Canadian International Food Security Research Fund

Understanding the CIFSRF Phase Two portfolio's contribution to sustainable increases in productivity

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Acknowledgements and disclaimer

The authors of this report are solely responsible for the opinions and ideas in this synthesis, including any errors and omissions. The views expressed do not necessarily reflect those of IDRC or ODI.

Abbreviations

CBPP	Contagious Bovine Pleuropneumonia
CIFSRF	Canadian International Food Security Research Fund
CILY	Coconut Lethal Yellowing (disease)
FAO	Food and Agriculture Organization of the United Nations
FNS	Food and Nutrition Security
IDRC	International Development Research Centre
IPM	Integrated Pest Management

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Summary

In July 2017, IDRC commissioned the Overseas Development Institute to assess CIFSRF's contribution to changes in agricultural productivity, incomes and nutrition for participants in CIFSRF projects, most of them smallholder farmers.

This paper synthesises effects of the CIFSRF Phase 2 projects on increasing sustainable agricultural productivity. The overarching question is that of the contribution of CIFSRF projects to raising agricultural productivity for project participants, and the lessons that may be derived from that experience. It addresses the following sub-questions:

1. What impact did the projects have on agricultural productivity and how sustainable are those impacts expected to be?
2. Who benefited from these increases, in what form and to what degree? What are the projects' projections about how many might benefit in future?
3. Overall, did the projects address issues that are to be expected, given current global understanding of sustainable agriculture? Were any significant issues overlooked?
4. Did they promote technologies and techniques that are compatible with the production systems of their intended beneficiaries and are feasible within their resource envelopes?
5. What are the lessons from early impacts? What factors made for success or prevented success? How effective were the research partnerships formed under CIFSRF in generating results and impacts?

This paper forms part of a set of three syntheses of impacts on income, nutrition and sustainable agricultural productivity, plus an overall synthesis of all results and impacts of the CISRF Phase 2.

To gather data to address these questions, six of the Phase 2 projects were visited between September and November 2017 to interview project participants, project staff and other stakeholders and to see activities in the field. In addition, desk reviews were carried out for the other twelve projects in the Phase 2 portfolio, drawing mainly on original proposals and technical reports. Most of the data for this review were collected by end December 2017. They have been complemented by final technical reports received from most of the projects that were available by mid-May 2018.

Key findings

Sustainable increases in agricultural productivity can contribute to increasing availability of and access to nutritious food. Thirteen of the eighteen CIFSRF Phase 2 projects have focused on these increases, with some notable successes.

The thirteen projects can be divided into three groups, as outlined in Table 1 in the main report.

First, six projects worked closely with farmers and local communities to adapt technologies and techniques to local conditions through field trials, supported in some cases by some initial provision of seed, planting material or hatchlings. They have succeeded in what they have set out to do: overall there have been some significant productivity gains, particularly where farmers' base yield was low.

The success of these six projects can be attributed to a combination of appropriate technology that was accessible to most farmers in the operating sites, and to committed staff who accompanyied groups of crop and fish farmers in applying innovations in the field. By and large, the projects have had more staff time and expertise per project participant than most ministries of agriculture and other public agencies could provide under their regular programmes.

Second, two projects specifically looked to provide agricultural extension-at-a-distance to spread innovations, through media such as radio. By these means, they reached tens of thousands of farmers. They helped raise yields by 15% to 100% across different production systems. Extension messages have been tailored to likely audiences with appropriately low-input technologies and techniques. That suggests they have found more economical ways to extend innovations than through face-to-face extension. A further two have focused on face-to-face advice, either through a social enterprise (Farm Shops) or by working with existing government and non-government institutions.

Third, four projects used cutting-edge science to reduce losses and spoilage of crops and livestock. Combating losses can be equally, if not more important to farmers than increasing yields. CIFSRF has funded research highly likely to generate returns in the millions of dollars to the global fruit industry, developing technologies that are simple and cheap enough that smallholder farmers will benefit. If the two livestock vaccine projects realise even 10% reductions in the diseases they are addressing

they could create similar, or even higher, levels of return.

All three sets of projects have been effective, or in the case of vaccines, promise to be effective. The three different strategies invite the question of the comparative returns to different approaches. It is not, however, easy to judge since both the technologies promoted and the local circumstances in which they are applied varied markedly.

Sustaining the gains and scaling them up

Most of the gains to agricultural production accrue to producers who have a vested interest in sustaining them. In some cases, the means to sustaining to them also involve private gain, in as much as input dealers have an interest in providing farmers with seed, tools and other inputs. Technologies that are embodied in these kinds of products have the character of private goods: it is reasonable to imagine that private enterprises will work with (private) farmers in markets to sustain such innovations.

The best examples of this can be seen in the Nanotech for fruits and two vaccines projects. Technically ambitious, these projects address problems with a regional or global reach and have developed technologies that are straightforward for users to apply and which deliver a high benefit-to-cost ratio. Commercial firms should have considerable interest in manufacturing and distributing hexanal spays and stickers, and vaccines.

Not all agricultural innovation is necessarily a private good. Some agronomic advice on matters such as intercropping, integrated pest management, or the management of organic fertilisers, are not embodied in private goods. On the contrary, they have a public character: once messages have been given, they can be heard by many, and are not used up by the first listener. Private firms find it difficult to provide such advice — veterinary advice, soil testing would be exceptions, since it is hard to obtain revenue from all who hear the advice and benefit. Hence, as public goods, such messages almost always have to be publicly provided.

In such cases, CIFRSF activity is only likely to be maintained if some public provider — a ministry, an NGO, perhaps with donor support — can be convinced to fund it. In these cases, the challenge is to reach policy-makers with convincing evidence of the effectiveness of innovations so that they fund public extension.

1. Introduction

1.1 Background: the Canadian International Food Security Research Fund (CIFSRF)

The Canadian International Food Security Research Fund (CIFSRF) was designed to address global problems of food and nutritional insecurity through applied, collaborative, results-oriented research. CIFSRF is a program of Canada's International Development Research Centre (IDRC) undertaken with the financial support of the Government of Canada, provided through Global Affairs Canada.

Phase 1 (2009-2014) focused on ***testing innovations***, while Phase 2 (2013-2018) aims to both ***test scaling up methods/mechanisms and to scale up practical solutions to: increase food production, raise income for farming families, and improve nutrition***. The emphasis in Phase 2 was to harness the best of the private, public and not-for-profit sectors to expand CIFSRF's research portfolio so innovations reach more people and have a greater impact globally to improve food security.

1.2 Questions and methods

In July 2017, IDRC commissioned the Overseas Development Institute to assess CIFSRF's contribution to changes in agricultural productivity, incomes, nutrition for participants in CIFSRF projects, most of them smallholder farmers.

This paper synthesises the effects of the CIFSRF Phase 2 projects on sustainable increases in agricultural productivity. This paper forms part of a set of three syntheses of impacts on income, nutrition and agricultural productivity, plus an overall synthesis of all results and impacts of the CISRF Phase 2.

