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Smallholder outcomes for increased food production

Research innovations in agricultural inputs and technologies

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The Food & Business Research programme

Food & Business Research aims at addressing persistent food and nutrition security challenges in low and middle income countries. It focuses on the urgent and growing need for adequate knowledge and solutions for regional and local problems related to food security. Food & Business Research consists of two funding instruments: the Food & Business Global Challenges Programme (GCP) and the Food & Business Applied Research Fund (ARF). Both are part of the Food & Business Knowledge Agenda of the Netherlands Ministry of Foreign Affairs (MoFA). The objective of GCP is to promote research-based advanced understanding of emerging key issues in global and regional food security and their impact on local food security and the role of private sector development. The objective of ARF is to promote research-supported innovations that contribute to food security and private sector development in the partner countries of Dutch development cooperation. Food & Business Research is funded jointly by the MoFA and NWO-WOTRO and is managed by NWO-WOTRO.

Research for Impact

NWO-WOTRO Science for Global Development aims to support researchers in increasing the societal and policy impact of their research projects. NWO defines societal impact of research as 'the contribution that innovative research makes to understand and solve global issues, with a focus on sustainable development and poverty reduction'.[1]

NWO-WOTRO developed its 'Research for Impact' approach[2] starting from the realisation that research insights and innovations do not automatically lead to changes in society. The Research for Impact approach is expected to contribute to and facilitate the relevance, and accordingly the use, of research results for policy makers, practitioners, private sector stakeholders and other relevant actors. The approach consists of three elements, also applied in the Food & Business Research programme: i. Co-creation of knowledge by transdisciplinary[3] consortia, ii. Theories of Change and Impact Pathways as guiding frameworks for research formulation and execution, and iii. Research Uptake strategies that spell out which efforts are undertaken to enhance the potential of the research to contribute to societal impact.

More detailed information on NWO-WOTRO's Research for Impact approach can be found on the NWO-website.

[1] From: www.nwo.nl/en/common/about-nwo/organisation/nwo-divisions/wotro/the-impact-of-research

[2] NWO-WOTRO's approach builds on concepts, frameworks and visions developed by partners such as DFID, ODI and IDRC.

[3] Transdisciplinarity refers to the involvement of different types of knowledge and knowledge holders: academic, practitioner's, indigenous and others.

1. Introduction

The Food & Business Research programme started from the premise that smallholders play a key role in contributing to food and nutrition security for their households and communities, regionally, as well as worldwide. Indeed, it is estimated that smallholders produce 50-80% of the world's food (Ricciardi *et al.* 2018). At the same time, smallholders and their families are counted among the poorest and most food insecure people in the global South. It is in this context that the Zero Hunger Challenge, launched by the United Nations in 2012, called for a 100% increase in smallholder productivity and income.[4] In 2016, this became a key target of SDG 2. The 2020 Global Food Policy Report once again reiterated this call, stating that 'boosting smallholder productivity and incomes and creating off-farm employment' are essential to help the poorest people in rural areas move out of poverty (IFPRI 2020, p. 15). Many studies report that within developing countries, smallholders are more efficient in producing food than larger farms. This inverse relationship between farm size and productivity serves as an additional incentive to focus agricultural development policies on smallholders to increase productivity and enhance overall food security (Rapsomanikis 2015, 10-11).[5]

A key ambition of the F&B Research programme was to contribute to 'the adoption by farmers of new knowledge and innovations for high yielding, nutritious and resistant varieties that will result in increased food production'.[6] Based on a review of thirteen projects (see below), this paper discusses the project *outcomes* that were achieved for increased food production by smallholders, and looks at the effects hereof on farmers' income and food and nutrition security. In its Research for Impact approach (see cover page), NWO-WOTRO defines outcomes as 'changes in behaviour (relationships, actions and activities) of stakeholders, resulting from exchange of knowledge and the uptake of research output from the research projects'.

The outcomes of Food & Business research projects for private sector, policymakers and practitioners are discussed in separate articles.[7] The research *insights* (as opposed to outcomes) relevant to smallholder agriculture are discussed in a separate, thematic, synthesis article.[8]

The paper is organised as follows. First, we present an inventory of the type of new and improved crop varieties, practices and innovations that were introduced by the projects and the extent to which these were applied by the small-scale farmers that were their target groups (Section 2). We then discuss our findings about the most important *drivers* and *barriers* for adopting the new knowledge and practices. This includes a consideration of the pathways that the projects used to move from new and relevant knowledge to actual adoption of new practices by the target groups (Section 3). In Section 4, we assess the results that were achieved by farmers who applied the improved crop varieties and agricultural practices, looking at production increases, economic and food and nutrition security outcomes. Section 5 summarises the key lessons and raises issues for future research.

[4] https://www.un.org/zerohunger/content/challenge-hunger-can-be-eliminated-our-lifetimes. Accessed 20 April 2020.

[5] The targeting of smallholders in national and international policy (e.g. HLPE, 2013) happens alongside other interventions and that focus on large-scale food production and which do not rarely interfere with the interests of smallholders.

[6] See F&B Research Revised Impact Pathway. "Resistant" varieties was not specified in the Revised Impact Pathway, but was translated by projects mainly to resistance to pests and diseases as well as drought tolerance.

[7] The outcome synthesis articles on the private sector and on policy makers and practitioners (to be published in June 2020).

[8] Thematic synthesis article on Smallholders.

For this synthesis, we reviewed eleven projects implemented in sub-Saharan Africa and two in Asia (see Annex). The smallholders targeted in these projects are all *producers* of food (farmers, fishers); we did not include projects that focus on small-scale food *processors*.

Box 1 Definitions of smallholders and Food & Nutrition Security (FNS)

The farmers targeted by the reviewed projects meet the definition of **smallholders** as 'those who work between less than 1 ha up to 10 ha, mainly using family labour, and using part of the production for household consumption' (FAO 2013: 1). The synthesis shows, however, that smallholders differ in socioeconomic status (resources and assets), which influences their ability and decisions to adopt research innovations.

Food and nutrition security refers to a situation wherein 'all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life' (FAO 2002).

2. Innovations to enhance smallholder productivity

The projects reviewed for this paper all focused on increasing the food production by smallholders. The possibilities for increasing production are reflected in the relationship between inputs, technology and outputs (Beddow 2015). The input is *what is used to produce food* (from land and seeds to water, fertiliser and pesticides). The output is *what is produced* (e.g. how many tonnes of potato or cassava per acre, how many litres of milk per cow). The technology determines *how inputs are turned into outputs*. The innovations researched and introduced by the projects focused on both inputs and technologies.

In this section, we distinguish two types of strategies used by the projects to enhance inputs and technologies: the identification and introduction of new or improved crop varieties (Section 2.1), and the introduction of improved agricultural practices (Section 2.2). Both strategies are well aligned with international expert outlooks, which suggest that 'Continued efforts to develop locally adapted improved crop varieties and to implement optimised management practices should further increase yields in Sub-Saharan Africa' (OECD/FAO 2019, p. 45).

In Table 1 and Table 2, we present an inventory that illustrates the wide range of innovations and practices researched and promoted by the thirteen Food & Business Research projects reviewed for this paper. It shows that, to increase food production, all projects used a variety of interventions and innovations (e.g. soil fertility innovations and seed multiplication sites) to address a complex set of problems (e.g. low yield due to high disease incidence and unpredictable weather). The information in Tables 1 and 2 also serves as a reference for the analysis in the remainder of the paper. The last columns in the tables include an indication of how well – or not - the different innovations and interventions were received and adopted by the target groups. This information was not available for all projects. Where it is available, the figures need to be read with caution as they are mostly based on assessments conducted towards the end of the project, while follow-up data on the sustainability of the intervention (i.e. continued uptake after project closure) is rarely available.

2.1 New and improved crop varieties

To improve smallholder productivity, the identification of the most suitable crop varieties for their local context is of key importance. The crop varieties and hybrids bred to achieve maximum yield in high-input farming systems, are often not suitable for low-input smallholder farming. Many crop varieties used by smallholders are moreover not resilient to changing climatic conditions, especially erratic rainfall and increased drought (Mugendi Njeru 2013). **The**

four reviewed projects that focused on identifying and introducing new or improved varieties, did so in response to smallholders' issues with low yield, slow crop maturity, high incidence of pests and diseases, and drought. These factors impacted their farm productivity and thus the availability of food for the household as well as income from farm sales. In several projects, the new or adapted local varieties were selected in close collaboration with the target farmers (see Section 3.1). Some projects took on board consumer opinions (e.g. on taste of the raw and processed products) as a selection parameter.

