronic disease: two were *ex ante* modelling studies, one from The Netherlands (Veerman 2006) and one from the US (Rickard 2011), and one was an *ex post* evaluation of a public distribution system policy in Egypt (Asfaw 2007). The analyses provide some support for the idea that changing the price of foods at a national level via agricultural price policies can effect outcomes including obesity and the prevalence of nutrition related chronic disease.

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Annex 1: Outcomes reported in retained studies

Primary outcomes						
	Micronutrient status		**Anthropometry**			
	Clinical signs of micronutrient deficiency	Biochemical assessment of micronutrient status	Height-for-age (stunting)	Weight-for-height (wasting)	Weight-for-age (underweight)	Other
Intervention: home gardens						
Bushamuka et al. 2005						
de Pee et al. 1998		Y				
English et al. 1997/ English and Badcock 1998	Collected, but not reported	Collected, but not reported	Y	Y		
Faber et al. 2002/2002a		Y	Y	Y	Y	
Greiner and Mitra 1995						
Hagenimana et al. 2001						
Jones et al. 2005						
Kerr et al. 2007						
Kerr et al. 2010					Y	
Kidala et al. 2000		Y				
Kumar and Quisumbing 2011		Y	Y			Y
Laurie and Faber 2008						
Olney et al. 2009		Y	Y	Y	Y	Y
Schipani et al. 2002		Y	Y	Y	Y	
Schmidt and Vorster 1995		Y	Y	Y	Y	
Intervention: Aquaculture						
Aiga et al. 2009			Y	Y	Y	
English and Badcock 1998			Y	Y		
Kumar and Quisumbing 2011		Y	Y			Y
Murshed-e-Jahan et al.						

2010						
Roos et al. 2003						
Intervention: Livestock						
Hoorweg et al. 2000			Y	Y	Y	
Kassa et al. 2003			Y	Y	Y	Y
Nielsen et al. 2003						
Olney et al. 2009		Y	Y	Y	Y	Y
Schipani et al. 2002		Y	Y	Y	Y	
Walingo 2009						Y
Intervention: Cash Cropping						
Haaga et al. 1986			Y			
Holmboe-Ottesen et al. 1989			Y	Y	Y	
Huss-Ashmore and Curry 1989			Y		Y	Y
Immink and Alarcon 1991			Y			
Kennedy and Cogill 1988						
Kurth 1989			Y			
Niemiejer et al. 1988			Y	Y	Y	
Sharma 1999			Y	Y	Y	
Intervention: Biofortification						
Akalu et al. (cRCT) 2010			Y	Y	Y	
Akalu et al. (RCT) 2010			Y	Y	Y	Y
Cercamondi et al. 2013		Y				
Hotz et al. 2011						
Hotz et al. 2012		Y				
Kodkany et al. 2013		Y				
Low et al. 2007		Y				
Singh et al. 1980				Y		Y

Secondary outcomes								
		Dietary intake						
	Agricultural production	Consumption	Macronutrient	Micronutrient	Dietary diversity	Household income	Household expenditure	Morbidity
Intervention: home gardens								
Bushamuka et al. 2005	Y	Y				Y	Y	
de Pee et al. 1998				Y				
English et al. 1997/ English and Badcock 1998	Y	Y	Y	Y		Y		Y
Faber et al. 2002/2002a	Y	Y	Y	Y			Y	
Greiner and Mitra 1995	Y			Y				
Hagenimana et al. 2001		Y		Y				
Jones et al. 2005		Y		Y				
Kerr et al. 2007		Y				Y		
Kerr et al. 2010								
Kidala et al. 2000		Y		Y				Y
Kumar and Quisumbing 2011			Y	Y				
Laurie and Faber 2008	Y	Y		Y			Y	Y
Olney et al. 2009	Y	Y		Y				Y
Schipani et al. 2002			Y	Y				
Schmidt and Vorster 1995		Y	Y					
Intervention: Aquaculture								
Aiga et al. 2009								