The overarching question for this paper is how the CIFSRF projects contributed to sustainable increases in agricultural productivity for project participants and the lessons that may be derived from that experience. It addresses the following questions:

1. What impact did the projects have on agricultural productivity and how sustainable are those impacts expected to be?
2. Who benefited, in what form and to what degree? What are the projects' projections about how many might benefit in future?
3. Overall, did the projects address issues that are to be expected, given current global understanding of agriculture production? Were any significant issues overlooked?
4. Did they promote technologies and techniques that are compatible with the production systems of their intended beneficiaries and are feasible within their resource envelopes?
5. What are the lessons that worked for early impacts? What factors made for success or prevented success? How effective were the research partnerships formed under CIFSRF in generating results and impacts?

To gather data to address these questions, six of the Phase 2 projects were visited between September and November 2017 to interview project participants, project staff and other stakeholders and to see activities in the field. Selected after being identified by IDRC staff as likely to show significant and revealing results, these were: Cambodia homestead food; Colombia potatoes; Ethiopia pulses; India small millets; Nepal terrace farming; and Tanzania fortified sunflower oil.

In addition, desk reviews were carried out for the other twelve projects in the Phase 2 portfolio, drawing mainly on original proposals and technical reports. [See Annex A for a list of these projects, with their full titles.]

Most of the data for this review were collected by end December 2017. They have been complemented by final technical reports received from most of the projects that were available from mid-May 2018.

Following a discussion of how 'sustainable increases in agricultural productivity' is defined, the rest of this paper is set out as follows:

- Section 2 assesses the results achieved, the impacts seen, and how they were achieved (Questions 1 to 4);
- Section 3 discusses how sustainable are the gains in agricultural productivity and the early lessons that can be drawn (Question 5).

Thirteen of the eighteen projects had a primary focus on increasing sustainable agricultural productivity and are analysed here. The remaining five focused on food processing rather than agricultural production: while they are not included in this report, they are included in the linked reports analysing CIFSRF's contribution to income generation and improving food and nutrition security.

1.3 Defining 'increases in sustainable agricultural productivity'

At the World Food Summit in 1996, food security was defined as existing when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet dietary needs for a productive and healthy life. The broader definition of food and nutrition security (FNS) that is now used is described by FAO as resting on four pllars: availability, access, stability and utilisation of nutritious food. Increasing sustainable agricultural productivity contributes to the goal of FNS through the first three pillars; raising the availability of and access to a range of foodstuffs and the stability of their supply. But this needs to be done sustainably: issues such as land degradation and nutrient loss, water scarcity and poor water resource management, pollution and the spread of pests and diseases compromise the ability of agricultural systems to raise production and provide stable supplies. The challenge, therefore, is not simply to raise total levels of production, but to increase output per unit of input—to raise agricultural productivity and to do so in a sustainable way.

Yield per hectare is the most popular measure of agricultural productivity[1], but CIRSRF is also committed to ensuring environmental sustainability. Yield data therefore needs to be complemented with an understanding of how those yields have been achieved.

Absent a specific definition of sustainable agricultural productivity for the CIFSRF programme, the analysis in this report draws on the principles of environmental sustainability set out in CIFSRF's Environmental Assessment Strategy. It highlights sustainable land management (principle 1), integrated water resources managment (principle 2) and protection and enhancement of biodiversity (principle 3).

This suggests three lenses through which the CIFSRF portfolio could be explored.

- The **yield gains** that were made (either yield per hectare, per farmer or total yields)
- **How many people benefited**: the total number of agricultural producers/processors reached by CIFSRF projects, their characteristics (gender, farm or business size)
- The **types of activity** promoted by the projects to ensure that these productivity increases would be sustainable:
    - Increasing and stabilising yields and diversifying production; both in terms of how the project expanded the area under sustainable production techniques, worked to increase yields of existing crops, or diversify the range of crops or livestock that were farmed for more diverse and stable production;
    - Sustainable land and livestock management; including new agricultural techniques such as soil conservation, better livestock production, intercropping, nutrient management;
    - Integrated water management; including improved irrigation techniques, watershed management to improve water infiltration, management of riverine and other aquaculture resources;
    - Protection and enhancement of biodiversity; through better pest and disease management, crop diversification and use of native varieties.

[1] Within the portfolio there is no standard methodology for measuring yield increases. Some projects measure yield/hectare, others yield/farmer and others total yields (see Table 1).

2. Findings: how CIFSRF projects have increased sustainable agricultural productivity

This section summarises the findings of the review and indicates the extent to which CIFSRF projects increased sustainable agricultural productivity. Three distinct sets of projects emerged in the analysis, as outlined in Table 1. One set of six worked closely with groups of smallholder farmers, running trials using participatory methods, problem solving and introducing new technologies and techniques to raise yields and diversify production for sale and/or home consumption. The second set of three trialled innovations to agricultural extension services, using technologies such as smartphones and radio to transmit messages (Ghana ICT & Tanzania legumes) or via agrodealers (Kenya Farm Shop). The third set of four sought to reduce losses and spoilage through the application of cutting-edge science (Côte d'Ivoire coconut disease, Novel vaccines, CBPP vaccine and Nanotech for fruit).

Table 1 presents what projects delivered in terms of increases in sustainable agricultural productivity, and who benefited. It also summarises projects' own projections about the potential future gains if their activities are successfully scaled up.

2.1 Who benefited from information about increasing sustainable agricultural productivity?

In total, CIFSRF phase 2 projects have reached well over one million people. Projects that have worked directly with farmers to test novel agronomic techniques have worked with numbers ranging from a few hundred (Nepal terrace farming, Cote d'Ivoire coconut disease, India small millets) to several thousand (Colombia potatoes, Nanotech for fruits). Those that have worked through extension workers or via radio have contacted several hundred thousand farmers and farm families with messages about how to increase agricultural productivity sustainably.

Most of these were small-scale, low-income producers, but others also benefited—from input suppliers who have a more diverse range of inputs to sell (Nepal terrace farming, West Africa vegetables, Ethiopia pulses), to better-trained agricultural extension agents (Kenya Farm Shop, Ghana ICT extension), to packers (Nanotech for fruits) and processors (Nanotech for fruits, Bolivia Amazon fish, India small millets). Information about increasing agricultural productivity sustainably has thus been fed along the supply chain.

Both women and men have benefited along the supply chain: the Tanzania legumes project trained male and female agro-dealers and extension staff, with 977 men and 705 women farmers attending project-led training days. Other projects have reached similar proportions of men and women farmers. Overall, women have tended to make up a higher proportion of those trained in new post-harvest processing techniques.

2.2 To what degree?

As noted earlier, increased productivity is often reported as yield gains, as figures are relatively easy to measure. Yield increases will depend on the types of techniques and technologies being adopted and which crops or livestock are affected. Yield data is reported inconsistently between projects but the results appear overall to be highly positive, with reported yields of milk rising by 13.4% (Kenya Farm Shop), of vegetables by 16–30% (Nepal terrace farming), of green leafy vegetables by 57% (West Africa vegetables, and of fish production by 137% (Bolivia Amazon fish) and for maize by 230% (Ghana ICT extension)[2].

CIFSRF projects have also expanded the area under sustainable agricultural techniques. Although not all projects report the area they have covered, there has been a 53% rise in the number of households with home gardens (Cambodia homestead food), and the area under improved potato cultivars has risen from zero to 734 hectares, representing 16% of the total cultivated area for yellow potatoes (Colombia potatoes). In West Africa, the area under green leafy vegetable production has increased by 161% in Benin and 768% in Nigeria.