Identifying the most suitable variety is one thing; making sure this agricultural input is available for smallholders is another challenge. Quality seed and planting material is often too expensive for smallholders, which is exactly why they tend to share and use inferior varieties.[9] Several projects tackled this issue by introducing multiplication sites or small seed plot technologies. Where farmers were in a position to copy these strategies on their own farms, the adoption of new crop varieties was very high (e.g. Cassava for Food Security[10] and Seed Potato Innovations[11]; see Table 1). In the case that farmers depended on buying high-quality seedlings from private nurseries, or when these were distributed for free, the adoption proved to be lower (i.e. Cashew Nut Farming[12]). Finally, policy issues also influence smallholders' access to quality seed (e.g. through seed certification and seed laws). The role of policy-makers is touched upon in Section 3.4, and further discussed in a separate article in this series.[13]

[9] See also the ongoing research on seed systems in Africa and Asia, a programme collaboration between NWO-WOTRO, CGIAR and the F&BKP.

[10] 'Cassava Applied Research for Food Security in Northern Uganda' (see Annex).

[11] 'Development of potato seed quality based innovations for small-scale farmers in the three provinces surrounding Bujambura town in Burundi' (see Annex).

[12] 'Introduction of cashew nut for income security for poor farmers in Northern Uganda' (see Annex)

[13] The outcome synthesis article on Policy-makers and Practitioners will be published in June.

Table 1 Projects that researched and introduced new and/or improved crop and/or seed varieties (*input*)

Project[14]	The Problem	The Innovation	Is focused on	Adoption by farmers
Seed Potato Innovations, Burundi	Farmers have no access to high-quality seed potato and therefore use low-quality tubers that they obtain locally; this seed potato is susceptible to diseases, leading to low yield per ha.	Introduction of a new seed potato variety, based on scientific comparison between improved and local varieties Introduction of small seed plot technology for farmers to create their own nurseries of 10 m2	Higher yield Resistance to common potato disease In dry lowland area: drought-tolerant variety	All 465 farmers trained by the project started using the good quality seed. They buy certified seed from formal seed sellers or they produce their own quality seed potato.
Cassava for Food Security, Uganda	Farmers use local cassava varieties that are low yielding and susceptible to diseases (brown streak and mosaic disease).	Ugandan research institute in collaboration with 12 farmer groups evaluated improved (near-release) cassava varieties Multiplication sites were established for farmers to produce disease-free planting material	Higher yield Shorter maturity period Resistance to common cassava diseases and pests Drought tolerance Taste (raw & cooked) Flour quality	All 12 farmer groups (around 30 members per group) adopted the new varieties in their gardens. Farmers planted the new varieties also in their individual gardens. Differences in preferences for specific varieties between male and female farmers were noted
Cashew Nut Farming, Uganda	Cashew is a promising cash crop for northern Uganda, but farmers lack knowledge about it. Existing cashew trees are low-yielding.	Introduction of 4 high-yielding and adapted cashew varieties 1 multiplication centre established	Higher yield of nuts Faster maturity (nut bearing) Increased tolerance to pest and diseases	New cashew varieties were disseminated to 3,200 farmers; 164,000 seedlings planted Survival rates for the trees are low, estimated at between 20% and 50%
Sesame Yield, Uganda	Sesame yields are low and unstable due to: Use of traditional varieties and management practices Poor pests and disease control Declining soil fertility Frequent extreme weather events.	Intensification of sesame production (rather than area expansion) by increasing land and labour productivity Identification of 5 climate-smart, drought-tolerant varieties (on-station) and 3 promising varieties (on-farm) that need further trials	Stabilising sesame production Increasing sesame productivity	Overall adoption rates not reported Farmers produced over 45 tons of Quality Declared Seed and Certified Seed

[14] Full titles of all projects as well as links to project webpages can be found in the Annex.

2.2 Improved agricultural practices

To increase farmers' yield and productivity for increased food production, the four projects in Table 1 combined the identification of improved crop varieties (*input*) with introducing improved agricultural practices (*technologies*). Another eight reviewed projects focused primarily on the latter technologies: researching, developing and introducing context-specific, improved agricultural practices. The synthesis shows that they used integrated approaches to address four issues that were primary factors in causing smallholders' low yields. The first is depletion of soil fertility, which across sub-Saharan Africa has been gradually caused by the continuous cropping with few external inputs that characterises most smallholder farming systems (Mugendi Njeru 2013; FAO 2016). Drought, worsened by climate change, is a second major constraint to which smallholders are particularly vulnerable because they have limited resources to invest in coping strategies (Cohn et al., 2017). Thirdly, high incidences of crop diseases and pests, which are expected to increase even more due to climate change, compromise smallholder food production.[15] A fourth major constraint are post-harvest losses due to lack of proper storage and/or processing facilities.

Table 2 shows the range of new agricultural practices and innovations (*technologies*) that were introduced to address these four issues, such as smart fertiliser use; better disease and pest management; user-friendly irrigation technology; promoting the use of certified seed; improved storage for seeds, fodder and produce; and improving access to processing technologies. The last column gives an indication about the adoption levels by farmers for these new practices. The fact that there are differences in the farmers' willingness and ability to adopt new practices, even between farmers targeted by the same project, is influenced by their poverty levels and by the drivers and barriers discussed in Section 3.

[15] In two of the reviewed projects, the crop losses are up to one third (for cocoa in Sierra Leone) and 80-100% (for tomato in Kenya).

Table 2 Projects that researched and introduced new and/or improved agricultural practices (*technologies*)

Project	Problem	Good Agricultural Practices	Adoption of practices by farmers
Seed Potato Innovations, Burundi	Yield is impacted by: ○ Use of low quality seed (see Table 1) ○ Low soil fertility ○ Insufficient pest management Bad storage facilities lead to post-harvest losses	○ Farmers encouraged to use certified seed tubers only ○ Farmers taught about fertiliser use ○ Farmers taught about fungicide use ○ Farmers taught to build diffuse light storage for potatoes	○ All 465 farmers in the project started purchasing, or producing their own, quality seed. ○ Thanks to word of mouth, 60-70% of the farmers in the project area became aware of the importance of using quality seed. This meant that the project reached more farmers than its target. ○ Not all farmers could afford to apply fertiliser and fungicide, or to construct proper storage
Cassava for Food Security, Uganda	Yield is impacted by: ○ Use of low-yielding varieties (see Table 1) ○ Spread of diseases between farms ○ Farmers' lack of knowledge about pest and disease management ○ Unpredictable periods of drought and bush fires Lack of proper storage causes post-harvest losses (cassava gets mouldy)	○ Farmers trained to recognise common cassava diseases ○ Farmers supported in establishing multiplication sites for producing clean planting material ○ Demonstration gardens used for size & spacing of planting material, weeding frequency etc. ○ Cassava chippers provided for better quality chips, reduced harvest losses and new income opportunities	○ All farmer groups planted new cassava varieties ○ Some farmer groups started their own multiplication sites for using and selling clean planting material ○ Number reached directly by the project was 2,500; this includes the farmers and their household members ○ Total number of farmers reached was higher due to voluntary sharing of insights with neighbouring communities
Sesame Yield, Uganda	Farmers use traditional agronomic practices while facing poor soil fertility and lacking adequate pest management measures. Effects: ○ Low yield ○ Poor grain quality ○ Less profitable crop ○ Less competitive in grain markets	○ Combination of fungicide and insecticide to reduce insect pest and disease incidences ○ Application of inorganic fertilisers to increased sesame yields ○ Integrated soil nutrient management ○ Conservation agriculture	○ 4,174 female and 3,398 male farmers were trained on sesame production and marketing of sesame seed and grain. Adoption levels among those trained are not available. ○ 4 farmer groups were contracted to produce Quality Declared Seed. They produced and sold 45 tons of QDS at a premium price.