English and Badcock 1998		Y						
Kumar and Quisumbing 2011			Y	Y		Y		
Murshed-e-Jahan et al. 2010		Y				Y		
Roos et al. 2003		Y						
Intervention: Livestock								
Hoorweg et al. 2000		Y	Y			Y		
Kassa et al. 2003		Y			Y	Y		
Nielsen et al. 2003	Y	Y				Y		
Olney et al. 2009	Y			Y	Y			Y
Schipani et al. 2002	Y			Y				
Walingo 2009	Y		Y			Y		
Intervention: Cash Cropping								
Haaga et al. 1986						Y		
Holmboe-Ottesen et al. 1989	Y		Y			Y		Y
Huss-Ashmore and Curry 1989						Y		
Immink and Alarcon 1991						Y	Y	
Kennedy and Cogill 1988			Y			Y	Y	
Kurth 1989						Y		
Niemiejer et al. 1988			Y	Y		Y		
Sharma 1999						Y	Y	

Intervention: Biofortification								
Akalu et al. 2010								
Cercamondi et al. 2013								
Hotz et al. 2011	Y		Y	Y				
Hotz et al. 2012	Y			Y				
Kodkany et al. 2013								
Low et al. 2007	Y			Y	Y			
Singh et al. 1980								

Other outcomes

	Cost-effectiveness	Sustainability	Gender roles and responsibilities	Impact on care practices	Knowledge
Intervention: home gardens					
Bushamuka et al. 2005		Y	Y		
de Pee et al. 1998					
English et al. 1997/ English and Badcock 1998					
Faber et al. 2002/2002a					Y
Greiner and Mitra 1995					
Hagenimana et al. 2001					
Jones et al. 2005		Y		Y	Y
Kerr et al. 2007					
Kerr et al. 2010					
Kidala et al. 2000		Y			Y
Kumar and Quisumbing 2011		Y			
Laurie and Faber 2008					Y
Olney et al. 2009					
Schipani et al. 2002					
Schmidt and Vorster 1995					
Intervention: Aquaculture					
Aiga et al.					

2009					
English and Badcock 1998					Y
Kumar and Quisumbing 2011		Y			
Murshed-e-Jahan et al. 2010			Y		
Roos et al. 2003					
Intervention: Livestock					
Hoorweg et al. 2000					
Kassa et al. 2003					
Nielsen et al. 2003					
Olney et al. 2009					
Schipani et al. 2002					
Walingo 2009					
Intervention: Cash Cropping					
Haaga et al. 1986					
Holmboe-Ottesen et al. 1989					
Huss-Ashmore and Curry 1989					
Immink and Alarcon 1991					
Kennedy and Cogill 1988			Y	Y	
Kurth 1989					
Niemiejer et al. 1988					
Sharma 1999				Y	
Intervention: Biofortification					
Akalu et al. 2010					
Cercamondi et al. 2013					
Hotz et al. 2011	Y	Y			
Hotz et al. 2012	Y	Y			
Kodkany et al. 2013					
Low et al. 2007					
Singh et al. 1980	Y				

Annex 2: Quality assessments for retained studies

Table 4 is the template used to record observations when assessing quality of retained studies against the principles of quality in the DFID note *Assessing the strength of evidence*.[7]

Table 5 is a summary indication of judgements against these quality principles for all studies used in the interventions section of the main paper.

An overall judgement yes/no/partially is given to express the degree to which the study matches the requirements of each principle. The overall study quality is aggregated from these judgements according to the definitions in table 3 (p16).

Table 5 also gives the study design: Experimental (EXP); Quasi-experimental (QEX); or observational (OBS).

Section 3: Evidence Paper Methodology in the main paper gives further details on the quality assessment process.

Principles of quality	Associated principles	Yes/no/comments
Conceptual framing	Does the study acknowledge existing research?	
	Does the study construct a conceptual framework?	
	Does the study pose a research question?	
	Does the study outline a hypothesis?	
Openness and transparency	Does the study present or link to the raw data it analyses?	
	Does the author recognise limitations/weaknesses in their work?	
Appropriateness and rigour	Does the study identify a research design?	
	Does the study identify a research method?	
	Does the study demonstrate why the chosen design and method are good ways to explore the research question?	
Validity	Has the study demonstrated measurement validity?	
	Is the study internally valid?	
	Is the study externally valid?	

[7] Available at: https://www.gov.uk/government/publications/how-to-note-assessing-the-strength-of-evidence.

Reliability	Has the study demonstrated measurement reliability?	
	Has the study demonstrated that its selected analytical technique is reliable?	
Cogency	Does the author 'signpost' the reader throughout?	
	Are the conclusions clearly based on the study's results?	