Some projects report changes in other aspects of agricultural productivity. Notably, the Colombia potatoes projects records that 87% of farmers reduced agrochemical use and 62% adopted recommended soil protection practices. The Nanotech for fruit project's Enhanced Freshness Formulation (EFF) sprays reduce fruit drop by up to 40% for mango and 50% for sweet oranges, reducing disease incidence by 80% and

[2] Across the portfolio, it is unclear which farmers had previously received productivity-enhancing advice.

therefore reducing the need for chemical inputs. In extending the shelf life of fruit the EFF products also reduce waste.

Table 1 Increases in sustainable agricultural productivity

Project Main activities	Who benefited?	Contributions to increased productivity
Agricultural improvement through groups of farmers		
Colombia potatoes Teaching potato seed production of improved varieties to potato farmers. Encouraging home gardens for improved potato production to rural households.	2,490 farmers directly benefited (1,223 men, 1,267 women); 1,845 children (1,336 boys, 1,509 girls), 5,000 shagras families & home gardens Indirect beneficiaries: 885 male & 686 female farmers Smallholder groups growing seed potato, 133 growers Smallholder home gardeners, 500 households The Project's three new yellow potato cultivars are currently available to 6.3 million Colombian consumers.	Cultivated area of 734 ha for maincrop potatoes, 16% of total cultivated area for yellow potatoes Certified seed tuber yield raised from zero to of 20t/ha. Accumulated production over the project totals 2,612 tonnes of seed tubers of new potato cultivars across 7 regions, with 335 tonnes for consumption. Projected consumption of yellow potatoes by 8.6 million people in 2018. 87% of farmer field school participants reported a reduction in agrochemical use, 62% adapted soil protection practices, 50% followed safety measures when handling agrochemicals, 54% established an orchard. A total of 160 shagras and home gardens were advanced, that prioritized organic agriculture practices and preserved and recuperated native genetic resources.
Cambodia homestead food Improve management of ponds for fish production. Increase availability of fingerlings on local markets. Production of vegetables in home gardens.	Project participants (3,656 households, estimated 17,500 individuals) have improved / diversified their diets	10 hatcheries established. Hatchery in Kampot selling 10k fingerlings/month. Other hatcheries report similar production levels. At least 4,500 home gardens in three provinces Increase in households with home gardens from 54% at baseline to 83% in final survey. 83% have adopted improved production techniques and new technologies. Data on projected productivity is not available.
Nepal terrace farming Improved varieties, planting techniques and new technologies, to be adopted and adapted by farmers to suit individual needs.	Smallholders in hill villages with terraced land growing diverse crops: 270k smallholder farmers reached in total, of which 26k households have purchased at least one sustainable agricultural kit (SAK) product 1,057 farmers reached directly with selected agricultural practices of which 74% are continuing to use them. In total 5,291 farmers have tested, and 4,508 are directly using, one or more of the recommended practices. Agronomic trials in 678 farmers' fields 1,986 households from outside the test sites are undertaking SAK practices, partially supported by the project or other institutions.	Increased vegetable production and consumption by 26% Legume yields increased by >25%; 0.43 tonne/ha yield increase of high-protein grain. Legume production (40kg/household) in previously unused terrace walls. Yield per ha increases from intercropping: • Maize-cowpea: 26% • Millet-soybean 26% • Mustard-pea: 30% 86% of farmers who tested intercropping will continue.

Bolivia Amazon fish Capacity building, credits & marketing support to increase paiche production. Fisheries law and organisational strengthening processes support better fisheries management and new fish leather value chain created to utilise fish skin (i.e. the whole fish rather than simply the meat).	1,030 families directly reached by the project across 40 communities (1,757 with other municipalities) 379 indigenous fishers, 32 other fishers applied good practices introduced by the project Approximately 20 fish farming families added one new pond or more Fish vendors, artisans (fish leather crafts), restaurants About half fish farming participants are women.	Fish farming: productivity increases to fish farming rose 57%: from 2.8 to 4.4 tonnes/family/ year. Total production rose from 811 to 4,805 tonnes/ year in the core region of 5 municipalities (455% increase). Number of ponds/producer rose from 3.4 to 4.6, increasing production to 5,114 tonnes/producer Fishing: *Paiche* production rose from 305 to 724 t/year (137% increase). Expected to rise to 1,200t/year (294% increase) 8400ft² of paiche leather produced (from zero base).
Ethiopia pulses Demonstrating value of pulse production, teaching new techniques and use of technologies (including use of inoculants).	Smallholders growing pulses: 51k farmers reached (42% female) with improved varieties and farming techniques, 665 seed producing clusters organised (3,324 farmers), 9 seed producing cooperatives established (3 women cooperatives). Guts Agro processes chickpeas to snacks: has women vendors.	Increase in yields from 1,000 to 3,200 kg/ha for chickpeas (220% increase). Bean yields in the range of 2,900 and 5,000 kg/ha, compared to 1,100 and 3,000 kg/ha for local varieties (increases of 164% and 67% respectively). NB it is unclear whether these yields are being achieved by farmers or only in variety testing.
West Africa vegetables Fresh leaf vegetables produced using microdosing technologies to increase yield.	Smallholder vegetable farmers: 338k, 51% women. Vegetable traders: 21k. 65% women in Nigeria, 72% in Benin. Processors: 315 Nigeria, 67% women; 9k in Benin, 95% women Seed growers and sellers: 576 Input dealers: 402 Students reached with extension and nutrition messages: 68,000 in Nigeria (46% female), 30,157 in Benin (4% female). 881 teachers trained in Nigeria, 76 in Benin	Fresh leaf yields of microdosed vegetables increased 46–57% compared to control groups. Land area under vegetable production in Benin project area increased by 161% (from 985 to 2,575 ha). Land area dedicated to microdosing is 280 ha. Land under vegetable production in Nigeria project area increased by 768% (from 9,105 to 79,110 ha). Land area dedicated to microdosing is 356 ha. Radio programming has the potential to reach 10 million listeners.
Agricultural improvement through extension		
West Africa vegetables	As above	As above
Kenya Farm Shop Providing extension advice and improved inputs through agrodealers.	74 franchised agricultural input shops, with 50% owners women, 54% assistants women Farm Shop served 35,000 smallholder farmer customers (54% women) 15 more shops being franchised at Feb 2018 26,600 smallholder farmers trained, (52% women) through 59 village demonstration plots. 21 shop assistants, 29 franchisees, 18 Farm Shop staff trained	731 farmers directly trained, though uptake and impacts of individual trainings not recorded in project documentation. Communities with a Farm Shop realised a 13.4% increase in milk production over those in communities with no Farm Shops—directly correlated with attending Farm Shop trainings. No data for other crops or livestock.
Ghana ICT extension Teaching land preparation, weed control, crop spacing, pesticide use, adoption of improved seeds through various information and communication	The project has reached 500k farmers across 6 rather than 3 regions (486k reached by radio, 14k reached through mobile-enabled agents). The project engaged 6 radio stations and aired 575 radio programmes; trained 264 buyers and 234 buyer agents; and provided information on 5 crops (maize, rice, cowpea, yam, soya). 243 field agents were trained and	Adoption rates amongst those who interacted with mobile-enabled extension agents indicated 93% for land preparation, 87% for weed control, 81% correct crop spacing, 54% for use of pesticides & improved seed. 75% of women interviewed applied an improvement.