Smallholder Dairy, Kenya	Smallholder dairy farmers are impacted by: ○ Low milk yields, mostly due to (seasonal) feed scarcity ○ High post-harvest losses ○ Low access to formal market due to issues with milk quality and safety ○ Drought due to climate change	Training on Good Dairy Management Practices: ○ Introduction of new types of high-yielding and drought-tolerant fodder ○ Training on constructing silage as storage to have feed available throughout the year ○ Cleaner milk production (equipment, barns, personal hygiene) ○ Reading cow signals, especially for early detection of mastitis ○ Withdrawing period for milk sales after antibiotics use ○ Producing home-made high-nutrient feed for lactating cows ○ Making compost and manure for increased soil fertility ○ Planting of multipurpose trees (fuel wood, fodder) to stop soil degradation ○ Two farmers trained as artificial insemination (AI) practitioners for breed improvement	○ 129 farmers became shareholders of the new cooperative ○ 75% of them adopted growing of new fodder varieties ○ 22% started practicing silage ○ Adoption of withdrawal period after antibiotics increased from 78% to 90% ○ 90% planted the multipurpose tree seedlings
Farmer-led Soil Innovations, Uganda	Low yields due to: ○ Labour shortages ○ Declining soil fertility ○ Increasing vulnerability to climate change ○ Low use of inputs (agrochemicals, manure or fertilisers) ○ Insufficient farming support mechanisms	○ Soil management. ○ Compared local farmers' knowledge of soil fertility with lab assessments based on a visual soil fertility classification tool ○ Identification and development of methods for improving the effectiveness, sustainability and resilience of local conservation agriculture (CA), e.g. through zero tillage (cost-effective due to labour savings); crop rotation and ensuring continuous ground cover	○ Capacity built of 106 model farmers (75 men and 31 women) to carry out on-farm experimentation and 'farmer to farmer' extension ○ Each model farmer on average trained 22 other farmers; if half of those adopted at least one of the CA innovations then the total number of farmers impacted by the project was 1,166. ○ Assessment of adoption rates by farmers indicated positive results, especially for mulching, growing cover crops, minimum tillage.

Integrated Pest Management, Kenya	Tomato production in peri-urban areas is affected by crop losses of 80-100% due to pest (Tomato leafminer) and disease (Fusarium wilt-root-knot nematode complex). Issues: ○ Resistance to chemical pesticide ○ Previous management options have had a negative impact on the environment ○ Alternative management options are not feasible with smallholder crop production systems owing to limited land resource	Introduction of integrated pest management strategies with emphasis on the use of biological control products: ○ Integration of mass trapping, botanical extracts, microbial insecticide and a chemical pesticide for management of Tomato leafminer ○ Integration of NatuGro system, a fungicide and a microbial nematicide for management of the Fusarium Wilt-Root Knot Nematode complex	○ Increase in the number of farmers that are willing and have started using biological control products ○ 14,700 farmers across different counties have directly implemented the new technologies
Irrigation App, Bangladesh	○ Farmers in delta region are forced to leave large tracts of land fallow during the dry winter months ○ Declining water levels due to climate change and competition for water between agriculture and growing cities ○	○ Optimise water resource management by enabling farmers to obtain field-specific irrigation advice ○ Smartphone app was developed that analyses ground cover from RGB photos taken by farmers. PANI, an irrigation scheduling app, uses this input to calculate a daily soil water balance and determine crop water use ○	○ Subsistence farmers are not willing to pay for the app service as they don't feel confident using the technology ○ Irrigation service providers do not want to invest in the app service as they worry it will reduce their earnings due to more efficient water use by the farmers ○ Project partners are trying to convince the government to include the app service in their extension services for smallholders
Sustainable Cocoa Productivity, Sierra Leone	Low yields and income levels due to: ○ Reduced local knowledge and minimal access to 'modern' cultivation practices ○ Abandoned micro-plantations (due to war) and old age of cocoa trees ○ Fungal disease Black Pod which causes farmers to lose up to a third of their crop ○ Increasing foreign investors and potential risks of 'land grabbing'	Investing in cocoa rehabilitation by establishing 'block farms': a hybrid model that benefits from smallholder plots supplying to larger farms. The investors provide the knowledge and tools required for the smallholder to produce what is needed while keeping his land and labour potential.	○ Pests and diseases have reduced in the region surrounding the block farms thanks to knowledge spill-over from those working on the block farms to neighbouring farms. ○ 30% of farm land owners participated in the block farm model (across 1400 households in 31 villages) ○ 30-40% of villagers offered their labour to the block farms ○ Actual levels of adoption are not available, partly because Ebola crisis diverted research focus

Fertile Grounds, Burundi	Low yields caused by insufficient knowledge and expertise to address: ○ Low soil fertility and micro-climates demanding variable responses in terms of types of inputs used ○ Soil and nutrient losses by erosion ○ Erratic rainfall due to climate change ○ Increased pressure on land following return of refugees from Tanzania Standardised advisory messages against erosion and for adaptation to climate change are not applicable and practical for smallholder farmers who face a multitude of micro-climates with differing needs.	Improved crop cultivation method that reduces labour inputs: ○ Use of herbicides to control perennial and persistent weeds (eliminating manual hoeing to prepare the ground for sowing) ○ Application of low doses of organic and inorganic fertilisers ○ Use of green manure (ground cover) so that herbicides are phased out Method made possible by mapping of the agro-ecological zones of Burundi, stipulating specific propositions for different areas.	○ 52 farmers validated the integrated approach (conservation agriculture + low doses fertilizer + green manures) as they experienced increased yields and enhanced labour productivity ○ Due to lack of transport infrastructure, fertiliser has to be manually transported to farms. The amount of fertiliser used is strongly influenced by farmers' distance from collection points.
Parboiled Rice, Benin	Low productivity of local rice cultivation *NB This project had two aspects: increasing rice production and improving parboiling techniques. In this article, we focus only on the first aspect.*	Best practices from the System of Rice Intensification (SRI) were adapted to the local context, focusing on: ○ the choice of seed ○ the treatment of seed before sowing ○ the sowing method adapted to the context of pluvial lowland rice ○ the organo-mineral fertilisation and the fertilisation period	Adoption rate of RSI practices by farmers trained through Farmer Field Schools is 72-74%.

3. Drivers and barriers for the adoption of innovations by smallholders

It is not a given that innovations for inputs and technologies, even if relevant and made available, are adopted by the target farmers. Tables 1 and 2 provide an indication of the adoption levels towards project closure, as reported by the projects. The synthesis reveals that, for these projects, three factors were most influential in acting as a driver: effective farmer organisation (3.1), a participatory research approach (3.2), and the buy-in of local governments (3.4). Farmer perceptions on business risks and prospects, on the contrary, acted as a key barrier to adoption (3.3). We start this section with three general observations about research uptake in the reviewed projects.

Firstly, several projects emphasised that the visible involvement of academic researchers and research institutions from the project countries and the Netherlands lent credibility to the project findings. As a result, and because of the scientific evidence that was shared with them, the smallholders were more inclined to take on board innovations and new practices.[16] This was reinforced in projects that actively involved the farmers in a knowledge co-creation process (see 3.2). Multi-stakeholder collaboration between academic, private and public organisations is a key feature of the NWO-WOTRO Research for Impact approach. A separate article in the synthesis study series will be dedicated to the lessons learned from implementing this approach across the Food & Business Research programme.

Secondly, the synthesis suggests that the **adoption of innovations is partly determined by differences in the availability of resources among farmer households**. Farmers with very few resources were unable to afford certain innovations, and may also be more risk-averse. This confirms an analysis of smallholder household data from nine countries, which concluded: 'Income risk also hinders the adoption of more productive technologies and good farm practices, in spite of their long term benefits for the individual farmer and for overall productivity growth' (Rapsomanikis 2015, 30)[17]. This factor was evident, for instance, in the Seed Potato Innovations project in Burundi, where farmers' relative wealth determined their adoption of the project innovations. While most farmers were able to start using the new seed potato varieties, fewer farmers could afford to apply the fertilisers and fungicides introduced by the project, and only a small number had the resources to construct light-diffuse storage facilities. These differences did not come as a surprise to the project team, but it did mean that the more well-off farmers benefited more from the project as their yields increased the most and their post-harvest losses were most significantly reduced.