Table 4: template used to record observations when assessing quality

Study	Design	Overall quality	Conceptual framing	Openness and transparency	Appropriateness and rigour	Validity	Reliability	Cogency
Aiga et al. 2009	OBS	Moderate	Partial	Yes	Partial	Partial	Yes	Yes
Akalu et al. 2010	EXP	Moderate	Partial	Partial	Yes	Partial	Partial	Yes
Bushamuka et al. 2005	OBS	Low	Partial	Partial	Partial	Partial	Partial	Yes
Cercamondi et al. 2013	EXP	Moderate	Partial	Partial	Yes	Partial	Partial	Yes
de Pee et al. 1998	OBS	High	Yes	Partial	Yes	Yes	Partial	Yes
English et al. 1997	OBS	Moderate	Partial	No	Yes	Yes	Partial	Partial
English and Badcock 1998	OBS	Moderate	Partial	Partial	Yes	Yes	Partial	Yes
Faber et al. 2002	QEX	Moderate	Yes	No	Partial	Partial	Partial	Yes
Faber et al. 2002a	QEX	Moderate	Yes	Partial	Partial	Partial	Partial	Yes
Greiner and Mitra 1995	OBS	Low	No	Partial	Partial	No	No	Partial
Haaga et al. 1986	OBS	Low	Partial	Partial	Partial	Partial	No	Partial
Hagenimana et al. 2001	QEX	Moderate	Yes	Partial	Yes	Partial	Partial	Yes
Holmboe-Ottesen et al. 1989	OBS	Moderate	Partial	Partial	Yes	Partial	Partial	Yes
Hoorweg et al. 2000	OBS	Low	Partial	Partial	No	Partial	No	Partial
Hotz et al. 2011	EXP	Moderate	Partial	Partial	Yes	Yes	Partial	Yes
Hotz et al. 2012	EXP	Moderate	Partial	Partial	Yes	Partial	Yes	Yes
Huss-Ashmore and Curry 1989	OBS	Moderate	Partial	Partial	Yes	Partial	Partial	Yes
Immink and Alarcon 1991	OBS	Moderate	Partial	Partial	Yes	Partial	Partial	Yes
Jones et al. 2005	OBS	Low	Yes	Partial	Partial	Partial	Partial	Yes
Kassa et al. 2003	OBS	Low	No	Partial	Partial	Partial	Partial	Partial
Kennedy and Cogill 1988	OBS	Low	Partial	Partial	Partial	Partial	No	Yes
Kerr et al. 2007	OBS	Low	Yes	No	Partial	Partial	No	Yes
Kerr et al. 2010	QEX	Moderate	Yes	Partial	Yes	Partial	Yes	Yes
Kidala et al. 2000	QEX	Moderate	Yes	Partial	Partial	Partial	Partial	Yes
Kodkany et al. 2013	EXP	High	Partial	Partial	Yes	Yes	Yes	Yes
Kumar and Quisumbing 2011	QEX	Moderate	Yes	Partial	Yes	Partial	Yes	Partial

Kurth 1989	OBS	Low	No	Partial	Partial	Partial	Partial	Partial
Laurie and Faber 2008	OBS	Low	Partial	Partial	Partial	Partial	Partial	Yes
Low et al. 2007	QEX	Moderate	Yes	Partial	Yes	Partial	Partial	Yes
Low et al. 2007a	QEX	Moderate	Partial	Partial	Yes	Partial	Partial	Yes
Murshed-e-Jahan et al. 2010	QEX	Moderate	Yes	Partial	Yes	Yes	Partial	Yes
Nielsen et al. 2003	OBS	Low	No	No	Partial	Partial	No	Partial
Neimiejer et al. 1988	OBS	Low	Partial	Partial	Partial	Partial	Partial	Yes
Olney et al. 2009	OBS	Moderate	Yes	Partial	Yes	Partial	Partial	Yes
Roos et al. 2003	QEX	Low	Partial	No	Partial	Partial	Partial	Partial
Schipani et al. 2002	OBS	Low	Partial	Partial	Partial	Partial	Partial	Yes
Schmidt and Vorster 1995	OBS	Low	Partial	Partial	Partial	No	Partial	No
Sharma 1999	OBS	Moderate	Yes	Partial	Partial	Partial	Partial	Yes
Singh et al. 1980	QEX	Low	Partial	No	Partial	Partial	No	Partial
Walingo 2009	OBS	Low	Partial	No	Partial	Partial	Partial	Partial

Table 5: summary indication of judgements against quality principles for all studies.

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