technologies (radio programmes, linked to mobile-enabled extension agents)	are using the SmartEx technology, and 13,299 farmers registered for their services.	Among radio listeners, average maize production per farmer rose from 919kg to 2208kg (230% increase). Yield differentials for listeners and non listeners were 2.25 vs 0.99 mt/ha for maize and 2.39 vs 1.95 mt/ha for rice. Average yield/ha increased by 16% (unclear whether this relates to all crops or just maize). Willingness to pay studies show that 82% of non-participants and 94% of participants in AgroTech SmartEx services would be willing to pay GHC30-40/acre/ season 500k farmers reached through radio, while 175k have adopted or used some of the promoted practices or technologies. That leaves 325k who may still adopt some of the technologies or practices. However there are doubts about the financial model that has been proposed as it requires a large up-front investment.
Tanzania legumes Teaching improved planting techniques via radio and other extension services. Training on incorporating residues when preparing land, use of improved varieties of common bean and soya bean, spacing, weeding, use of fertilizer with common bean, use of inoculant with soya bean, use of PICS (Purdue Improved Crop Storage) bags – hermetic storage bags to prevent weevil/pest damage and aflatoxin)	Smallholders: 600k reached, mainly through radio; 129k farmers adopted at least one technical innovation. Training farmers in improved agricultural techniques (32 demonstration plots across N and S Tanzania over 2 years with up to 1,682 farmers (977 men, 705 women) attending training days, with an estimated 19–20,000 influenced by the training days). 75 agricultural input dealers reached. 14 Hub agro-dealers (12 men and 2 women) and extension staff (17 men and 5 women) were trained on improved seeds and good agronomic practices for legumes. 341 rural agro-dealers and extension officers at retail level were trained on improved seeds and technologies	Project produced >30 tonnes of certified seed and 24 tonnes of basic seed of promoted varieties. Farmers report increased yields for improved pulse varieties. Yield data not available. Project estimates potential listenership of up to 8 million farmers.
Reducing losses and spoilage with cutting-edge science		
Côte d'Ivoire coconut disease Research on disease to control and mitigate effects of Cote d'Ivoire Lethal Yellowing disease on productivity of coconut trees.	Smallholders with coconut groves: 10 field schools, 6 women's groups (173 members), 9 plant clinics, 8 Women's Coconut Fairs	Disease- affected coconut trees yield no more than 15 nuts/year/tree. Healthy trees yield 104 nuts/tree/year (593% increase), 240g copra/nut, and 3.5 tonnes of copra/ha/year (though it is unclear whether this has been achieved by farmers or in test sites) Improved techniques (application of poultry manure) can decrease impact of CILY by a half. (Infection rates are 85% in CdI). Future impacts on productivity at farm level not projected
Nanotech for fruits Extending shelf-life of fruit (mangoes, oranges, banana) to reduce post-harvest losses and reducing pest attack to reduce pre-harvest	India: farm advisory services offered to 4,360 farmers (81% defined as small or marginal farmers, 32% women), 2,000 model farms established in Tamil Nadu with 3 knowledge hubs. Over 2,000 farmers directly informed, an additional 25,000 farmers reached through farmer-to-farmer dissemination. 16 training sessions in value addition (i.e. making jams	India: EFF spray reduces losses by up to 10% in mangoes and can extend the harvest period by 14–21 days in a range of fruits, which allows farmers to spread their marketing activities and benefit from premium prices later in the season. Cost: benefit ratio per tree calculated to be 1:5.

losses through nanotechnology.	and pickles) for post-harvest entrepreneurs reaching women (360) and men (90) Kenya: unclear how many farmers have been reached	Kenya: EFF spray improves on-tree fruit retention of by 13–14 days per season, reduces fruit drop of sweet oranges by up to 50% (45.4% in mango) Tanzania: EFF spray reduces fruit drop in mango by 40% with reduced pest attack Global: post-harvest dips extend shelf life of a range of fruit by 12-18 days depending on fruit, reduces disease incidence by 80%. Nano stickers also extend shelf life of mango & banana by 12-18 days. Project has not estimated long-term uptake, but it could be very considerable indeed. No challenges to the widespread rollout have been foreseen: in the review team's assessment, the project could benefit millions of small scale fruit farmers and associated packers/shippers.
Novel vaccines for livestock Vaccine to reduce livestock loss and increase productivity per animal.	Small animal livestock owners and their communities in Kenya and South Africa	Project has yet to conduct efficacy and safety tests to inform robust projections. However, estimated global annual losses from Peste des Petits Ruminants alone are of $1.4–2.1 billlion. Even a 10% reduction in losses would represent a $14m annual gain.
Africa CBPP vaccine Vaccine to reduce bovine livestock loss and disease to increase productivity per animal.	Bovine livestock owners and their communities in Africa	Project has yet to conduct efficacy and safety tests to inform robust projections. However with mortality rates of up to 80%, the potential gains from a successful vaccine are very considerable indeed.

Source: Authors' construction using IDRC documentation.

2.3 What explains the differences in yield increase?

Yield increases reported by CIFSRF projects ranged from modest (but still valuable) gains of 20-40% to gains of well over 100%. There may be several reasons for this variability. First, the base yields being achieved by farmers before they interacted with the projects were so low that even modest measures could produce large percentage gains. Grain production in Ghana, for example, rose from 1t/ha to 2.25t/ha. This is a high percentage increase, but 1t/ha is a very low yield; it is relatively easy to double it with good seed and fertiliser.In other cases, farmers were introduced to technologies with the potential to increase yield several-fold, such as the polytunnels in Nepal terrace farming or the drip irrigation and microdosing fertiliser in West Africa vegetables. In most cases, however, projects introduced incremental technologies to fields that were already cultivated with medium to high intensity. The resulting yield gains were therefore relatively modest, though still very valuable.

2.4 Which elements of increasing sustainable agricultural productivity were addressed?

As a whole, the thirteen projects covered all four elements of sustainable agricultural productivity: that is, increasing and diversifying yields, sustainable land and livestock management, integrated water management, and protection and enhancement of biodiversity. Table 2 in Annex A gives more details on the activities projects used within each element.

All projects that emphasised **increasing and diversifying yields** linked their work to the objective of strengthening food security through providing a more diverse and more nutritious diet, or more diversified income sources. This diversification was less an attempt to introduce entirely new crops to farmers, but more to encourage them to cultivate a wider range of crops that were probably already familiar to them and to re-introduce landraces whose cultivation had fallen in favour of newer varieties. For most, diversifying production was linked to providing alternative sources of income and nutritious foods. But diversification was not only related to dietary needs: the Colombia Potatoes project, while focusing on potatoes, paid specific attention to the nature of ancestral diets as part of its community development approach; introducing home gardens to grow indigenous crops and pass on ancestral production techniques.

Eight of the thirteen projects incorporated a range of improved and more **sustainable land/livestock management** techniques. They promoted a mix of improved technologies and management techniques, consistent with the low-input approach to supporting agriculture for low-income farmers. Thus while Nepal terrace farming introduced corn shellers, yam sacks, garden gloves, plastic greenhouses and cattle shed improvements for manure collection, it also encouraged improved techniques such as intercropping, growing crops on terrace edges to reduce soil erosion and planting a range of legumes to improve nitrogen fixation. No other projects promoted such a long list but most combined several techniques such as protecting soil nutrient and organic matter content, soil erosion control, reducing the use of agrochemicals and other inputs through manuring, inter- and relay-cropping and other forms of integrated pest management.