Thirdly, in nearly all reviewed projects farmers' risk perceptions related to climate change played a role as either driver or barrier for research uptake. In many cases, it was a driver, as farmers in areas where harvests have repeatedly failed due to erratic rainfall or increased drought, were highly receptive to trying out drought-tolerant crop varieties or other innovations meant to mitigate climate change impacts. In these cases, the climate risk perceptions acted as a driver for uptake. The Farmer-led Innovations project[18] in Uganda purposely built on the conservation agriculture practices developed by the farmers to increase adoption of relevant, climate-smart innovations. In other cases, however, the unpredictability caused by climate change made farmers reason that there was no point in investing in project innovations because 'no one knows when the next drought will strike'. The insecurity caused by climate change became a risk factor that negatively influenced their decisions.[19]

[16] The same finding is illustrated in the outcome article on the private sector .

[17] The nine countries include: Albania, Bangladesh, Bolivia, Ethiopia, Kenya, Nepal, Nicaragua, Tanzania and Viet Nam.

[18] 'Farmer-led soil innovations to sustain food production' (see Annex)

[19] A separate article in this synthesis study series, to be published in late 2020, will focus on climate-smart agriculture.

3.1 Participatory approach involving farmers

Several **projects indicated that a major driver for adoption of innovations by the farmers was their participatory approach**. The explanations given are consistent with the objectives of the Farmer Participatory Research that started to spread in the late 1980s (Orabi 2017). Firstly, in projects that used a participatory approach, **the farmers were motivated to try the new practices because they had consistently been asked for their input**, opinions and feedback from the start of the project. As a result, they felt they co-owned the project's interventions. Secondly, **the participatory approach allowed projects to build on farmers' indigenous knowledge, which enhances the chances that the innovations are relevant to their needs** and will be adopted. The Farmer-Led Innovations project, for example, built on indigenous conservation agriculture practices; while the Smallholder Dairy project[20] in Kenya built on farmers' knowledge about treating animal health with botanical and organic products rather than with antibiotics that compromise milk quality and safety. Thirdly, the participatory approach meant that the **farmers could 'see with their own eyes' the positive changes brought about by the interventions**, such as higher yields due to new varieties, better soil fertility, or lower disease incidence. Rather than relying on hearsay, the farmers could trust their own observations, which helped in getting them on board and willing to invest resources (money, time) in trying out new varieties or practices (see Box 2).[21]

Demonstration gardens and field trials, used by most reviewed projects, proved an effective tool in the participatory approach and encouraged peer-to-peer learning. Mutual learning is the key feature of 'learning platforms' or 'innovation platforms', which were used by a smaller number of projects.[22] These platforms encourage interaction and joint learning *beyond* the farmer community, purposefully including also private and institutional actors, and researchers. This is the approach used by the Inclusive Value Chain Collaboration' project[23] in Ghana and South Africa, which focused on learning about low-cost, bottom-up innovations based on farmers' own knowledge, day-to-day challenges and (limited) access to assets (Ros-Tonen et al. 2019). The Parboiled Rice project in Benin set up innovation platforms for stakeholders of the rice sector in the two municipalities where the research was conducted. Organisations of rice farmers and parboiling women, traders and food sellers, public administrations and other actors came together to devise innovative solutions to support the domestic rice sector. A marketing campaign for '*riz blanc*' was started to encourage pride in producing and consuming a domestic product.

[20] 'Innovations for sustainable and profitable intensification of smallholder dairy in Kenya' (see Annex).

[21] The importance of farmer involvement in research is also noted in Mariano et al. (2012).

[22] This is further discussed in the thematic article on Smallholders and will be elaborated on in a separate article will focus on NWO-WOTRO's Research for Impact approach as implemented in the Food & Business Research programme.

[23] 'Inclusive partnerships and innovation platforms for sustainable landscapes and greater food sovereignty among tree crop farmers in Ghana and South Africa' (see Annex).

Box 2 Seeing is believing

The Cassava for Food Security project in northern Uganda used Participatory Variety Selection (PVS) sites to actively include the farmers in the evaluation and testing of three newly released as well as four near-release cassava genotypes. Together with a Ugandan agricultural research institute (NaCCRI[24]), the farmers determined the selection criteria: yield per plant, maturity rate, resistance to pests and diseases, drought tolerance, how they grow (many or few branches), taste (raw and cooked) and flour quality. Farmers selected different cassava varieties for different purposes, e.g. for food, for stems (planting material), or for intercropping. Interestingly, the preferences differed by gender. Men preferred a variety with a lot of branches, as this reduces the time needed for weeding (saving labour costs) and offers opportunities for selling cassava stems (increasing income). The women chose the variety with fewer branches, because this allowed them to intercrop the cassava with protein-rich beans to help diversify the household diet. Growing beans moreover contributes to nitrogen in the soil, which in turn has a positive impact on cassava yield. 95% of all farmers (342 of 360 farmers in the 12 groups) adopted the newly released cassava varieties. By the end of the project, several farmers had started to increase the land under cassava cultivation and had assigned different plots for different varieties. Notably, the participatory approach may also influence adoption at policy level, as NaCRRI expects that the fact that the four near-release genotypes were evaluated with first-hand input from the farmers will help to fast-track their approval and release by the Ugandan Ministry of Agriculture, Animal Industry and Fisheries (MAAIF).

3.2 Farmer organisations

The synthesis findings suggest that the organisation of farmers into cooperatives or producer groups was a key driver for the successful adoption of research insights and innovations by farmers. This gives a slightly new angle to the oft-cited advantages of farmer organisation that focus more on the tangible business benefits of working in cooperatives and farmer groups, i.e. reducing costs for inputs (seeds, fertilisers), aggregating produce, and improving bargaining power (e.g. IFAD, undated). The synthesis shows that working with farmer groups was also an effective means to enhance research adoption. First, farmer organisation is an effective means to address smallholders' concerns about business risks and prospects which might stop them trying out new crops or practices. The prospects of working as a group and sharing responsibilities, reduces risk perceptions. This was a primary success factor in the Smallholder Dairy project in Kenya (see box 3) and played a facilitating role in Burundi and Uganda, where producer groups for potato and cassava pooled resources to create spaces to bulk their – bulky - harvests for easier access to trading routes and purchases by intermediaries. A second advantage of working with groups is that it facilitates training and promotes peer-to-peer learning and joint decision making. Within and between groups, farmers are keen to copy new practices, even if only to not miss out on the opportunity that peers are seizing. This peer-to-peer dynamic is a driver for adoption, and can even act as a catalyser for adoption of innovations in neighbouring farming communities.[25] Enthused by the group's successes, farmers often started to formally (trainer of trainers, model farmers) or voluntarily (early adopters) share their insights and new practices. Several projects reported that as a result of this, adoption levels surpassed project targets. The Cassava for Food Security project, for example, aimed at 20% adoption of new varieties but achieved 95%. Thirdly, farmers have also been organised into producer groups to address fragmentation of land, which can also act as a barrier to adoption of innovations.

[24] National Crops Resources Research Institute, Uganda.

[25] Krishnan and Patnam (2013) note the specific role of neighbours after the initial importance of extension agencies.

Box 3 The cooperative incentive

Intensification of smallholder dairy farming is a priority of the Kenyan government. Smallholders produce up to 80% of the country's milk and the demand for dairy is fast increasing due to a growing and more affluent population. The Smallholder Dairy project in Nakuru County was designed in response to this context. The dairy farmers targeted by the project, however, were reluctant at first to try out the project innovations, such as investing in new fodder varieties and hygiene to improve milk yields and quality (see Tables 1 and 2). The farmers doubted that they would be able to market higher quantities of milk and feared wastage of milk and money. Given the farming communities' proximity to urban markets, the project team had not anticipated this resistance. Yet realising it might jeopardise the project outcomes, the team went back to the drawing table and decided to set up a cooperative that could serve as a marketing platform. It proved to be the right move. 129 farmers became shareholders of the cooperative, which helped to solicit support (milk coolers and pasteurizer) from both the county and national government and to negotiate a supply contract with a milk processor. By the end of the project, all farmers had adopted elements of the innovations depending on their financial and labour resources, and with considerable returns in terms of increased milk yields and income (see Case 1 in Section 4).

3.3 Risk perceptions and business prospects

Several projects reported that small-scale farmers were reluctant to adopt new crop varieties or agricultural practices if they doubted that there were viable business prospects. Their key concerns were gaining a higher income through access to new and reliable markets and/or to processing facilities for their raw material. Without such assurances, they considered the risks of investing too high, realising they would be left with excess produce that would likely go to waste due to their lack of proper storage or transport facilities.[26] It appears that several projects underestimated how the risk perceptions of the farmers would constitute a barrier to research uptake. Project teams may have wrongly assumed that if *they* were convinced of the business prospects, this would equally convince the farmers. Due to their lack of a financial buffer and because smallholders face many hidden costs when trying to enter formal markets (Pouw et al, 2020), they have very small windows of opportunity for taking investment risks. Several projects noted that rather than only the *size* of the potential market, its perceived *reliability* was an equally or even more important factor for smallholders in their decisions to adopt new crops or practices.[27]

The Pond System Farming project in Vietnam had a hard time convincing the fish pond farmers that their 'nutritious pond' innovation meant that the farmers needed to fewer feed additives to achieve the same fish yield. The farmers had been involved in field trials, yet doubted the impact of this new approach on their productivity and income. This uncertainty was reinforced by the powerful marketing about the importance of additives by the fish feed industry. A spin-off of the Vietnam project in Bangladesh, on the contrary, was successful in getting the farmers on board. The reason given was the collaboration in Bangladesh with WorldFish, which – unlike the team in Bangladesh - had built up relationships of trust with fish farmers over many years. As was illustrated in Box 3, the Smallholder Dairy project in Kenya responded to the farmers' concerns about marketability by setting up a cooperative, which reduced the farmers' perception of investment risk. The Cashew Nut Farming project in northern Uganda was less successful in convincing their target farmers that investing in cashew would pay off, as is discussed in Box 4.

[26] Abebe et al. (2013) also report that market-related factors may play an even more important role in adoption than production-related characteristics of the innovation.

[27] E.g. Smallholder Dairy project in Kenya, and Market-Oriented Dairy Systems project in Kenya and Ethiopia and Solar Mango Drying project in Ghana, discussed in the synthesis article on the private sector and the synthesis article on smallholders.

Box 4 No farmer commitment without processing prospects

The Cashew Nut Farming project introduced the cashew tree as a high-potential cash crop for northern Uganda. Scientific research had proven its adaptability to dry areas and market research conducted by the project revealed a high demand from supermarkets and restaurants. Around 160,000 seedlings were distributed to 3,200 smallholders. However, the farmers were sceptical about the business prospects and as a result didn't put much time or effort into looking after the young cashew trees. Only 20 to 50% of the trees survived. It appears that the project didn't manage to convince the farmers that capacities for collecting and processing the nuts would be put in place to ensure they would be able to sell their harvest. Also, cashew is a tree crop that matures much more slowly than vegetable or staple crops, which meant that the 'seeing is believing' strategy could not be used within the project's timespan. Finally, it seems that adoption was low because the farmers didn't feel they co-owned the project. They had not been involved in project design and had been given the seedlings for free (despite disagreement on this approach from some project partners) and, as one of the partners summarised 'who will put effort into something that comes for free if no immediate benefit is seen?'

3.4 Buy-in from governments

Securing the cooperation and buy-in of government agencies was a fourth important factor for positive adoption outcomes. The set-up of the Food & Business Research programme lay the groundwork for this buy-in, by requiring that projects were driven by local demands, and for ARF projects that they were aligned with the Multi-Annual Strategic Plans of the Dutch Embassies in the project countries. Projects that intentionally focused on government priorities (e.g. Smallholder Dairy in Kenya, Cassava for Food Security in Uganda, Seed Potato Innovations in Burundi) seem to have relatively easily gotten government officials on board to cooperate with or actively support the project (see Boxes 5 and 6). The Cashew Nut Farming project in Uganda, which did not manage to get the farmers on board, did manage to convince the government of the high potential of cashew as a tree crop for northern Uganda. The long-standing good rapport between some of the project partners and government agencies at both national and district level contributed to this: they were invited to present their research findings at the Prime Minister's Office. The Ugandan government has since included cashew as a new priority tree crop in its 'Operation Wealth Creation' programme, that is meant to transform the agricultural sector.

In several cases, where research results were validated within the project lifespan and had a proven impact on food production, government extension officers started integrating the methods in their curriculum and advice to farmers. The fact that they had been actively invited to partake in project trainings and workshops was a key factor in this (e.g. Fertile Grounds in Burundi; Integrated Pest Management in Kenya; Smallholder Dairy in Kenya). Local governments in northern Uganda prioritised sesame in their development plans and strengthened input regulation for sesame farmers because of their engagement with the Sesame Yield programme. Also in northern Uganda, the Cassava for Food Security project successfully lobbied for a local government ordinance stating that animals are no longer allowed to freely roam in the dry season to avoid them destroying young cassava plants. The NGO partner of project emphasised that the positive involvement of the district's agricultural department lent credibility to the project. It helped to convince the farmers to participate. It had been a conscious project strategy to closely involve the district agricultural departments, especially as an exit strategy to ensure sustainability of the results after project closure.

Getting active government support, however, is not always easy. The Irrigation App project in Bangladesh was well-aligned with government priorities, both in terms of its focus on improving the livelihoods of smallholders, addressing climate change impacts, and integrating technology solutions for the agricultural sector following the 'Digital Bangladesh Vision 2021'. The project developed a user-friendly smartphone app that can provide field-specific irrigation advice to subsistence farmers. Because farmers were unwilling to pay for the service, the private partner in

the project is liaising with the Department of Agricultural Extension, suggesting they offer it as a service. There are clear signs of interest, but it is to be a long process, requiring many government actors to come on board.[28]

Box 5 Leveraging county government investments in dairy

Dr Immaculate Maina, Nakuru County Executive Committee Member in charge of Agriculture, Livestock and Fisheries on the county's engagement with the Smallholder Dairy project: 'Nakuru County has the largest number of cows in Kenya, yet we are only the third largest producer of milk. This means that our animals are not producing at the optimum level and we therefore need to improve the smallholder dairy systems. The research project, which trained farmers on better dairy management strategies such as better feed and hygiene, was perfectly in line with our objectives. Because I come from a research background myself, I am always looking for scientific evidence to support our policies. The project established that farmers lose a lot of their harvest due to milk spoilage. These post-harvest losses are a key concern for the government. That is why both the Ministry and we as a county stepped in and provided two milk coolers and a pasteurizer to the cooperative that was established by the project.' (see also Case 1 in Section 4)

Box 6 Law amendments benefit smalls-scale seed multiplication in Burundi

Gilbert Buhanza, National Office of Control and Certification of Seeds in Burundi: 'Insights from the Seed Potato Innovations project made me realise that if we want to change the seed sector, our policies should target smallholders. Regulations for seed multiplication in Burundi stipulated that certified potato seed can only be produced on areas of at least 2 ha. This excluded smallholders from participating in this key value chain activity. Partly as a result of advocacy efforts based on the project's insights, the national law was amended, allowing certified seed multiplication on 1 ha plots. As a result, many smallholders became registered seed producers. Simultaneously, our office started training extension workers to conduct quality control and inspection of seed multiplication. The capacity increased from 5 to 47 trained (of whom 35 operating) seed inspectors country-wide. These changes have helped to increase the quantity of seed potato production in Burundi, reducing the farmers' dependency on imported seeds. The same strategy of small-scale multiplication is now being introduced for other crops such as maize and beans.

[28] This case will be elaborated in the outcome synthesis article on policy makers and practitioners (to be published June 2020).

4. The results of innovation adoption by farmers

Section 2 presented the range of innovations in *inputs* (new and improved crop varieties) and *technologies* (improved agricultural practices) that were researched and introduced to support small-scale farmers in enhancing their food production (*output*). In this section, we assess the impacts of the adoption of these innovations by the farmers. We start with the *output* results: did the projects record increases in yield? We then look at whether increases in yield had an impact on, firstly, the income and livelihoods of the farmers, and secondly, their food and nutrition security. Two case studies presented at the end of this section illustrate how the integrated approach taken by most projects pays off and what challenges remain.