Integrated water resource management was a focus for seven projects. In Bolivia, farmers were encouraged to construct ponds on previously degraded land for fish production; water resources were managed through improving rainwater harvesting (Cambodia homestead food), better irrigation techniques (Kenya Farm Shop, West Africa vegetables), construction of small ponds (Nepal terrace farming). In Colombia, the project helped reforest and thus rehabilitate watersheds, improving water infiltration thereby enabling streams to run all year.

Protecting and enhancing biodiversity was not a distinct priority across the portfolio, but in five projects (Cambodia home gardens, Bolivia Amazon fish, Colombia potatoes, West African vegetables, India small millets) it was achieved via the objective of diversifying production. In Cambodia and Bolivia, fish farmers were encouraged to rear smaller indigenous species as well as the larger and potentially more productive commercial ones. In Bolivia, the project contributed to changing a law regulating fishing land use, to ensure the sustainability of native fish populations and prevent incursion of invasive species. Landraces tend to be genetically diverse and were encouraged by three projects: Colombia potatoes, India small millets and West Africa vegetables.

3. What are the lessons from CIFSRF's early impacts?

3.1 Sustaining the gains

Are the improvements to agricultural productivity likely to be sustained? What can be done to increase the likelihood of achievements being sustainable?

The first observation is that tangible benefits of behaviour change can increase the likelihood that the gains will be sustained over the long term. A number of projects created short-term benefits for participants, which should also generate the necessary resources to allow smallholder farmers to continue to apply the given techniques or technologies and continue to produce the higher yields the projects have developed. Projects such as Cambodia homestead food, Ethiopia pulses, Tanzania legumes and Nepal terrace farming created higher returns for farmers within one season. Growing green leafy vegetables (West Africa vegetables) can produce gains in the very short term because of short cropping cycles, and one project (Bolivia Amazon fish) created a new value chain in *paiche* leather. For these projects, improvements are particularly likely to be sustainable as the results visibly increase yields and incomes.

Nanotech for fruit similarly improved returns within a single season and farmers' willingness to pay indicates that the EFF sprays are commercially viable without external support. These are projects where results are both tangible and can be seen within a single cropping season. However, sustaining those results will depend on ensuring that the inputs introduced by the project remain readily available.

Efforts to improve environmental sustainability may need several years to demonstrate results such as greater soil fertility, less erosion, more water infiltration and reduced incidence and virulence of pest attack. And even if these environmental gains are sustainable, they may not have the sorts of tangible effects on yields other projects have demonstrated. For long-term sustainability, environmental improvement measures need to accompany other techniques and technologies that have a more immediate focus on raising yields.

Policy change can support increases in sustainable productivity, but generally requires work to improve institutional capacity. The Bolivia Amazon fish project shows how a change in law can both contribute to improved ecological sustainability and put in place the elements to support increased production. The Ethiopia pulses project succeeded in persuading government of the need to include pulses in extension training manuals and to teach women about the importance of pulse consumption through health extension workers. However, the ability of pulse seed farmers to sell their crops at a premium was jeopardised by weaknesses in the state-funded seed enterprise to purchase their outputs.

Five projects worked to scale up their impacts through different extension methods: providing advice and inputs through local agrodealers (Kenya Farm Shop, Nepal terrace farming), trialling novel extension methods using radio and social media platforms (Ghana ICT, Tanzania legumes, West Africa vegetables) and by working in partnership with public sector organisations such as official youth empowerment schemes, education authorities and the prison service (West Africa vegetables). All these projects have raised yields and have done so through promoting sustainable practices. They have developed and demonstrated approaches that could effectively augment publicly-funded extension services, though none have developed a financial model that would be sustainable without external funding once the project has stepped away.

The regulatory environment is an important consideration. Three projects introduced technologies that are not just new to beneficiaries, but scientifically novel: Novel vaccines, CBPP vaccine and Nanotech for fruit. Understanding regulatory issues can be essential for commercialisation, particularly where production techniques are new (vaccines) or the technology is not that well understood (nanotechnology). This is not just a question of involving social scientists to run willingness to pay studies, but of ensuring that researchers are provided with strategic business development support that helps them navigate what is often a complex maze of regulatory bureaucracy. Interviews with CIFSRF staff indicated that although little emphasis had been placed on addressing regulatory issues at the beginning of Phase 2, it became necessary fairly quickly and the programme as a whole recognises how important it is to encourage projects working with novel technologies to consider the regulatory environment at quite an early stage in product development.

Projects have not been asked to estimate their potential future impacts, and the overall picture that emerges from project documentation is difficult to assess. Scaling up and sustaining the gains made in agricultural productivity will, for many projects, depend on the continued functioning of public and private agricultural services such as provision of seeds and other inputs, and marketing infrastructure such as roads, to ensure that increased production can be sold. Several projects contributed to the process of changing government regulations which enabled farmers to take advantage of potential productivity increases; changing regulations around seed production (Tanzania legumes), access to new fishing areas (Bolivia Amazon fish), vaccine production (Novel Vaccines) and to allow commercial production of a novel product (hexane in Nanotech for fruit). However changing regulations does not in itself lead to sustainable gains: without adequate marketing infrastructure, for example, some Tanzanian legume

farmers found themselves with excess supply they were unable to sell.

All projects have built capacity of local organisations they believe have the potential to continue the work. These include Tamil Nadu University (Nanotech for fruit), local research organisations with good connections to smallholder farmers (Côte d'Ivoire coconut disease) and a range of organisations including schools, marketing co-operatives, prisons involved in innovation platforms in Nigeria and Benin (West African vegetables).

Several projects have focused on commercialisation strategies to complement efforts to raise production. The Bolivia Amazon fish project helped create a new value chain for leather made from *paiche* skin, Cambodia homestead foods established hatcheries to produce fingerling fish for sale, Colombia potatoes developed local capacity to produce certified seed tubers and Ethiopia pulses established seed producers' groups. All have the potential to ensure that the sustainability gains continue to be realised in the long term. Three projects focused on commercialising single products: the two vaccines projects and Nanotech in fruit with its hexane-based sprays and hexane-infused packaging. However commercialisation is not guaranteed: in two cases (Kenya Farm Shop, Ghana ICT extension) the projects' financial projections do not yet indicate long-term sustainability. In Kenya there is debate over the break-even size of the Farm Shop model, and in Ghana it has proved challenging to find investors willing to consider the large up-front cost of setting up and running the radio- and digitally-enabled extension service.

In terms of the potential for large and long-term sustainability gains, three projects stand out. Although the Novel Vaccines and CBPP vaccine projects have not yet conducted the safety and efficacy trials that would allow them to estimate the likely impacts of their work, their potential is enormous. FAO estimates that the annual global damage to peste des petits ruminants alone is $1.4–$2.1 billion, Rift Valley Fever has a 20% mortality rate in sheep (10% in cattle), and sheep & goat pox has a mortality rate that varies 10–70%. Contagious Bovine Pleuropneumonia (CBPP) is one of the most important infectious cattle diseases in Africa, with some herds experiencing losses of up to 80%. Heat-stable vaccines that prove effective in controlling outbreaks could — if supported by continent-wide rollout strategies — have a hugely significant effect on smallholder livestock production.

The Nanotech in fruit project has similar possibilities for increasing agricultural productivity sustainably. The technology to produce the sprays and the associated hexane-infused packaging materials has been well tested in Tamil Nadu and is at the point of commercialisation. Regulatory issues have not been a major hurdle in India, Canada or the Caribbean which suggests that it may be relatively simple to license the products in many other countries. Once the product is commercialised, CIFSRF will not be able to control whether the fruit supply chain passes the gains to smallholder farmers in way that aligns with the programme's priorities. However willingness to pay trials with small and marginal Indian mango farmers indicated a cost:benefit ratio per tree of 1:5 for EFF sprays, making spraying profitable even for these low-income groups.

3.2 Factors influencing success

All projects reviewed in this report introduced farming technologies and techniques that were a good fit for the local farming systems and that farmers could understand and use—as expected from a portfolio that had been preselected based on prior performance. They paid particular attention to the needs of women farmers and some to the needs of indigenous groups. All worked with farmers whose production has been highly constrained, either by access to inputs or access to technical advice. During Phase 1 the most promising innovations had been selected and developed with participants to be locally relevant. This explains the high levels of local uptake observed for most innovations in Phase 2. The question is whether those successes can be sustained and scaled up, as well as how extension services can be rendered more effective.

Two issues arise: first, whether local markets can absorb the increase from productivity gains (in Tanzania, the legumes project found this to its cost when farmers were unable to sell their increased production because local markets were under-developed). The second is whether inputs and advice will remain available after projects have finished. Project teams for all thirteen projects reviewed here have addressed both these questions. On the input side they have improved the supply of certified seed (Tanzania legumes, Colombia potatoes), encouraged local seed production (West Africa vegetables, Ethiopia pulses) and strengthened access to a range of inputs (Nepal terrace farming, Cambodia homestead food). Some projects worked with agroprocessors and traders to strengthen markets (West Africa vegetables, Nanotech for fruit, Bolivia Amazon fish), though in most cases ready markets were available to farmers for the selected crops.

Taking these approaches to scale requires extension. Four projects have specifically looked at different extension approaches that mix face-to-face training and advice with distance methods. Kenya Farm Shops helped agrodealers

provide advice, inputs and other services to tens of thousands of smallholder farmers with whom they interacted relatively intensively through trainings and in-shop advice. The Tanzania legumes and Ghana ICT projects used radio programming to reach hundreds of thousands of farmers, and in Ghana some farmers received visits from mobile extension agents to back up this advice. The West Africa vegetables project worked through schools, government youth entrepreneurship programmes and local prisons to reach audiences in excess of 300,000. Between the four projects yield gains of between 13% and 100% have been realised, depending on the crop. The evidence suggests that these distance extension approaches work at scale and at a significantly reduced cost per capita: farmers engaged and applied the suggested techniques, and as a result yields rose.

The extension models that were developed are not yet financially sustainable without external support. The Ghana ICT approach requires significant up-front investment, and Kenya Farm Shops is still debating the size of the break-even model. Tanzania legumes and West Africa vegetables provide limited information on their model's financial sustainability. There are few areas where wholly privately-funded extension activities are viable (veterinary and soil testing advice are two known examples) so complete financial sustainability is not to be expected. What is clear is that the projects have developed a range of approaches that make better use of resources spent on extension so that public funds can go further in reaching farmers.

3.3 CIFSRF research partnerships' contributions

How have CIFSRF partnerships performed in helping develop technologies and practices that address questions about sustainable increases in agricultural productivity?

CIFSRF has succeeded in identifying and funding a number of unusually collaborative and productive partnerships. All six of the detailed case studies concluded that Canadian institutions had built meaningful partnerships with their counterparts. Arguably the most important aspects of these relationships were not only that new technologies or approaches could be applied in different contexts, but also that Canadian institutions brought the expertise necessary to test new approaches and technologies. In the process, a great deal of Canadian expertise seems to have been transferred to create capacity in other parts of the world.

Where partnerships worked best, Canadian teams brought expertise in an area that was missing in-country but that was complementary to local expertise. For example, in the case of the Ethiopia pulses project, Canadian partners brought expertise in the area of nutrition. This allowed for increases in pulse production to be translated into gains in food and nutrition security, as well as sustainable increases in productivity. Conversely, research on rhizobia innoculants that occurred in the context of this project saw expertise being transferred from Ethiopia to Canada. And while the science behind Nanotech for fruit saw Canadians bringing expertise in understanding nanotech and its potential application, the idea of using banana waste for wraps and packaging came from the Indian researchers. Nepal terrace farming and Côte d'Ivoire coconut projects also saw successful partnerships between lab and field workers. In Nepal the project team conducted trials of a wide range of low-input technologies, and in Côte d'Ivoire the CIFSRF researchrs worked across a range of highly scientific questions — identifying possible vectors for the disease and genes that conferred resistance to lethal yellowing — as well as issues with immediate practical application such as whether the application of chicken manure increased coconut palms' resilience to the disease.

In other cases, Canadian partners brought expertise in knowledge dissemination or behaviour change, which meant that project messages could be spread more effectively through local media. In the case of the Tanzania legumes and Ghana ICT extension projects this worked very well. Masters-level and PhD students from developing countries worked in Canada and vice versa, helping cement relationships and also ensuring a healthy, multi-directional exchange of knowledge and expertise.

3.4 Policy influence

As noted earlier, influencing public policy can contribute to ensuring that productivity gains made by projects can be realised in the long term and have the potential to spread more widely. But 'policy change' is not simply about changing what is written (*instrumental changes*): it is also important to contribute to changing the debates about key agricultural productivity issues *(conceptual changes)*, building policymakers' capacity to create effective policies (*capacity building changes)*, and strengthening networks that policymakers can rely on for expertise and advice in future (*changes in connectivity)*[3].

For example, changing seed regulations in Tanzania to fine producers of fake seed is an *instrumental* change

[3] These four categories are used by the DFID-ESRC Growth Research Programme which seeks to strengthen the impact of academic research on aspects of economic growth in low-income countries.

(influenced by the project on Tanzania legumes), but it also sends important signals to the wider community about the government's commitment to ensuring trust in the seed production system *(conceptual change)*. The novel vaccines project worked closely with regulators to help clarify technical issues relating to the new type of vaccine they were developing (*capacity building change*) and together with the CBPP vaccine project is contributing to the development of regional approaches to vaccine regulation (*capacity and connectivity changes*).