4.1 Results in terms of yields

First and foremost, we see that, **in all projects reviewed where new varieties and agricultural practices were adopted, farmers' yields did indeed increase.** The projects that measured the yield increases, revealed that significant yields were realised, ranging from 20 to 100% (see Table 3). These are the figures that were provided by the projects in their final reports. None of the project teams had the resources to conduct follow-up assessments, which could however give more valuable insight into the sustainability of these positive results.[29] Nevertheless, several project partners stated that they have witnessed farmers continuing to use the new crop varieties and apply the improved practices after project closure (e.g. Smallholder Dairy, Cassava for Food Security, Integrated Pest Management, Seed Potato Innovations). As also suggested in Section 3.2, an interesting question for follow-up research is to what extent farmer organisation leads to increased adoption of research innovations, and thus could trigger higher increases in overall food production and possibly scaling of the innovations. This knowledge would complement examples in literature that suggest that participation in farmer groups is associated with increased yield and technical efficiency (e.g. Rahaman & Abdulai 2018).

Table 3 Effects of new inputs and technologies on output (yield)

Project	On-farm effects of innovations on yield
Cashew Nut Farming, Uganda	Field experiments showed that new varieties can yield between 8-15 kg of Raw Cashew Nut (RCN) per tree, compared to 4,5 kg per tree of existing trees. However, whether smallholders introducing the trees in their gardens achieved this RCN yield has not been assessed because maturity of the cashew trees was beyond project lifespan.
Cassava for Food Security, Uganda	The average increase for new cashew varieties was from 19.7 tonnes per acre to 28.9 tonnes per acre. The maturity period of the new varieties was reduced from 2 years to 12-18 months. Average increase for local varieties, due to improved agricultural practices, was from 9.2 pa to 23.8 pa.
Farmer-led Soil Innovations, Uganda	Yield increases of more than 500 kg per hectare for groundnut and up to 1000 kg per hectare for maize. Average groundnut yields in Uganda are often significantly under 1 tonne per hectare and maize production is on average at 2.5 tonnes[30]

[29] This would be relevant information in light of the known fact that the difference between commercial yields achieved by farmers and experimental yields achieved by researchers can be considerable (Beddow 2015).

[30] Jeliffe et al. 2018; Simtowe et al. 2019.

Fertile Grounds, Burundi	Farmers achieved yield increases, but no quantitative data is available.
Integrated Pest Management, Kenya	Farmers achieved a 20% increase in tomato yields and a significant reduction in post-harvest losses due to adopting IPM.
Parboiled Rice, Benin	Farmers increased their rice yield by 100%, from around 2.5 tonnes/ha to 5 tonnes/ha.
Sesame Yield, Uganda	Improved seeds increased farmers' sesame yield by 44% in 2016. New seed varieties increased yield from 1.5 bags per acre to 3 bags per acre (1 bag = 90 kg). Use of inorganic fertiliser increased yields by 105% over 2 years in 8 locations, with a higher response in improved varieties.
Seed Potato Innovations, Burundi	Using improved variety seed increased yield by 20%; using healthier seed potato tubers increased yield by 80%. Application of fungicides increased yield by 50% Application of fertilisers increased yield by 60% Storing seed in diffused light stores increased yield by 20%.
Smallholder Dairy, Kenya	Average milk yield of 6.8 litres per day per cow increased to 15 to 30 l/day/cow depending on the range of innovations adopted (improved fodder, silage, hygiene and disease management).
Sustainable Cocoa Production, Sierra Leone	Quantitative data on yield increases is not available.

4.2 Results in terms of incomes and livelihoods

The second key question is: does the increased yields and total food production also led to increased incomes for the farmers? The answer depends on a range of external factors, including whether the farmers have access to informal and formal markets where there is a reliable demand for their produce. While most reviewed projects that realised increased yields reported indications of increased income and profitability for the farmers, only four projects quantified the raises in income, revenue or gross margins that had been or could be achieved (see Table 4). Whether these increases were achieved by all or most farmers who adopted the innovations, and whether they will prove to be sustainable, was beyond the scope of this study.

Table 4 Actual or potential increases in income resulting from increased yield

Project	From higher yield to higher income
Cashew Uganda	Field experiments show that increased Raw Cashew Nut yields due to new varieties can result in gross margins going up from current 53 USD/ha to 272 USD/ha.
Sesame Yield, Uganda	The quality declared and certified seeds are fetching a premium price of UGX 5,000/kg (euro 1,20/kg) at farm-gate, compared to the current farm-gate price of UGX 3,400/kg (euro 0,80/kg).
Seed Potato Innovations, Burundi	Shifting to a newly released variety, improved seed, diffused light store use, fertilizers and fungicide utilisation gave marginal rates of return of respectively: 202%, 230%, 162%, 230% and 185%.
Smallholder Dairy, Kenya	Farmers improved their revenues from on average KSh 47,409 (€400) per herd to KSh 60,964 (€525) to 108,374 (€935), depending on which selection of innovations was adopted.

Beyond quantified data on incomes, **the projects did provide interesting narrative evidence on positive impacts on farmers' livelihoods.** Several projects reported that farmers used increased income to improve their homes (especially roofing) and pay for their children's education. In several cases, furthermore, did the project innovations result in **new business opportunities that had not been foreseen in the project design**,[31] such as the cassava farmers in Uganda who started selling clean planting material and are exploring opportunities for value addition for high-end markets (see Case 2). The Fertile Grounds project in Burundi reported that farmers started producing green manure seeds at scale, while certified agro-dealers started to import herbicides, which were introduced by the project to control persistent weeds. Women, who traditionally are responsible for weeding, were most appreciative of the new method as it saves them a lot of time at the start of the planting season.

A couple of the reviewed projects explicitly reported that a selection of farmers managed to transform from subsistence level to being market-oriented. There might well be more examples that we are not aware of, either in the reviewed projects or in projects not included in this paper. The projects with known positive examples are the Smallholder Dairy project in Kenya (see Case 1) and the Seed Potato Innovations project in Burundi. Some farmers in Burundi who started using the project innovation of seed plot technology for producing seed potato, have since become formal seed producers recognised by the new seed law. They started exclusively focusing on seed potato, rather than ware potato, and 34 of them succeeded to obtain supply contracts with 174 producers of potato for consumption. In the case of the Cashew Nut Farming project, new business opportunities were also generated as a spin-off of the project, yet these opportunities were seized by more resourceful agri-entrepreneurs who started cashew nurseries and plantations, while the smallholders who had been targeted as the beneficiaries of the project did not invest in cashew (see Box 4). The insights from the Pond System Farming project in Vietnam have high potential for fish pond farmers and private businesses alike in the aquaculture industry, and follow-up research and trails are being conducted for the innovations to be implemented in the near future.[32] In Benin, the Parboiled Rice project resulted in new arrangements between rice farmers who increased their productivity and commercial rice processors.[33]

[31] Related to this, see the sections on 'new market players' and 'new value chains' in the outcome synthesis article on the private sector.

[32] See the outcome synthesis article on the private sector.

[33] The project findings and results also contributed to a new project, the Fair Rice project, that aims at enhancing the competitiveness of local rice production and processing and which will benefit many of the rice farmers by giving them better market access.

4.3 Results in terms of food and nutrition security

Lastly, we tried to examine the impact of increased yields and incomes on the food and nutrition security of the farmers and their households. Improved FNS is the long-term objective of the Food & Business Research programme. **None of the projects, however, quantified the FNS impact of their innovations; it was too soon to try and do this in any relevant manner before project closure. The evidence of project impact towards improved FNS that is available, therefore, is of a narrative and often anecdotal kind.** Several projects mentioned that increased yields, for instance of cassava, potato, sesame, rice and milk, were partly used to boost household consumption of these products. Other projects gave examples of how increases in income were used to buy different vegetables and/or meat to improve household dietary diversity, or to start planting and intercropping different crops such as beans for the same purpose. Two projects mentioned that farmers started rearing poultry to produce eggs and meat, or even bought a cow to have milk for household consumption and possibly informal sales. The Smallholder Dairy project revealed how the farmers in their project location became more food resilient in times of drought (see Case 1).

This anecdotal evidence is not enough to conclude that increases in income – through increased food production and market access – automatically lead to improved food and nutrition security. **That higher income automatically leads to improved FNS is a persistent assumption in many research projects as well as in policy, yet this relationship merits dedicated empirical research**.[34] **At the same time, divorcing livelihood and nutrition outcomes can be an artificial undertaking in the everyday reality of smallholder farming systems where both parameters are intrinsically linked**. If smallholders' income goes up, they will have different purposes for the extra money depending on current needs. For instance, depending on the season, part of the money may be used to diversify the household diet by buying meat or fish. Another part may be used for buying fertiliser or certified seeds, which in turn will result in more and/or higher-quality produce that may support FNS in the next season. Even using increased income for paying for children's education is a livelihood strategy that may in the long-term improve the family's food security.