All 13 projects reviewed for this report had meaningful interactions with policymakers at different levels. While this cannot guarantee that all the lessons learned are integrated into national or regional policies, some projects have already demonstrated that they have made plausible and distinct contributions to policy changes in various ways:

- Tanzania legumes has influenced five amendments to the Seed Regulations (2007) Act covering the setting up of a new official seed certification institute and a seed unit within the Tanzanian Agricultural Research Institute, legislation fining producers of fake seeds, harmonisation of regional policies about seed testing and approval processes, and a commitment to review the Act to allow Quality Declared Seed to be sold in a way that encourages seed production by private seed companies to help with current capacity shortfalls in government agencies *(conceptual, instrumental, capacity building and connectivity)*;
- Nanotech in fruit has worked with regulators in several countries to approve the use of hexane-based sprays and packaging material to allow for commercialisation (mainly *instrumental* change, possibly some *conceptual* change around the use of nanotech);
- Ethiopia pulses collaborated with the government extension service to introduce farmers to better techniques for producing chickpeas and haricot beans. This moved pulse production up the national list of priorities for the agricultural sectors, as it was able to demonstrate a cost-effective way of bringing new skills to farmers and their communities. The fact that the project had impact in agriculture and nutrition and had worked with both relevant ministries greatly increased its influence; (mainly *conceptual* and *connectivity* changes, unclear whether *instrumental* changes have yet resulted);
- In South Africa, Novel vaccines worked hard to understand the regulatory environment and to contribute to discussions about wider regulatory changes affecting vaccine production (*conceptual* and *instrumental* changes; *connectivity* changes at a regional level); and,
- Bolivia Amazon fish was able to influence the Sustainable Fisheries and Aquaculture Law which opened up new areas to sustainable fishing practices (*instrumental* changes, accompanied by *conceptual* changes about what sustainable fishing practices look like).

4. Conclusions

Sustinable increases in agricultural productivity are central to improving food and nutrition security, and thirteen of the eighteen CIFSRF Phase 2 projects have had it as a clear focus of their work with some notable successes.

Across the portfolio CIFSRF has funded projects that have contributed in a range of ways to improving agricultural productivity. There is no clear answer to the question of which approaches generated the best results, either in terms of yield gains or the depth of local impacts. Projects have worked with very yield-constrained farmers for whom simply improving access to the required inputs, or reducing losses and spoilage, can result in a significant percentage increase in yields. And the presence of highly qualified and committed researchers for several years has provided the support necessary for farmers to see the benefits over more than one cropping cycle and adapt their farming techniques. In terms of the depth of local impacts and the degree of yield gain, there is no discernable difference between projects advocating low-input or high-tech approaches.

Six projects have worked closely with farmers and local communities; running field trials, problem solving, adapting technologies and techniques to local conditions and helping provide improved inputs such as seed, fertiliser and different crop or livestock management techniques . They have succeeded in what they have set out to do: overall there have been some significant productivity gains, particularly where farmers' base yield has been low.

There are two reasons for their success. First, they have selected appropriate technologies and not tried to be overambitious. Second, they have provided more resources (inputs and advice) per project participant than do most public agencies. This is an important point as it raises the issue of whether impacts at scale are likely once the projects close. In some cases they will leave a legacy of strengthened local institutions and private sector actors such as traders and processors. This will ensure that excess produce can be sold to generate income that will feed back into both household food and nutrition security and

additional inputs for agricultural production. All of this will contribute to sustaining productivity at local level. But it is not yet clear whether the local structures and institutions that remain after projects have left will be able to sustain similar rates of increase.

The next question is whether CIFSRF projects have contributed to achieving impacts at scale through distance rather than close working with local communities. Four projects have explored different models—face to face, using traditional media such as radio, more innovatively with social media, and working through government programmes. All approaches have had impacts on yields on a variety of projects with reported gains of between 15% and 100% across different production systems. Extension messages have been tailored to likely audiences with appropriately low-input technologies and techniques, and they have reached large numbers of people.

While the projects have not managed to develop a sustainable financial model that would function in the absence of external funding in their particular institutional contexts, they have generated very useful lessons for other projects and for wider debates on agricultural extension. In particular, the projects have made contributions to understanding how effective extension services can be provided in a cost-effective manner. This has been demonstrated in very different ways: in Kenya the focus was on private sector providers of extension advice and inputs, while in Ghana and Tanzania farmers were effectively reached through mass media. All three achieved significant changes in behaviour and subsequent yield increases.

Finally, four projects have used cutting-edge science to reduce losses and spoilage. Combating losses can be equally, if not more important to farmers than increasing yield per hectare or yield per animal. The project on Fruit nanotech has reached the point of commercialisation and two other projects (CBPP vaccine, Novel vaccines) appear to be close. These are technically ambitious projects that address problems with a regional or global reach and have developed technologies that are simple to administer with a high benefit:cost ratio. In addition, the routes through which the technologies would be brought to scale are already established. Private gain to farmers in these cases can be supported by public action, but does not rely on it. CIFSRF has funded research that is highly likely to generate returns in the millions of dollars to the global fruit industry, developing technologies that are simple and cheap enough that smallholder farmers will benefit. And if the two livestock vaccine projects realise even 10% reductions in the diseases they are addressing they could create similar, or even higher, levels of return.

In summary, the CIFSRF projects have generated significant gains as a result of committed staff, appropriate technology and being able to deploy more staff time per participant than many regular government extension programmes can. However it is hard to compare the gains made by the projects, since across the portfolio the technologies, farming systems and other circumstances are very diverse. Projects also differ in their approaches to scaling up their messages; some have worked closely with local communities and others using distance extension. Distance extension seems to have been as effective as face-to-face extension and promises a more economical form of extension; though as a complement to, rather than a substitute for, public extension services.

Can these gains be sustained? Where they have delivered clear private gains to farmers, input suppliers and processors this is very likely. This is most likely where technologies are embodied in a product that gives a clear commercial incentive such as the hexanal sprays or livestock vaccines which have the potential for very high gains indeed`. More complicated agronomic advances tend to be public goods that require public services. Their sustainability will depend on the willingness and interest of government and other public actors to continue and replicate projects' efforts.

References

Most of the information for this report comes from reading of project documentation, above all Project Approval Documents, recent Technical Reports and publications from the 18 research studies funded under CIFSRF Phase 2.

This synthesis also drew on reports on the six projects that were visited in the field:

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- Wiggins, Steve & Ricardo Vargas Meza, 2018, Expanding production of more nutritious yellow potatoes in Colombia, Overseas Development Institute

Annex A

Table 2: Understanding which approaches CIFSRF Phase 2 projects used to contribute to sustainable increases in agricultural productivity

		The elements of sustainable agricultural productivity			
Project	**Who is intended to benefit?**	**Increasing, diversifying and stabilising production**	**Sustainable land and livestock management**	**Integrated water resource management**	**Protection / enhancement of biodiversity**
Agricultural improvement through close working with groups of farmers					
Colombia potatoes	Smallholder potato farmers and farm families in Nariño province; benefiting from collective and home gardens (collectively known as 'Shagras para la vida') Smallholder groups growing seed potato; benefiting via the introduction of improved varieties *Project improved governance of local groups, developing capacities for political influence by producer communities*	Expanding the area under cultivation of improved varieties of yellow potatoes Production of certified seed tubers and new potato cultivars Introduced *shagras para la vida* which promoted, collective gardens, home gardens and home orchards for crop diversification and to promote ancestral diets.	Reduced agrochemical usage, improved soil protection practices including soil erosion control and water management (see next column). Implementation of four short circuits for commercialization of high-quality seed tubers reduced the dispersion of pathogens.	Reforesting the watershed to promote water infiltration.	160 shagras groups promoted collective & home gardens; diversifying composition of plants, ancestral production techniques, organic / natural fertiliser and reduced chemical use
Cambodia homestead food	Small scale farm households in three provinces, via establishment/ improvement of home gardens, fish ponds and production of improved fish feed. Fish hatcheries established to improve the supply of improved and indigenous species	Improving management of ponds for fish production. Increasing availability of fingerlings in local market Increasing production of vegetables by households with home gardens	Use of vermiculture and compost, some intercropping with legumes. Promotion of sustainable production techniques through training, including low-input farming methods. For example, live fencing used in place of plastic / metal fencing. IPM techniques to reduce need for pesticides, and other low-input farming methods	Better use of rainwater for drinking water consumption Techniques to reduce the need to water home gardens in the dry season	Rearing of small indigenous fish species in home ponds together with large species