[34] See also the thematic synthesis article on Smallholders, which discusses the same assumption.

Case 1: Kenyan dairy farmers join forces to increase milk yield and incomes

The Smallholder Dairy project (2016-2019)[35] worked with 129 farmers in Nakuru County in Kenya's Rift Valley to integrate good dairy management practices for profitable and environmentally sustainable dairying. Dairy is the most important value chain in Nakuru County.

Increased milk yield

The key innovation for increasing milk yield, were new types of high-yielding and drought-resistant fodder (sorghum, yellow maize). The farmers (75%) who started growing and then feeding their cows this fodder, instead of leaving them to graze randomly, achieved substantial increases in milk yield: from 6.8 litres per cow per day to 15 to 30 l/cow/day. The highest increases were achieved by the farmers (22%) who also adopted silage in addition to improved fodder. Silage is an innovative method for feed conservation, which ensures availability of quality feed throughout the dry season. 100 farmers have not yet been able to afford the silage construction material.

Other practices focused on milk safety and quality, to support the farmers in marketing their milk to formal processors. These included training on early detection of diseases (especially mastitis), withdrawal period for cows who are on antibiotics, and better hygiene. Adoption of these practices again partly depended on farmers' resources.

Income benefits

Before the project, the farmers mainly sold small quantities of milk on roadside markets, to intermediaries, neighbours and local hotels, with the surplus used for household consumption. The project helped the farmers establish a cooperative that could serve both as a training and learning hub, as well as a marketing platform. All 129 farmers became shareholders of the cooperative (also see Box 3). With a registered cooperative, they became eligible for government support. The Ministry of Agriculture, Livestock and Fisheries donated a milk cooler of 3200 litres, and the Nakuru County government donated another 500 litres cooler as well as a 500 litres pasteurizer. For the first time, the farmers could bulk their milk and even keep their evening milk – which normally gets wasted - cool overnight. The farmers negotiated a supply arrangement with a leading East African dairy processor, the Kenya Cooperative Creameries (KCC), which pays a higher price per litre than the middlemen. Together, the farmers invested in a community seed system for quality fodder seed multiplication, and hired farms to produce fodder seeds and commercial fodder for sale.

The increased market access has benefited all 129 farmers, giving them a higher *and* more regular income. The farmers improved their revenues from KSh 47,409 (€400) on average per herd per year to KSh 60,964 (€525) or even KSh 108,374 (€935) for those who managed to adopt the silage practice. These 29 farmers transitioned from being subsistence farmers to running a small farming enterprise. The increased income from milk sales allowed them to employ 2 or 3 persons to work fulltime on their farms (watering, feeding and milking the cows, washing dairy equipment and cleaning the barns), thus also contributing to local employment.

Impact on food and nutrition security

The impact of the project on the food and nutrition security of the 129 households has not been systematically assessed. There is evidence, though, that the cooperative members have increased home consumption of milk. Some families have started making yoghurt and fermented milk, which contributes to improved nutritional outcomes in those households. The most interesting evidence of improved levels of FNS is that all cooperative members refrained from registering for food hand-outs during the 2018 drought, while they had been on the county government and NGO hand-outs list during previous drought and scarcity episodes.

[35] Consortium members: Mt Clara Mtakatifu Mwangaza Centre, Kenya; Egerton University, Kenya; WUR, the Netherlands.

Case 2: Cassava farmers in Uganda seize new business opportunities

The Cassava for Food Security project (2016-2019)[36] in Uganda worked with 12 farmer groups (60% of the 360 participating farmers were women) to research, test and introduce innovations for increased yields. Cassava is the main staple crop in the region of northern Uganda where the project was implemented.

Increased cassava yield

The combined adoption by the farmers of effective disease management and improved agricultural practices resulted in increased cassava yields of 50 to 100%. Farmers who adopted the newly released varieties, achieved an average increase from 19.7 per acre to 28.9 per acre (plus a shorter maturity period of 12-18 instead of 24 months); the average yield of local varieties increased from 9.2 pa to 23.8 pa. All groups as well as individual farmers with small plots reported increases in yield. By the end of the project, several farmer groups had increased the land dedicated to growing cassava and assigned different plots for different varieties. Farmers had also started applying the improved practices in their individual gardens.

Income benefits

The higher cassava yields that were achieved raised the farmers' incomes. Sales were mostly limited to nearby markets. For individual farmers, who often live remotely, it is expensive and time-consuming to transport their bulky harvest by motorcycle over bad roads to formal trading centres. To facilitate marketing, the farmer groups decided they needed bulking centres. The groups provided the land and made bricks, the project provided iron sheets for roofing of the bulking centres. At these centres, the group's harvest can be stored and processed (chipping, drying and packaging) and better prices can be negotiated with traders who prefer to buy in bulk.

New business opportunities emerged as a result of the research. The project had trained farmers on the importance of using clean planting material to stop the spread of crop diseases (mostly brown streak and mosaic disease), and had established multiplication sites per group for clean planting material (cassava stems). Towards the end of the project, some groups had set up additional multiplication sites because selling the cassava stems proved to be a profitable new business that complemented the selling of cassava tubers. As a result, other farming communities in the area also gained access to high-quality planting material.

More new business opportunities were created when the project partners provided cassava chippers to each of the farmer groups. The chippers save a lot of time when making cassava chips (10 minutes per sack compared to the three hours women spend chopping manually). Moreover, faster drying results in chips of better quality (no aflatoxin and no risk of getting mouldy) that keeps its white colour. This value addition intervention led to more cassava products in the market. However, it proved difficult to fetch a higher price for the higher quality cassava chips and flour, as consumers are used to using brown, fermented flour. The research explored a range of other high-potential business opportunities for cassava (e.g. as raw material for breweries, bio-ethanol, or biodegradable packaging), yet these require interest and investments from government and private sector actors.

Impacts on food and nutrition security

The impact of increased food production and incomes on FNS was not measured. It was noted, nevertheless, that the farmers increased their household consumption of cassava and that the women farmers started to intercrop cassava with beans to diversify family diets. The increased planting of cassava was done on previously unutilised land in the communities that was available and therefore did not happen at the expense of other food crops. The project emphasised the importance of crop diversification and witnessed farmers growing fast-maturing vegetables alongside their cassava.

[36] Consortium members: Oxfam Uganda; NACCRI, Uganda, Africa 2000 Network, Uganda.

5. Key lessons and a way forward

In this paper, we assessed the contribution of the F&B Research programme to the adoption by farmers of new knowledge and innovations that can result in increased food production, to ultimately benefit their food and nutrition security. The discussion was based on a selection of thirteen research projects funded by the programme (see Annex). In this final section, we summarise the key lessons from this synthesis and list some recommendations and issues of attention for future research.

Co-creation

Co-creation is a central element of NWO-WOTRO's Research for Impact approach. In the F&B Research programme, co-creation was a mandatory element meant to promote research uptake and impact. **Projects that prioritised including their ultimate target group – the small-scale farmers – in the co-creation efforts appear to have achieved high adoption rates of innovations.** Co-creation happened by involving farmers in design and implementation of the project, participatory selection of crop varieties, field trials and innovation platforms. These strategies appeared to instil a sense of co-ownership of the project on the part of the target farmers.

A way forward

This paper specifically highlighted co-creation efforts with farmers, yet other stakeholders from policy and practice are also included in the projects' knowledge co-creation processes. A separate article will be devoted to the overall lessons learned from implementing the Research for Impact approach in the Food & Business Research programme. The initial adoption of innovations appears to be positively influenced by co-creation. A key question for investigation is whether the co-creation approach equally contributes to more long-term sustainability of outcomes and impacts.

Drivers and barriers for adoption of innovations by farmers

Across the projects, we found **a high uptake of new and improved crop varieties**, focused on high-yielding, drought-tolerant and disease-resistant food crops for consumption and/or sales. Within farming communities, there was more **variation in the adoption rates for improved agricultural practices** (e.g. innovations for soil fertility, disease and pest management, post-harvest storage), depending on the smallholders' resources (time & money). Overall, we identified one key barrier for innovation adoption – i.e. farmers' perceptions on business risks and prospects - and three key drivers: a participatory research approach, effective farmer organisation, and the buy-in of local governments.

- **Farmers' risk perceptions concerning business prospects** (e.g. reliable market access, available processing capacity, profitability) constituted a barrier to research uptake, which in several cases was underestimated in project design. Some projects successfully adjusted strategies to address these concerns; adoption of innovations was lower in projects that failed to do so.
- A lack of access to scientific agricultural and agronomic knowledge is a bottleneck for smallholders.[37] Most reviewed projects chose to involve the farmers in a **participatory learning approach**, and some explicitly built on their knowledge and existing practices. These approaches had a significant positive impact on the adoption levels.[38]

[37] Agricultural research is becoming increasingly private, targeting larger commercial farms with knowledge-intensive technologies. This renders technology adoption by small farmers difficult (Rapsomanikis 2015, 13).

[38] The findings seem to confirm that "New approaches and technologies that apply blended modern agricultural science and indigenous knowledge, and integrate local farmers as main stakeholders, are likely to offer more practical solutions to food insecurity in SSA" (Mugendi Njeru 2013, 67).

- **Effective farmer organisation** proved a driver for research uptake in some projects; it facilitated participatory and peer-to-peer learning, created ownership, and helped to take away some of perceived investment risks that acted as a barrier to uptake.
- **Buy-in from local governments** acted as a driver for research adoption and was used as a strategy by some projects to strengthen the sustainability of project results. Projects that were well aligned with government policies and priorities quite easily obtained government buy-in.

A way forward

Future research projects should include the **important issue of farmers' risk perceptions** in their project design, as this appeared to be a significant barrier to research uptake. This insight has prompted the decision to devote a separate article to the issue of risk management in the second phase of the synthesis study (to be published late 2020/early 2021).

Follow-up research is recommended to study **to what extent farmer organisation indeed leads to increased adoption of research innovations**, as was found in some of the reviewed projects. The insights could be actively used by research projects that aim for outcomes in food production and scaling of the innovations.

The synthesis study revealed that certain factors were only scarcely reflected upon by the projects, even though these might act as drivers and/or barriers for research uptake by smallholders. These include land rights and tenure security, gender, access to credit and insurances, and supportive physical infrastructure. It remained unclear whether these factors were overlooked or deliberately not taken into consideration. We recommend that future projects include an **extensive mapping of drivers and barriers for research uptake in their project design**, and reflects and report on their actual influence during project implementation.

Effects of innovation adoption: yield, income and FNS

Many of the farming communities targeted by the research projects had been experiencing low and unpredictable yields due to climate change impacts (e.g. erratic weather, drought, soil depletion) and high incidences of pests and diseases. **The approach used by all projects to simultaneously focus on enhancing *inputs* (new and improved crop varieties and fertilisers) as well as *technologies* (improved agricultural and dairy practices) appears to carry significant potential for achieving more stable and increased food production**.

- In all projects reviewed where new varieties and agricultural practices were adopted, farmers' yields increased. Where this increase was measured, it was significant, ranging between 20 to 100%.
- Where yields increased, projects reported that there were indications of increased income and profitability for the farmers. Only a few projects, however, quantified this effect. How much farmers will be able to benefit economically from their increased productivity will for a large part depend on external factors such as access to markets, consumer demand and a favourable policy and infrastructure environment. In several cases, furthermore, did the project innovations result in new business opportunities that had not been foreseen in the project design.
- The reviewed projects **did not generate much information on the food and nutrition security effects of increased production and incomes**. These effects were not systematically studied, partly because the timespan of the projects did not allow this. Several projects provided anecdotal evidence of increased and/or diversified household consumption because of project innovations. The synthesis moreover suggests that divorcing livelihood and nutrition outcomes can be an artificial undertaking in the everyday reality of smallholder farming systems where both parameters are intrinsically linked.

A way forward

That higher income leads to improved food and nutrition security is a persistent assumption in policy that merits systematic empirical research.[39] Such research requires a longitudinal and interdisciplinary approach dedicated to investigating risk perceptions, decision-making processes and other socio-economic conditions influencing the lives of small-scale farmers.

Whether the increases in yield and income were achieved by all, most, or some farmers who adopted the innovations was not always clear from the available data. Furthermore, whether these positive productivity and livelihood outcomes will prove to be sustainable, was beyond the scope of this study. Follow-up research for a selection of projects is recommended to achieve insight into these mechanisms. This can generate important information on the viability of change processes over time and the potential for upscaling of some of the promising innovations researched and introduced by the Food & Business Research projects.

[39] See also the thematic article on Smallholders in this series, which discusses the same assumption.

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7. Annex

Reviewed ARF projects

Cassava for Food Security in Uganda

'Cassava Applied Research for Food Security in Northern Uganda'

Harriet Mbabazi (Oxfam Uganda)

https://www.nwo.nl/en/research-and-results/research-projects/i/40/14140.html

Cashew Nut Farming in Uganda

'Introduction of cashew nut for income security for poor farmers in Northern Uganda'

Hellen Acham (North East Chili Producers Association, Uganda)

https://www.nwo.nl/en/research-and-results/research-projects/i/90/11690.html

Integrated Pest Management in Kenya

'Development, Validation and Dissemination of Integrated Pest Management Packages for Tomato Leafminer (Tuta absoluta) and Fusarium wilt-root knot nematode complex affecting tomato production in Kenya'

Geoffrey Ongoya (Koppert Biological Systems Ltd, Kenya)

https://www.nwo.nl/en/research-and-results/research-projects/i/37/13737.html

Farmer-Led Soil Innovations in Uganda

'Farmer-led soil innovations to sustain food production'

Roelof van Till (ZOA, Uganda)

https://www.nwo.nl/en/research-and-results/research-projects/i/11/12211.html

Fertile Grounds in Burundi

'Building on fertile grounds in Burundi'

Geoff Andrews (ZOA, Burundi)

https://www.nwo.nl/en/research-and-results/research-projects/i/89/11689.html

Seed Potato Innovations in Burundi

'Development of potato seed quality based innovations for small-scale farmers in the three provinces surrounding Bujambura town in Burundi'

Pierre Nahayo (CAPAD, Burundi)

https://www.nwo.nl/en/research-and-results/research-projects/i/13/12213.html

Sesame Yield in Uganda

'Stabilizing sesame yields and production in the Lango Region, Northern Uganda'

Francis Alacho (Africa Innovations Institute, Uganda)

https://www.nwo.nl/en/research-and-results/research-projects/i/62/12562.html

Smallholder Dairy in Kenya

'Innovations for sustainable and profitable intensification of smallholder dairy in Kenya (ISPID)'

Godfrey Nyang'ori (Mt Clara Mtakatifu Mwangaza Centre, Kenya)

https://www.nwo.nl/en/research-and-results/research-projects/i/31/14131.html

Irrigation App Bangladesh

'Bangladesh: ground cover app for scheduling irrigation'

Shahid Akbar (BIID)

https://www.nwo.nl/en/research-and-results/research-projects/i/32/14132.html

Parboiled Rice

'Ensuring sustainable and sustained food security by enhancing local parboiled rice value-chain competitiveness in Gogounou and Banikoara areas in Benin (PARCR)'

Jean Kpetere (DEDRAS, Benin)

https://www.nwo.nl/en/research-and-results/research-projects/i/80/13180.html

Reviewed GCP projects

Sustainable Cocoa in Sierra Leone

'Helping Poor Farmers Grow Money: Sustainable Cocoa Productivity and Socio-Economic Impacts of International Investments in Sierra Leone'

Maarten Voors (WUR)

https://www.nwo.nl/en/research-and-results/research-projects/i/09/11509.html

Inclusive Value Chain Collaboration in Ghana and South Africa

'Inclusive partnerships and innovation platforms for sustainable landscapes and greater food sovereignty among tree crop farmers in Ghana and South Africa'

Mirjam Ros-Tonen (UvA)

https://www.nwo.nl/en/research-and-results/research-projects/i/12/11512.html

System Pond Farming in Vietnam

'Nutritious system pond farming in Vietnam'

Marc Verdegem (WUR)

https://www.nwo.nl/en/research-and-results/research-projects/i/08/11508.html