Project	Who is intended to benefit?	The elements of sustainable agricultural productivity			
		Increasing, diversifying and stabilising production	Sustainable land and livestock management	Integrated water resource management	Protection / enhancement of biodiversity
Nepal terrace farming	Smallholders in hill villages with terraced land growing diverse crops: benefiting from improved agricultural techniques and new technologies	Improved varieties, planting techniques and new technologies to increase yields. Project introduced 25 improved agronomic practices and 21 new tools/ products	Using intercrops and relay crops to provide soil cover to limit erosion, and for integrated pest management Planting crops along the edges of terraces to limit soil erosion Boosting soil fertility and organic matter by using leguminous crops and better management of organic manures from livestock	Water management to prevent soil erosion. Creation of small ponds to conserve rainfall.	No specific focus on biodiversity conservation
Bolivia Amazon fish	Indigenous fishers and their families benefitted from improved techniques for fish production & fish pond management Fish vendors, artisans (fish leather crafts), restaurants. Strengthened fisheries law and local organisations to support better fisheries management; and created a new fish leather value chain.	Capacity building, credits & marketing support to increase production of paiche and other fish. Establishment and improvement of fish ponds for aquaculture Legal advances by the project brought new fishing areas into production.	Sustainable production techniques taught to fish pond operators. Improved management of fish ponds for fish production. Use of unused and overexploited rice land. Reduction of decomposing fish skins on river banks as skin is being used as leather.	Increased use of rain-fed fish ponds and over-exploited & often unusable rice agriculture land.	New fisheries & aquaculture law to regulate fishing land use for sustainable fishing and conservation, invasive species management & sustainability of native fish populations
Ethiopia pulses	Smallholder farmers growing pulses via the introduction of improved varieties and farming techniques. Farming families benefit from improved nutrition. Co-operatives and clusters established to produce seeds and process snacks; women snack vendors	Demonstrating value of pulse production, teaching new techniques and use of technologies (including use of inoculants).	Soil fertility improvements through pulse production Introduction of rhizobium inoculant reduces need for fertilizer	Better use of residual moisture in fields at end of main season	Reduced use of firewood through improved pulse processing (soaking)

Project	Who is intended to benefit?	The elements of sustainable agricultural productivity			
		Increasing, diversifying and stabilising production	Sustainable land and livestock management	Integrated water resource management	Protection / enhancement of biodiversity
West Africa vegetables	Smallholder vegetable farmers in Nigeria and Benin and their families; benefited from improved agricultural techniques to raise production of fresh leaf vegetables Vegetable traders and processors, seed growers, seed sellers and agricultural input dealers	Fresh leaf vegetables (including indigenous varieties) produced using microdosing technologies to increase and stabilise yields.	Microdosing to reduce fertiliser use, preserving soil fertility without over-fertilising.	Reduce water usage through drip irrigation technology	
Agricultural improvement through extension					
West Africa vegetables	Schoolchildren, entrepreneurs, prisoners, all trained in vegetable production through innovative extension platforms				
Kenya Farm Shops	Franchised agricultural inputs shops, which provide support to smallholder farmers through ad-hoc advice, training (in-person and via manuals), demonstration plots, provision of soil testing, provision of ecologically sustainable products, product disposal services	Providing extension advice and improved inputs through agrodealers.	Sustainable farming practices incorporated into trainings and training manuals for 15 specific aspects of sustainable land, crop, livestock and water management. Qualified animal health assistants help avoid misdiagnosis and minimise risk of improper prescribing of agrochemical and pharmaceutical products Soil testing and analysis encouraged through Farm Shop advice and practical demonstrations. Farm Shops provide environmentally friendly pest control technologies and safe disposal services of expired products	Training on irrigation and water management provided to farmers through Farm Shop trainings and manual	Training on biodiversity is not specifically highlighted in project documentation

Project	Who is intended to benefit?	The elements of sustainable agricultural productivity			
		Increasing, diversifying and stabilising production	Sustainable land and livestock management	Integrated water resource management	Protection / enhancement of biodiversity
Ghana ICT extension	Smallholder farmers in 6 regions cultivating 5 crops (maize, rice, cowpea, yam, soya) who were reached via radio programmes and digitally enabled agricultural extension workers Agricultural extension workers who were trained in the use of the SmartEx technology	Teaching land preparation, weed control, crop spacing, pesticide use, adoption of improved seeds.	Baseline status on improved seed, fertilizer application and pesticides application were exceeded by 85%, 50% and 71% respectively	Project advice incorporated the principles of agricultural sustainability, so attention to water management is likely to have been incorporated	N.A
Tanzania legumes	Smallholder legume farmers through the use of technical innovations Rural agricultural input dealers and extension officers trained in using improved seeds and good agronomic practices for legumes.	Production of certified seed and basic seed for the promoted varieties, to raise yields	Focus on production of nitrogen-binding legumes.	N.A.	N.A.
		What approaches were used by the projects?			
Project	Who is intended to benefit?	Increasing, diversifying and stabilising production	Sustainable land and livestock management	Integrated water resource management	Protection / enhancement of biodiversity
Reducing losses and spoilage with cutting-edge science					
Cote d'Ivoire coconut disease	Smallholders with coconut groves and womens' groups	Research on disease to control and mitigate effects of CILY disease on productivity of coconut trees.	Use of chicken manure and other soil protection & water management practices to boost soil fertility. Training farmers in disease prevention.	N.A.	
Nanotech for fruits	Small, marginal and medium sized farmers of a range of fruits in India, Kenya and Tanzania, Caribbean and Canada. Benefitted from improved fruit production and post-harvest packing/ processing. Packagers and shippers: benefited from improved packaging that prolongs shelf life India: post-harvest entrepreneurs	Reducing fruit drop in field, lengthening harvest period, extending shelf-life of fruit (mangoes, oranges, banana) to reduce post-harvest losses and reducing pest attack to reduce pre-harvest losses through nanotechnology.	Use of EFF sprays reduce fruit drop in the field and the need for post-harvest pesticides.	N.A.	

Project	Who is intended to benefit?	The elements of sustainable agricultural productivity			
		Increasing, diversifying and stabilising production	Sustainable land and livestock management	Integrated water resource management	Protection / enhancement of biodiversity
Novel vaccines for livestock	Small animal livestock owners and their communities in Kenya and South Africa	Vaccine to reduce livestock loss and increase productivity per animal.	N.A.	N.A.	N.A.
Africa CBPP vaccine	Bovine livestock owners and their communities in Africa	Vaccine to reduce bovine livestock loss and disease to increase productivity per animal.	N.A.	N.A.	N.A.

Source: Authors' construction using IDRC documentation.